THE STATUS AND DISTRIBUTION OF KITTLITZ'S MURRELET *BRACHYRAMPHUS BREVIROSTRIS* IN NORTHERN ALASKA

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Received 15 April 2010, accepted 13 May 2011

SUMMARY

DAY, R.H., GALL, A.E., PRICHARD, A.K., DIVOKY, G.J. & ROJEK, N.A. 2011. The status and distribution of Kittlitz's Murrelet *Brachyramphus brevirostri*s in northern Alaska. *Marine Ornithology* 39: 53–63.

We summarize information on the status, distribution and abundance of Kittlitz's Murrelet *Brachyramphus brevirostris* in northern Alaska, an area for which little information is available. Nine, and possibly 11, nests of Kittlitz's Murrelets have been found in northern Alaska; a substantial amount of potential nesting habitat appears to be unoccupied, especially in and near inner Norton and Kotzebue sounds. There are extensive records (museum, sight, photographic, aerial-survey and at-sea) of Kittlitz's Murrelets in the eastern Chukchi Sea from Cape Prince of Wales to Point Barrow and two recent records from the Beaufort Sea. The population of Kittlitz's Murrelet in northern Alaska was an estimated 450 birds during the breeding season (April–August) and 8500 birds in the post-breeding season (September–October), although 95% CIs for the latter estimate were large. There was no overlap, however, in CIs between the breeding and post-breeding seasons, indicating that a large number of murrelets move into the region during the latter period. At sea, the species was found over the shelf of the Chukchi Sea during a 7-month period from mid-April to mid- or late October, with the highest densities occurring within 50 km of shore. There was strong evidence from at-sea data for seasonal variation in abundance (highest densities in September–October), but there was no evidence for population change between the periods 1970–1999 and 2000–2009 during either the breeding or post-breeding seasons. Information presented here indicates that the Kittlitz's Murrelet is widespread and fairly common at times in the Chukchi Sea but is rare and casual (not annual) in the Beaufort Sea.

Key words: Alaska, *Brachyramphus brevirostris,* distribution and abundance, habitat use, Kittlitz's Murrelet, population trend, status

INTRODUCTION

Because of concern about the survival of the Kittlitz's Murrelet *Brachyramphus brevirostris* due to poor productivity (Day & Nigro 2004, Kaler *et al.* 2009) and what are believed to be population declines in several parts of its range (Piatt *et al.* 2007), the species is a candidate for listing under the US *Endangered Species Act* (US Fish and Wildlife Service 2010). This species also is on a variety of other governmental and non-governmental watch lists (e.g. Kirchhoff & Padula 2010), indicating widespread concern about its welfare.

Unfortunately, little is known about Kittlitz's Murrelet over much of its range, especially in areas away from glaciated fjords in the Gulf of Alaska, making protection and management difficult. Here, we compile and summarize data for northern Alaska, where little information previously has been available. Specifically, our objectives were (1) to describe nesting locations and habitat and evaluate potential nesting areas in the region, (2) to describe the nesting and at-sea distribution and abundance of murrelets, (3) to estimate population size and evaluate temporal variation in abundance, and (4) to describe environmental characteristics of areas where the species occurs in northern Alaska.

STUDY AREA

Coverage differed between land and sea (Fig. 1). The terrestrial portion of the study area extended from the northern bank of the Yukon River to the Arctic Ocean, east to the US–Canada border, and inland up to 100 km (~60 miles). The marine portion of the study area included waters of the Chukchi Sea from Bering Strait to the deep Arctic Ocean and waters of the Alaska and Canadian Beaufort Sea.

METHODS

Data sources

We extracted nest records from the literature and unpublished sources and compiled data on specimens in major museums across North America. Additional data consisted of observations or photographic records from a variety of sources, including publications, unpublished reports and the unpublished records of individuals. We evaluated the credibility of each unpublished sight record lacking photographic documentation, considering the experience and our personal knowledge of the source (e.g. researchers with experience studying birds in Alaska).

We used data from systematic aerial surveys conducted in June–August 1978 in our summaries; these data are part of the North Pacific Pelagic Seabird Database (NPPSD v. 1; USGS Alaska Science Center, Anchorage, Alaska). Sampling methods included a 30 m flight altitude in a 50 m wide strip transect on each side of the plane with a ground speed of 200 km/h (Harrison 1982, Drew & Piatt 2005). We also analyzed NPPSD boat-based data from systematic surveys conducted by various researchers in April–October 1975–1978, 1980–1981, 1983–1986, 1991, 2000 and 2006–2008 and a recent (2008–2009) oceanographic study in the Chukchi Sea (Gall & Day, unpublished data). A few additional at-sea data from published sources (Swartz 1967, Watson & Divoky 1972) and unpublished records were added to maps. Sampling methods usually consisted of a 300 m wide strip, transects of 10-min duration and the "snapshot" method of counting flying birds (Gould & Forsell 1989, Drew & Piatt 2005). Some data were previously summarized in reports for the Outer Continental Shelf Environmental Assessment Program in the Chukchi and Beaufort seas (1970s and 1980s; Divoky 1984, 1987).

Data analysis and synthesis

We defined a "confirmed" Kittlitz's Murrelet nest as one in which an egg, eggshell fragments, adult and/or chick was found, and defined a "probable" nest as one in which a credible observer flushed a bird thought to be a Kittlitz's Murrelet but was unable to identify the bird with certainty or to locate a nest. Given the scarcity of nest information, we considered all nests in our analysis but recognize the uncertainty of some records. We mapped locations of all Kittlitz's Murrelet nests in the study area and examined habitat relationships by using land-cover classes (US Geological Survey National Land-cover Database; US Geological Survey 2001) within 100 km (~60 miles) of the coast (slightly more than the inland limit of verified nesting; Day *et al.* 1999) and within the documented range of elevations for nests in the region.

To define the overall range of Kittlitz's Murrelet in northern Alaska, we compiled all museum specimens and sight and photographic records of Kittlitz's Murrelets geographically. We also compiled records of Kittlitz's Murrelets on aerial and boat-based surveys.

To examine spatial variation in abundance, we compiled boat-based density data by geographic strata (Fig. 1): (1) Southern Chukchi (from just south of Bering Strait to the latitude of Cape Lisburne, west to the US–Russia border, and east to the western boundary of the Kotzebue Sound stratum); (2) Kotzebue Sound (bounded on the west by a line from Kivalina to the northeastern edge of Shishmaref Inlet); (3) Northern Chukchi (north of Cape Lisburne, west to the US–Russia border, north to the shelf break, and east to a line running north from the tip of Point Barrow [156.47917°W]); (4) Arctic Ocean (deep basin north of the Northern Chukchi stratum and east of the US–Russia border); and (5) Beaufort Sea (east of the Point Barrow longitude to the Canadian Beaufort Sea, including the deep basin of the Arctic Ocean). Boat-based data were strip-transects; we assumed perfect detection within 300 m (Gould & Forsell 1989) and calculated mean density (birds/km^2) of Kittlitz's Murrelets. Data were uncorrected for sightability by group size or distance from the ship because such information was not available for most records. Hence, our methodology probably underestimates population size.

Because much at-sea survey effort was opportunistic rather than randomly distributed spatially or temporally, population estimates over-represent those areas and time periods with greater survey effort. To help correct for potential biases inherent in the data, we incorporated such variables as geographic stratum, distance to shore, season and decadal time period of data collection in the analysis and estimation of population size of Kittlitz's Murrelet. While imperfect, this approach requires only the simple assumption that the surveyed transects were representative of the geographic stratum and distance from shore during the season and time period considered.

Specifically, we divided each stratum into zones of distance from shore (0–50 km, 51–100 km, 101–150 km, 151–200 km and >200 km). We incorporated distance from shore into the calculations because densities of Kittlitz's Murrelet in northern Alaska decrease away from land (Fig. 2) and because survey effort varied nonrandomly (spatially and temporally) by distance from shore. We calculated estimates separately for the breeding season (April–August) and the post-breeding season (September–October) because densities differed greatly between the two seasons (see Results). Within each season, we first calculated a mean for each combination of distance zone and geographic stratum—for all years combined, for data collected during the period 1970–1999, and for data collected during the period 2000–2009—then converted the mean density in each zone to a population estimate. We summed the zone-based totals to obtain a population estimate for each stratum during each season. We recognized distinct time periods because data were collected primarily between the 1970s and the early 1990s or in the

Fig. 1. Study area in northern Alaska; red lines are boundaries of strata for summarizing data on at-sea densities of Kittlitz's Murrelet.

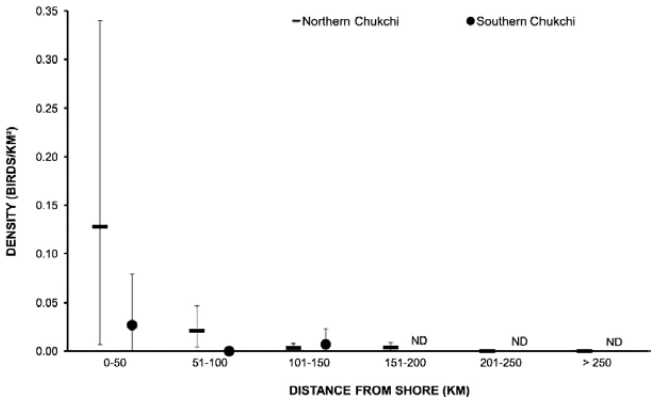

Fig. 2. Mean densities (± SE) of Kittlitz's Murrelet in the Northern Chukchi and Southern Chukchi strata by distance from shore, 1970–2009; data from all years combined. ND = no data.

latter half of the decade 2000–2009 and because those time periods corresponded with apparent declines of this species in other parts of its range (Piatt *et al.* 2007, US Fish and Wildlife Service 2010). Because we lacked data for Kotzebue Sound for the later time period (2000–2009), we assumed that the population estimate for that area was unchanged from the earlier time period (1970–1999).

For each estimate of population size, we used bootstrapping to generate 95% CIs. The bootstrap estimates were calculated by randomly selecting, with replacement, a sample of survey days equal to the number of survey days in each stratum and distance-to-shore category, then calculating the population estimate for the generated sample. We repeated the process 3000 times for each population estimate, with the 95% CI calculated as the range of estimates after excluding the lowest and highest 2.5% of values.

To examine seasonal (monthly) variation in the abundance of Kittlitz's Murrelet in northern Alaska, we used data from boat-based surveys to calculate mean densities (birds/km^2) in the northern and southern Chukchi strata by month and distance from shore (excluding the Kotzebue stratum, where only a single bird was recorded). To characterize marine habitat use, we summarized environmental data associated with boat-based surveys. These data included sea-surface temperature (SST), sea-surface salinity (SSS), percent ice cover and water depth. SST (°C) and SSS (practical salinity units [psu]) generally were measured by a recording thermosalinograph attached to the ship's flow-through sea chest, sampling water characteristics within the upper ~2 m. Percent ice cover was estimated to the nearest percentage category (e.g. 0%, 1%, 5%, 10%, … 90%, 100%). Water depths were measured (+1 m) on the ship in real time or estimated later from maps of regional bathymetry (Amante & Eakins 2009). We mapped locations of all records and examined their distribution in relation to major water masses.

RESULTS

Terrestrial distribution

Nest locations and characteristics

Nine confirmed and two probable nests of Kittlitz's Murrelets are known from northern Alaska (Fig. 3). Eight (including one previously undescribed nest) were found on the Seward Peninsula, and three (including one previously undescribed nest) were found on the mainland of Alaska north of Kotzebue Sound (near the DeLong Mountains and Lisburne Hills). Day *et al*. (1983, 1999) and references therein described nine nests; therefore, we provide new information here on two of the previously described nests and document two new nests.

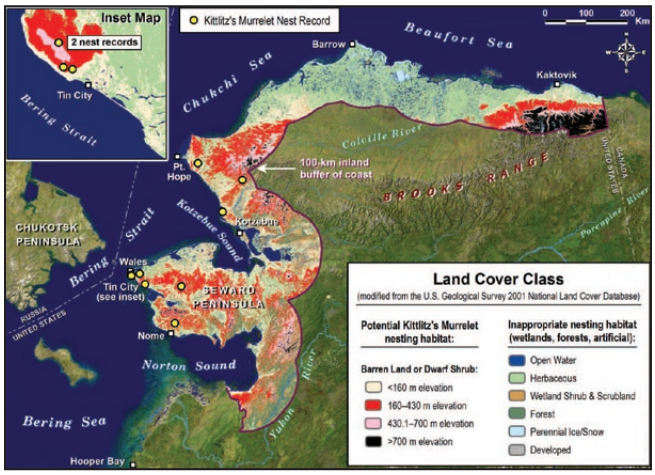

Fig. 3. Locations of Kittlitz's Murrelet nests found in northern Alaska, overlaid on most-suitable nesting habitat type and elevation within ~100 km of the coast. Data from USGS (2001).

A nest near Tin City (Bailey 1948) was believed by Day *et al*. (1999) to be located on Potato Mountain, northeast of Tin City. Updated (corrected) coordinates for that nest are 65.64783°N, 167.57708°W (World Geodetic System [WGS] 84). A second (probable) nest was attributed to the "Iron River" (Bent 1919, Day *et al.* 1983). Kessel (1989) provided what she considered to be correct coordinates for the nest ("Iron Creek"). We accept the corrected location but reject the conclusion that it was a Marbled Murrelet *B. marmoratus* nest, because the location is so far north of the breeding range of that species (Nelson 1997).

A probable Kittlitz's Murrelet nest was found recently on the Seward Peninsula at 64.73150°N, 166.29800°W (WGS 84; Fig. 3, Table 1). On 7 June 2005, botanists C.L. Parker (University of Alaska Museum of the North, in litt.) and R. Meyers (National Park Service, Kotzebue, AK, in litt.) flushed a bird they thought was a Kittlitz's Murrelet in the Moon Mountains area, ~50 km (~32 miles) northeast of Cape Rodney and north–northwest of Nome. The "cliff"-site was a small, nearly vertical rock face with narrow ledges above a steep slope that dropped another ~25–30 m (~80–100 feet) in elevation. The bird, which was "brown and plump and had short wings and a short, stubby tail," glided and flapped downward several feet before attaining enough lift to maintain altitude (Parker, in litt.; Meyers, in litt.). There was little vegetation in the immediate vicinity of the nest, only small, scattered patches of *Dryas* or other low vegetation; the vicinity had scree slopes composed of unstable rock rubble. The observers estimated the nest-site was at ~160 m (~500–550 feet) above sea level (asl) and ~20 km (~13 miles) inland.

A nest was found by ornithologists at 67.30457°N, 163.70888°W (WGS 84) in the Kakagrak Hills, north of Kotzebue Sound, on 15 June 2010 (L. DeCicco & N. Hajdukovich, in litt. and pers. comm.; Fig. 3, Table 1). A Kittlitz's Murrelet was incubating a greenish egg on 20 June, when it was last visited by the researchers; thus, the fate of this nest was not determined. The area consisted mainly of fractured bare rock with ~20% cover of *Dryas,* small sedges and lichens. The nest site itself had a slope of about 5° but was near the base of a 20° slope; aspect was almost due south, the nest was at ~170 m (~550 feet) asl, and the ocean was visible from the site, which was ~3.7 km inland.

In addition to those known and probable nests, there is evidence for nesting farther north in the Chukchi Sea region. Kittlitz's Murrelets were seen flying up and down Selin Creek at the Cape Lisburne Long-range Radar Site in July 1995 and July–August 2001–2005 (Day *et al*. 1999; D.G. Roseneau, US Fish and Wildlife Service, pers. comm.). Hence, the species almost certainly nests as far north as the Cape Lisburne area, in the Lisburne Hills.

Nesting habitat

Although few Kittlitz's Murrelet nests have been found in northern Alaska, and not all information on habitat characteristics of those nests is available, habitat features at or near the nests were fairly

consistent (Table 1). All nests in the region were found at or below ~700 m asl, primarily at 160–430 m asl. For perspective, many mountains on the western Seward Peninsula are ~600–1450 m high, and elevations in the western DeLong Mountains and the Lisburne Hills are at or below ~1000 m. Thus, murrelet nests have not been found at the highest elevations in the area. Data on the aspect of nests are limited and variable—four nest sites faced south, one faced west, and one faced north. Most nests were found on slopes of 15–30°; however, most scree slopes and talus piles used for nesting in the region have slopes of ~23–30°. Distance from the coastline ranged from ~0.25 km (Hill Point, Wales) to ~75 km (Wulik River). Plant cover around nests in this region was minimal—0% at three nests and 20–50% at four others. Vegetation at the latter nests consisted of low-lying forms such as lichens, mosses, short sedges and herbs such as *Dryas*. Hence, all nests occurred in areas of bare rocks or rocks mixed with spare, low vegetation.

Extent and location of potential nesting habitat

All Kittlitz's Murrelet nests discovered in northern Alaska were found in areas of barren land (unvegetated scree slopes) or dwarf shrub habitat (partially vegetated drier areas with low, prostrate vegetation; Fig. 3, Table 1). Those two habitat types occur over a wide expanse of the study area, from near the mouth of the Yukon River (the Nulato Hills) to east of Cape Beaufort (the Amatusuk Hills) and as far north as Wainwright and inland. A second area of possibly suitable habitat is found south of Kaktovik, on the northern slope of the Brooks Range. However, most of the Arctic

TABLE 1
Habitat characteristics of confirmed and probable Kittlitz's Murrelet nests found in northern Alaska, 1904–2010 (modified from Day *et al.* 1999)

Category/name	Elevation, m	Aspect	Slope, °	Distance to nearest coastline, km	Vegetative cover, %	Comments	Source
Confirmed nests							
Hill Point	230–270	—	—	0.25–0.30	—	Nest facing the sea	Ford (1936)
Wales Mountain	≤700	—	—	—	—	Nest "on top of mountain"	Ford (1936)
Cape Mountain	330	Southeast	24	0.55	None	Nest on scree slope	Day & Stickney (1996), Day et al. (1999)
Cape Mountain 2	~340	East–southeast	23	0.6	None[a]	Nest on scree slope	Day & Stickney (1996, Day et al. (1999)
Tin City	—	—	—	8	—	Probably on Potato Mountain; coordinates in Day *et al.* (1983) are corrected in text	Bailey (1948), Day *et al.* (1983)
Tin Creek	370	South–southeast	30	6.4	25	Nest on mountain	Day et al. (1983)
Kakagrak Hills	~170	South	20	3.7	20	Nest below rock near foot of slope; ocean visible from nest; habitat mixed rock and *Dryas*, sedges and lichens	Lucas DeCicco (in litt.); Nicholas Hajdukovich, personal communication)
Angmakrog Mountain	430	"West"	15–20	25	50	Nest a depression in lichens	Thompson et al. (1966)
Wulik River[b]	300	North	30	75	None	Nest on talus slope	Day *et al.* (1983), Murphy *et al.* (1984), David G. Roseneau (in litt.)
Probable nests							
Iron Creek[c]	—	—	—	—	—	Coordinates in Day *et al.* (1983) corrected by Kessel (1989)	Day *et al.* (1983), Kessel (1989)
Moon Mountains	~160	—	"Cliff"	~20	None	Bird flushed from "cliff"	Carolyn L. Parker (in litt.); Randy Meyers (in litt.)

[a] Because the nest itself was not found, plant cover in the area where the nest occurred was not listed in Day *et al.* (1999)—it was at or close to 0% (R.H. Day, unpublished data).

[b] Same as Chukchi Sea nest in Day *et al.* 1983; Murphy *et al.* (1984) indicated that geologists saw a "similar bird" nearby, which D. Roseneau (in litt.) believes was a second nest ~1.5 km (~1 mile) away.

[c] Iron River nest in Day *et al*. 1983.

Coastal Plain between Wainwright and Kaktovik is low and marshy and, hence, unsuitable as nesting habitat for Kittlitz's Murrelet. Restricting the habitat assessment to types (e.g. barren land) and elevations (160–430 m) at which nests have been found, the extent of potential nesting habitat is restricted accordingly (Fig. 3), although the same general areas described above still offer some potential habitat.

Marine distribution

Aerial-survey data

Kittlitz's Murrelets were recorded only five times during systematic aerial surveys; other records are from aerial surveys for which we have no information on tracklines (Fig. 4). A low ability to detect this species from the air may partially explain the paucity of records. Groups of three birds were seen near Cape Lisburne, near Point Lay, and in Ledyard Bay, and two groups of five birds each were seen farther offshore from Point Lay. In addition, D. Roseneau (in litt.) saw a total of ~12 pairs of Kittlitz's Murrelets during aerial surveys "in late July to mid-August 1978." Occurring consistently in pairs, the birds were "30–50 miles" (~50–80 km) offshore, between Cape Thompson and Cape Lisburne. Because definite coordinates are unavailable for those records, we randomly assigned locations within the corresponding area on the aerial-survey map (Fig. 4).

Ship-based data

Kittlitz's Murrelet records from systematic ship surveys were concentrated in four main areas (Fig. 5). There was a concentration within ~50 km north of Bering Strait and in the vicinity of the Point Hope–Cape Lisburne Peninsula, especially near shore. A third concentration occurred on the continental shelf north and northeast of Cape Lisburne, from near the coastline to ~180 km offshore. Finally, a concentration was apparent over the head of Barrow Canyon, a submarine feature west of Barrow, with sightings ranging from near the shoreline to ~50 km offshore. There were also areas with few or no Kittlitz's Murrelets—e.g. only one record in Kotzebue Sound and no records from the Arctic Ocean north of the Chukchi shelf of Alaska or from the Beaufort Sea, either on or off the shelf.

In addition to records from systematic boat-based surveys, five other sets of records are included on the at-sea map (Fig. 5). Swartz (1967) saw Kittlitz's Murrelets at sea four times in August 1960. Watson & Divoky (1972) mapped observations of Kittlitz's Murrelet between Barrow and Bering Strait from 22 September to 18 October 1970. K. Morgan (Canadian Wildlife Service, in litt.) provided three records from the passage of a Canadian icebreaker through the northeastern Chukchi Sea in July–August 2008. J. Puschock (Seattle, WA, in litt.) photographed an alternate-plumaged Kittlitz's Murrelet ~30 km northeast of Point Barrow on 29 August 2008, and S.J. Kendall (US Fish and Wildlife Service, in litt.) saw what he believed were two Kittlitz's Murrelets between Angun Lagoon and Kaktovik on 30 July 2008, following several days of strong westerly winds. Given Kendall's extensive experience with the species (e.g. Agler *et al.* 1998, Kendall & Agler 1998), we considered his a valid sight record, despite its being much farther east than any previous record.

Ancillary data

At least 11 museum specimens and a few sight or photographic records of Kittlitz's Murrelet are available from the western Seward Peninsula, but none east of Nome (Appendix 1). Specimens ranged geographically from the Diomede Islands to Wales and Tin City, dated 28 April (birds in pack ice near Wales) to 16 July (bird on a nest). Bailey (1943) saw two birds on the water near Wales on 28 April 1922 and on the following day. He also saw two birds "near Diomede Islands" on 3 June 1922 (Bailey 1948). Kessel (1989) cited nesting in mountains on the western half of the Seward Peninsula and noted the species has been seen (one bird) as far east as Nome; at sea, Kittlitz's Murrelet was sighted between Nome and Bering Strait (Kessel 1989).

We are unaware of any museum specimens or sight/photographic records of Kittlitz's Murrelet in Kotzebue Sound. Grinnell (1900) recorded none in the region, and Kessel (1989) did not record the species on the northern side of the Seward Peninsula.

Six museum specimens and numerous sight/photographic records are available for Kittlitz's Murrelets between Cape Thompson and Cape Lisburne (Appendix 1, available online). Specimens are from

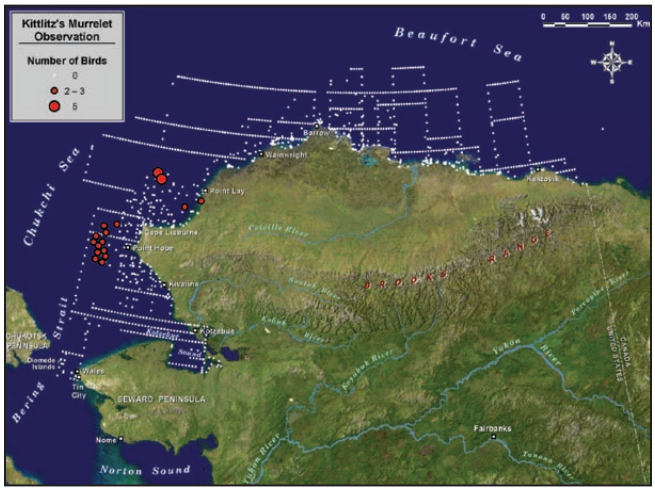

Fig. 4. Locations of Kittlitz's Murrelets recorded in northern Alaska during systematic aerial surveys, June–August 1978. White lines/dots show location of survey effort.

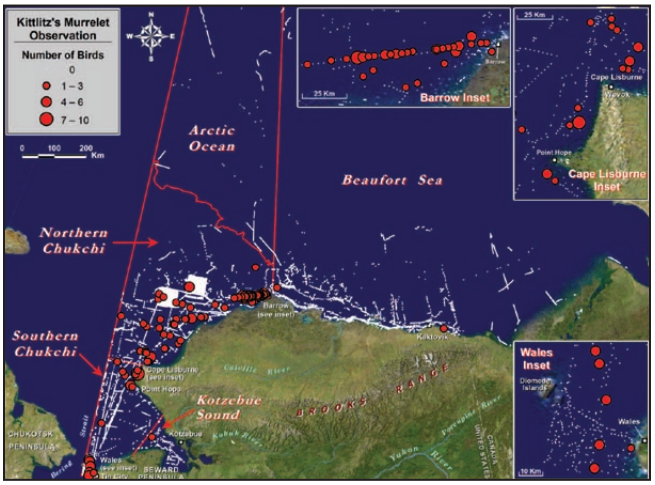

Fig. 5. Locations of Kittlitz's Murrelets recorded in northern Alaska during systematic boat-based surveys conducted irregularly by various researchers between 1970 and 2009. White lines/dots show location of survey effort.

near Cape Thompson north to Point Hope and Cape Lisburne, dated 15 April (birds in an ice lead) to 17 August. D. Roseneau (in litt.) annually saw ~4–5 birds at Cape Thompson in June–July 1976, 1977 and 1979. B.E. Lawhead (ABR, Inc., Fairbanks, AK, unpublished data) saw four Kittlitz's Murrelets in ice leads near Point Hope on 19 April 1980. D. McGuire and G. van Vliet observed at least nine Kittlitz's Murrelets from a small boat between Point Hope and Cape Lisburne in late July 1981 (D. Roseneau, in litt.). D. Roseneau (in litt.) annually saw 5–6 Kittlitz's Murrelets in spring ice leads near Cape Lisburne, late June–early July 1995–1997.

Few records of Kittlitz's Murrelets exist for Ledyard Bay to Peard Bay. There are no museum specimens from the vicinity of Point Lay and only four from or offshore near Wainwright, all taken 9–15 June (Appendix 1). Moreover, there is only one sight record from this area: four birds seen from shore in Peard Bay on 28 August 2006 (D.A. Nigro, US Bureau of Land Management, in litt.). At least 30 museum specimens are from the Barrow area, possibly a reflection of the extensive collecting and ornithological research at that location: three (possibly four) from May, one from June, two from July, seven from August, 15 from September, one from October and one taken in "fall" (Appendix 1). In addition, there are two sight/photographic records from Barrow: one bird seen near the shore southwest of Barrow on 27 July 2004 (D.M. Troy, Anchorage, AK, in litt.) and a basic-plumaged bird photographed from shore near the Point Barrow spit on 7 July 2004 (J. Barry & D. Froelich, Seattle, WA, in litt.).

We found no museum specimens or sight records from the Beaufort Sea. (Two boat-based sight records are included with at-sea data, as they occurred substantial distances offshore.) Although he did extensive boat surveys of seabirds throughout the Alaska Beaufort Sea, Divoky (1984) recorded no Kittlitz's Murrelets. Similarly, Divoky has not recorded the species over the past 35 years (1975–2010) at Cooper Island (~30 km east of Barrow), where he has recorded many other species of alcids (Divoky, unpublished data). Johnson & Herter (1989) did not report the species in the Beaufort Sea.

Marine abundance

Estimated population

At-sea densities differed substantially between the breeding season (April–August) and the post-breeding season (September–October; Table 2). Estimates calculated by stratum and distance from shore indicated a population of Kittlitz's Murrelet in the Chukchi Sea during the breeding season (all years combined) of 451 birds (95% CI 0–933) and 8517 birds (95% CI 2288–17 868) in the post-breeding season (all years combined). Although the CI for the latter estimate was large, there was no overlap in CIs between seasons.

Temporal variation

Patterns of seasonal occurrence for the northern Chukchi were similar across distances from shore (Fig. 7). In all but the 51–100 km zone in August, mean monthly density increased from spring to fall, with the highest densities recorded in October and, to a lesser extent, September. The maximal mean density (0.67 birds/km^2) was recorded in the 1–50 km distance-zone in October. Patterns of seasonal occurrence for the southern Chukchi stratum by distance from shore were less clear. Mean density in the 1–50 and

TABLE 2
Population estimates for Kittlitz's Murrelet in northern Alaska during the breeding season (April–August) and post-breeding season (September–October), 1970–2009[a]

Scheme	Region, stratum estimate (bootstrapped 95% CI)					Total
	Southern Chukchi	Kotzebue Sound[b]	Northern Chukchi	Arctic Ocean[b]	Beaufort Sea	
Area, km^2	51 715	15 610	179 012	269 398	1 269 797	
Breeding season						
By stratum and distance from shore, all years	128 (0–309)	0	323 (0–782)	0	0	451 (0–933)
By stratum and distance from shore, 1970–1999	146 (0–360)	0	356 (0–1135)	0[b]	0	502 (0–1306)
By stratum and distance from shore, 2000–2009	0	0	295 (0–958)	0	0	295 (0–958)
Post-breeding season						
By stratum and distance from shore, all years	1052 (0–3075)	83 (0–260)	7382 (1464–16 629)	0	0	8517 (2288–17 868)
By stratum and distance from shore, 1970–1999	1256 (0–4250)	83 (0–274)	1982 (0–5978)	0[b]	0	3321 (103–8191)
By stratum and distance from shore, 2000–2009	81 (0–267)	83[b] (0–274)	16 383 (762–43 439)	0	0	16 546 (933–43 583)[c]

[a] Data collected on boat-based surveys of opportunity; estimation scheme based on season, time period and geographic stratum.
[b] No data were collected in Kotzebue Sound after 1999 or Arctic Ocean before 2000; we assume for population estimation that numbers in those areas remained constant.
[c] Excluding data from Barrow Canyon for one day in October 2007, population size for 2000–2009 was 3508 birds (95% CI 815–6681).

101–150 km zones peaked in September but was zero in October (as was the value for the 51–100 km zone). Nonetheless, data from the northern Chukchi indicate the species must occur in the southern Chukchi until at least October, as birds from the northern Chukchi migrate southward. Hence, zero densities shown for the southern Chukchi in October (Fig. 7b) are unrealistic, perhaps because of reduced sampling effort at that time.

Estimated populations of Kittlitz's Murrelet differed between the breeding and post-breeding seasons for both survey intervals (Table 2). In the breeding season, we estimated 502 (95% CI 0–1306) murrelets in northern Alaska during 1970–1999 and 295 (95% CI 0–958) during 2000–2009. Those estimates are of the same general magnitude and had almost complete overlap of 95% CIs. For the post-breeding season, we estimated 3321 murrelets (95% CI 103–8191) during 1970–1999 and 16 546 (95% CI 933–43 583) during 2000–2009. The estimates differed substantially but had a large overlap of 95% CIs. A large number of Kittlitz's Murrelets seen within 50 km of shore over Barrow Canyon on a single day in October 2007 accounts for the dramatic increase in estimated population size and variability between study intervals. Excluding those Barrow Canyon data, our population estimate for 2000–2009 was 3508 birds (95% CI 815–6681), similar to the 1970–1999 period.

Environmental variation

Few data on the at-sea environment of Kittlitz's Murrelet are available for northern Alaska. The mean SST where Kittlitz's Murrelets were found was 5.1 °C (SE 0.2 °C, range 3–7 °C; n = 46), and mean surface salinity was 30.1 psu (SE 0.1 psu, range 27.8–31.5 psu; n = 43). Mean ice cover was 0% (n = 46), and mean water depth was 30.5 m (SE 1.6 m, range 19–68 m, n = 46). Our map of distribution and abundance indicates the species was found only over continental shelves in both the Chukchi and Beaufort seas (Fig. 6).

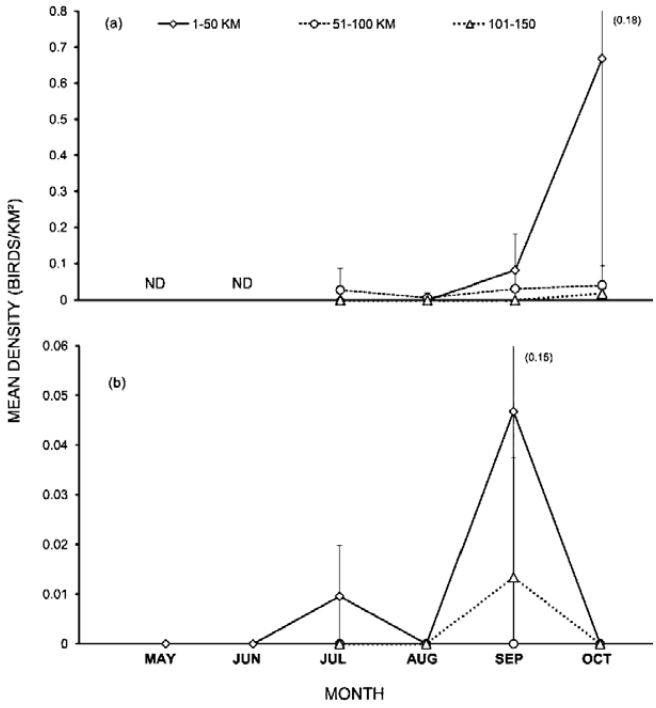

Fig. 7. Mean at-sea densities (± SE) of Kittlitz's Murrelet in: (a) the Northern Chukchi, and (b) Southern Chukchi strata by distance from shore and month; data from all years (1970–2009) combined. Note differences in density scales on the y-axis.

There is a possible association with oceanographic fronts and/or fast currents, which may produce fronts at their boundaries (Fig. 6). Three of the four identified concentrations of Kittlitz's Murrelets were in areas where high current speeds would be expected (Bering Strait, the Point Hope–Cape Lisburne Peninsula) or in areas with both high current velocities and known oceanographic fronts (Bering Strait, Barrow Canyon; Coachman *et al*. 1975, Pickhart *et al*. 2005, Weingartner *et al*. 2005, Woodgate *et al*. 2005, 2006). It also is possible that fronts occur near the Point Hope–Cape Lisburne Peninsula, given the likely acceleration of Alaska Coastal Water (ACW) near that landmark.

DISCUSSION

Data presented here indicate that Kittlitz's Murrelets occur regularly in northern Alaska, albeit in smaller numbers than previously suggested (Divoky 1987, who used at-sea data to estimate ~15 000 birds in the Chukchi Sea, including Russia). The species occurs in high numbers during autumn in the Chukchi Sea, apparently reflecting post-breeding movements of birds northward. Currently, the world population estimate of this species is ~31 000 to ~57 000 birds (US Fish and Wildlife Service 2010), so our estimates suggest that 15–27% of the species' population is found in northern Alaska in September and October.

Nesting

In northern Alaska, nests of Kittlitz's Murrelets have been found in an arc from the western third of the Seward Peninsula to the western end of the DeLong Mountains and in the Lisburne Hills. This description agrees with Day *et al*. (1999)—only two new nests have been located in the intervening period. No nest records exist in or near the Nulato Hills, the eastern two-thirds of the Seward Peninsula, Kotzebue Sound, the western end of the Baird Mountains, or northeast of Cape Beaufort. Hence, the area of potentially usable nesting habitat is much larger than the area actually used. Other factors, especially oceanography, may limit the terrestrial occurrence. Notably, only one at-sea record exists as far east as Nome (Kessel 1989; NPPSD data). Similarly, although potential nesting habitat occurs adjacent to inner Kotzebue Sound, especially in the western Baird Mountains, there is no recorded nesting, and we have only one at-sea record of the species in central Kotzebue Sound.

As defined by land cover and elevation, the amount of potential nesting area may be fairly limited. Low-lying dwarf-shrub habitat may form marshes, especially where soils are poorly drained. If known nesting elevations (160–430 m) define usable nesting habitat, the amount of such habitat in northern Alaska is quite small. Future modeling that incorporates slope, for example, may improve the delineation of potential nesting habitat.

No relationship between geology and the nesting of Kittlitz's Murrelet in northern Alaska is apparent. On the Seward Peninsula, nests have been found in areas characterized by uplifted marine rocks of Precambrian and Paleozoic age and by undifferentiated volcanics of Precambrian age; such rocks occur throughout the entire peninsula (Beikman 1980). Similarly, most of the area bounded by Cape Krusenstern, the western DeLong Mountains and Cape Beaufort consists of sedimentary and metamorphic rocks of Cretaceous to Jurassic age, with the southeastern part of the area having smaller

patches of sedimentary and igneous rocks. Again, similar rocks are found in and near inner Kotzebue Sound, near the Baird Mountains.

There is, however, a strong relationship between maximal Pleistocene glaciation and the nesting range of Kittlitz's Murrelets in northern Alaska. On the Seward Peninsula, all nests except those at Wales and Tin City were found in areas covered during the glacial maximum (Kaufman & Manley 2004; Manley & Kaufman, unpublished data). Likewise, in the region bounded by Cape Krusenstern, the western DeLong Mountains and Cape Beaufort, the Wulik River nest and possibly the Kakagrak Hills nest were in areas covered during the maximum. Our results from northern Alaska support the conclusion (Piatt *et al*. 1999) that Kittlitz's Murrelets generally nest in glaciated or formerly glaciated areas.

Status, distribution, and abundance

In northern Alaska, Kittlitz's Murrelet is an uncommon, annual summer visitor to the continental shelf of the Chukchi Sea but an extremely rare, casual (i.e. not annual) visitor to the continental shelf of the Beaufort Sea. There are no records in the deep basin of the Arctic Ocean north of the shelves of the Chukchi and Beaufort seas off Alaska or in the Canadian Beaufort Sea, and only one record of the species in central Kotzebue Sound. Concentrations in the Chukchi Sea, four in all, occur just north of Bering Strait and on the nearby Seward Peninsula, near and inland from the Point Hope–Cape Lisburne Peninsula, on the continental shelf north and northeast of Cape Lisburne, and over Barrow Canyon and near Barrow itself. On the Chukchi coast of Russia, the species occurs from East Cape to the vicinity of Cape Billings and at Wrangel Island (Thayer & Bangs 1914, Kozlova 1957, Portenko 1973, Flint & Golovkin 1990, Stishov *et al. 1991, Shuntov 1998).*

Kittlitz's Murrelets occur in northern Alaska during a 7-month period, with the earliest record on 15 April and the latest record on 18 October. The substantial number of early records suggests that birds may penetrate far north well ahead of sea-ice retreat. The species probably occurs in the area after 18 October, but few at-sea surveys are available from late October. The absence of records from November to March, despite at-sea survey effort, suggests that Kittlitz's Murrelets migrate out of the northern Alaska region in winter.

Population estimation

The population of Kittlitz's Murrelets in northern Alaska is about 450 birds during the breeding season and 8500 birds in the post-breeding season, with no overlap in 95% CIs between seasons. Evidently, large numbers of murrelets move into the region after

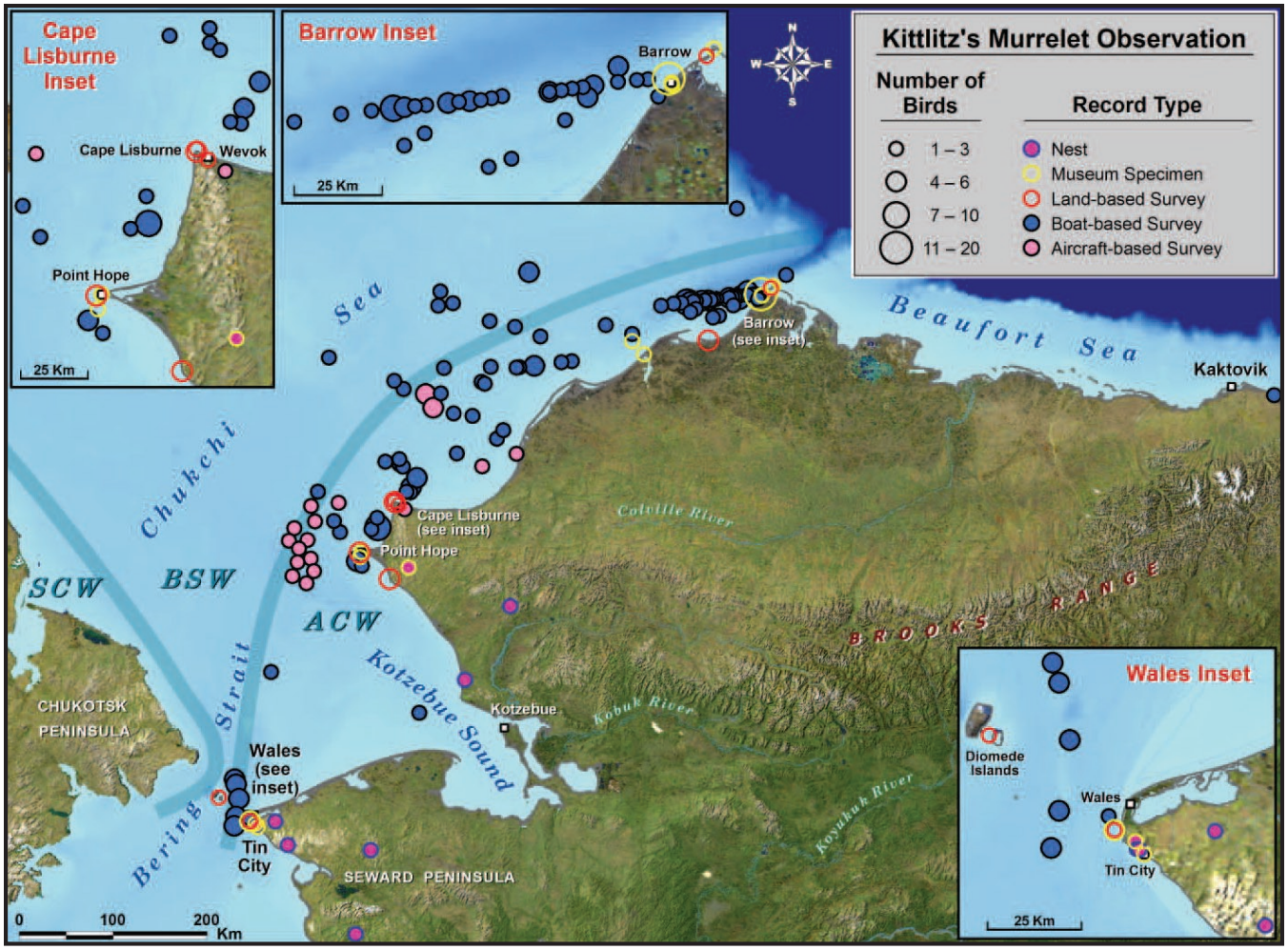

Fig. 6. Locations of all Kittlitz's Murrelets recorded in northern Alaska as museum specimens, as miscellaneous sight/photographic records, and during all surveys. Also shown are the three main water masses (SCW = Siberian Coastal Water; BSW = Bering Sea Water; ACW = Alaska Coastal Water).

breeding. Our population estimates are affected by several factors, including spatial coverage, distance from shore and an exceptional concentration of murrelets near Barrow Canyon on one day in October 2007. The coverage of at-sea surveys varied substantially, as expected for surveys that depend on opportunistic use of ships. Nevertheless, overall coverage of the region, especially the Chukchi Sea shelf, was good and should not have a strong effect on population estimates. Calculations for 50-km distance zones yield more accurate numbers because the approach accounts for decreasing density with increasing distance from shore and lessens the influence of murrelets concentrated near Barrow. That concentration suggests that Kittlitz's Murrelets have a clumped distribution, at least during a portion of the year. Collecting more information on the spatial and temporal occurrence of large aggregations would increase confidence in population estimates, although we believe that the population estimates presented here are reasonably accurate.

Temporal variation in abundance

The evidence for seasonal variation in the abundance of Kittlitz's Murrelet in northern Alaska is strong, with numbers during the post-breeding season estimated to be nearly 20 times those during the breeding season. In the northern Chukchi, at-sea densities were greatest in September and October, shortly before sea ice begins its southward advance. In the southern Chukchi, at-sea densities were greatest in September, although the passage of murrelets through the area in October is inferred, as noted previously.

Evidence is weak for long-term (1970–2009) changes in Kittlitz's Murrelet numbers in northern Alaska in both the breeding and post-breeding seasons. Population estimates for the breeding season were similar, with complete overlap of 95% CIs between 1970–1999 and 2000–2009. In the post-breeding season, murrelets were ~5 times more numerous during the recent survey period. There was nearly complete overlap in 95% CIs between periods, however, and our estimate for the recent period was strongly influenced by the large number of birds seen in Barrow Canyon in October 2007. Excluding that outlier, estimates were nearly identical, suggesting no large changes in population size over time. Despite large confidence intervals, this lack of a clear decadal-scale change in abundance contrasts with population declines believed to be occurring in southern Alaska (Piatt *et al.* 2007).

Environmental relationships

Our results on mean SST, SSS and ice cover in marine waters where Kittlitz's Murrelets were observed in northern Alaska were consistent with Day *et al*. (2003) regarding Kittlitz's Murrelets in Prince William Sound. While mean salinity in this study was noticeably higher than in Prince William Sound (cf. Day *et al.* 2003), both data sets indicate the Kittlitz's Murrelet's preference for cold, lower-salinity coastal water with little ice cover and shallow depths, as occurs in the eastern portion of the Chukchi Sea. Hence, the same marine habitat factors that separate Kittlitz's and Marbled murrelets in the Gulf of Alaska (Day *et al.* 2003) may exclude Marbled Murrelets from northern Alaska.

In general, Kittlitz's Murrelets at sea in northern Alaska are found almost entirely within 100 km of shore. The species is neritic, no birds having been recorded off the continental shelf. Its preference for neritic waters pertains to both summer (Day *et al.* 1999) and winter seasons (Day *et al.* 1999, Day 2006) and anticipates food habits reported by Sanger (1987). Perhaps the strongest environmental relationship, however, involves a preference for coastal water. This type of water is known as Alaska Coastal Water (ACW) in the eastern Chukchi and as Siberian Coastal Water in the western Chukchi (Weingartner *et al.* 1999, 2005, 2008). ACW originates in the Bering Sea, has a large input from the Kuskokwim and Yukon rivers, and flows northward through Bering Strait, eventually exiting the Chukchi Sea shelf near Barrow (Grebmeier *et al.* 2006, Hopcroft *et al.* 2008). Nearly all Kittlitz's Murrelets on the North America side of the Chukchi Sea occurred within this water mass.

At-sea data also suggest a possible association of Kittlitz's Murrelets in the eastern Chukchi Sea with oceanographic fronts and/or areas with high current velocities—three of the four areas of concentration (Bering Strait, the Point Hope–Cape Lisburne Peninsula, and Barrow Canyon) are so characterized (Coachman *et al.* 1975, Weingartner *et al.* 2005).

CONCLUSIONS

In northern Alaska, the Kittlitz's Murrelet is widely distributed and, at certain times, fairly common in the Chukchi Sea but is extremely rare and casual in the Beaufort Sea. Potential nesting habitat appears to be unused, although other environmental factors (e.g. oceanography of adjacent marine waters) may limit the breeding range. Population estimates (450 birds in the breeding season, 8500 post-breeding) are imprecise because the species is rarely encountered at sea in northern Alaska. There is no clear evidence of population change between historical (1970–1999) and recent (2000–2009) surveys in either season.

Several important questions about this species remain unanswered: (1) What, in its entirety, is the extent of Kittlitz's Murrelet nesting in the region? Knowing where the species nests may aid in the protection of breeding habitat, and knowing where some nests occur repeatedly may support a monitoring program for reproduction. In addition, understanding why murrelets do not nest in certain areas may point to factors that constrain population size and growth. (2) What is the productivity of Kittlitz's Murrelets in northern Alaska, and what factors affect it? Having found only a few nests, we know practically nothing about reproduction in this vast region. (3) Why do Kittlitz's Murrelets arrive early in the region—nearly 2 months before nesting is thought to commence? Alternatively, does the species begin nesting earlier than the currently understood phenology (Day 1996), or are early-arriving birds not the ones that nest in the area? (4) Why do so many Kittlitz's Murrelets occur as far north as Barrow in the fall, and why are they so common in northern Alaska generally at that time? Some are molting birds (Sealy 1977), but that fact probably reflects the timing of molt (August–October; Day *et al.* 1999) more than the possibility that northern Alaska is a "molting area" *per se* to which Kittlitz's Murrelets migrate for the purpose. Alternatively, is this an area where breeding adults and fledged young go? Further, do birds simply drift northward with prevailing currents during the molt, or do they pursue schooling fish or other environmental characteristics present only in autumn? (5) What is the use of the Barrow Canyon by Kittlitz's Murrelets, and how often do large numbers congregate there?

ACKNOWLEDGEMENTS

This research was funded by the US Fish and Wildlife Service (USFWS), Fairbanks and Anchorage Fish and Wildlife Field

Offices. Many of the at-sea data and all of the aerial-survey data were provided from the North Pacific Pelagic Seabird Database by G.S. Drew and J.F. Piatt of the USGS Alaska Science Center, Anchorage, AK, and by K.J. Kuletz of the USFWS, Anchorage, AK. Additional at-sea data were from a study funded by ConocoPhillips Alaska, Inc., and Shell Exploration and Production Company, Anchorage, AK; we thank C.L. Rea of ConocoPhillips for permission to include them here. Unpublished nest records, sight records, and/or photographs were provided by J. Barry and D. Froelich of Seattle, WA; L. DeCicco and N. Hajdukovich of Fairbanks, AK; S.J. Kendall of the USFWS, Fairbanks, AK; B.E. Lawhead of ABR; R. Meyers of the National Park Service (retired), Kotzebue, AK; K.H. Morgan of the Canadian Wildlife Service, Sidney, BC, Canada; C.L. Parker of the University of Alaska Museum of the North, Fairbanks, AK; J. Puschock of Seattle, WA; D.G. Roseneau of the USFWS, Homer, AK; M.C. Thompson of Winfield, KS; and D.M. Troy of Anchorage, AK. We also thank A.L. Zusi-Cobb of ABR for the maps. This publication has benefited from the reviews of S. Kendall, M. Kissling, and C. Strong. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the US Fish and Wildlife Service.

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