KITTLITZ'S MURRELET *BRACHYRAMPHUS BREVIROSTRIS* ON FRESHWATER LAKES IN THE BRISTOL BAY REGION OF SOUTHWESTERN ALASKA

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SUMMARY

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Kittlitz's Murrelets *Brachyramphus brevirostris* are seabirds endemic to the North Pacific and Bering Sea. A pilot survey in August 2013 confirmed their presence on a freshwater glacial lake in the Bristol Bay region of southwestern Alaska. We carried out a more comprehensive survey in 2014 during the late nesting and early post-nesting periods, covering three lakes in the Wood River lake system, largely within Wood–Tikchik State Park, as well as Togiak Lake within Togiak National Wildlife Refuge. Kittlitz's Murrelet presence was confirmed on Lakes Aleknagik and Nerka, with a peak of 66 birds on Lake Aleknagik on 4 August. Distance sampling was employed on Lake Aleknagik during replicate surveys. Maximal abundance (95% confidence intervals) was estimated at 253 birds (100–644). No hatching-year birds were observed; however, one adult was observed holding a fish in its bill, which may indicate nearby nesting activity. These findings warrant further research, given the sensitivity of this species and its novel use of freshwater resources, an aspect of Kittlitz's Murrelet life history that had not previously been reported in the literature.

Key words: Kittlitz's Murrelet, *Brachyramphus brevirostris*, density and abundance, freshwater resources, Bristol Bay, Alaska

INTRODUCTION

The population size and distribution of Kittlitz's Murrelet (KIMU) in Alaska remains poorly understood, despite long-term, longitudinal studies in Glacier Bay, Icy Bay and Prince William Sound (Kuletz *et al*. 2003, Kissling *et al*. 2007, Piatt *et al.* 2011). Studies on Kodiak Island also have provided important insight into nesting ecology (Lawonn *et al.* 2011). However, these studies represent geographically isolated accounts of KIMU across an expansive and variable range.

Brachyramphus murrelets are the only alcids that nest non-colonially. In Alaska, they nest from mid-May to late July in scattered coastal breeding grounds. KIMU nest on or near steep mountaintops in glacial or glaciated areas, up to 75 km inland (Day *et al*. 1999). In contrast, Marbled Murrelets *Brachyramphus marmoratus* (MAMU) typically nest in trees in mature coastal forests (Nelson 1997). Both species lay a single egg that is incubated for about 30 d. It takes an additional 25–30 d for KIMU chicks to fledge, at which point the young are roughly 50% of adult mass, with wings 80% of adult length (Kaler *et al.* 2009). Fledglings are poor fliers during their first week, leaving the nest and heading toward water in late July to early August (Day 1996). By mid-August, it is nearly impossible to tell whether hatching-year birds were produced in the area or arrived during the post-breeding migration.

The presence of KIMU on freshwater lakes has not been reported in the literature, despite years of murrelet sightings by lake visitors in the Bristol Bay area. In August of 2013, staff at Togiak National Wildlife Refuge conducted a pilot survey on Lake Aleknagik and counted at least 26 individuals from 41 observations (Walsh 2013). Interestingly, the count included one deceased MAMU fledgling, a species that has not been described on Lake Aleknagik since 1980 (Gibson 1980). One adult KIMU also was observed holding what appeared to be a stickleback (*Gasterosteus* or *Pungitius* sp.). The records of KIMU and presence of at least one pair of breeding MAMU motivated a more extensive survey of the Wood River lake system and of Togiak Lake in 2014.

Three objectives guided efforts on Lake Aleknagik: to document the presence of KIMU during the late nesting and early post-nesting periods; to estimate their summer population density; and to record evidence of nesting activity by observing hatching-year birds or other indicators of a breeding population. Determining the presence or absence of murrelets was the only objective of surveys on Lake Nerka, Lake Beverly, and Togiak Lake, because there were no anecdotal records informing these efforts.

STUDY AREA AND METHODS

All lakes in the study area are situated within the Bristol Bay region of southwestern Alaska (Fig. 1) and surrounded by mountain slopes that are vegetated or consist of bare rock with steep talus fields. The Wood River lake system consists of a series of glacial lakes near Togiak National Wildlife Refuge. This chain of lakes drains into the Wood River, which flows into the Nushugak River, Nushugak Bay, and, ultimately, into Bristol Bay. Many of the lakes in the Bristol Bay area are deep and extend below sea

level because they formed in cryptodepressions left by receding glaciers (Burgner 1991).

This study focused on the three coastward lakes in the chain: Lakes Aleknagik, Nerka and Beverly. Lake Aleknagik is a long, narrow lake that covers ~88 km^2 (Brown 2005). Lake Nerka is the largest lake at ~202 km^2, with several branches extending from its upper and lower divisions; Little Togiak Lake is situated just to the west. Lake Nerka drains into Lake Aleknagik via the Agulowak River and connects to Lake Beverly via the Agulukpak River. Lake Beverly is the third lake, spanning 90.6 km^2.

Togiak Lake is situated within the federally designated Wilderness Area of Togiak National Wildlife Refuge. Its axis runs north to south, draining into the Togiak River, which empties into Bristol Bay. Togiak Lake covers just under 39 km^2 (MacDonald 1996).

Fig 1. Study area, centered over the Bristol Bay region of southwestern Alaska.

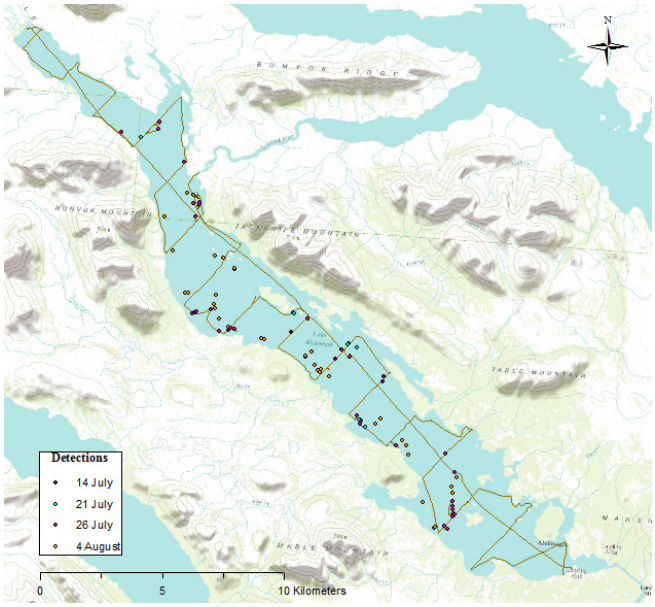

Fig. 2. Spatial distribution of Kittlitz's Murrelet groups on Lake Aleknagik, Alaska, in July–August, 2014. Line shows the transect route followed during surveys.

Data collection

Replicate surveys were conducted on Lake Aleknagik during the KIMU late nesting (14 July) and early post-nesting (21 and 26 July) periods, in addition to effort spent 4 August scouting for hatching-year birds. Crews consisted of one boat operator and two observers, and surveys followed a series of transects spaced 2 km apart and oriented perpendicular to the shoreline (Fig. 2). Transects were developed using 2 km × 2 km grids in ArcMap 10.1, part of the ArcGIS platform (Environmental Systems Research Institute [ESRI], 2012, Redlands, CA, USA). Survey points were exported as shapefiles (.shp) into DNRGPS and converted to the GPS eXchange format (.gpx) compliant with Mapsource v6.16.3 (Garmin Ltd., 2010, Schaffhausen, CH).

Surveys on Lake Aleknagik were conducted using an 18–20 foot motorized skiff traveling on average 18–22 km/h. Transect legs were assigned initial sun-glare scores and sea scores based on the Beaufort sea scale. When a "group" of one or more murrelets was detected, we stopped the boat, estimated the diagonal distance to the group and measured its compass bearing. An initial waypoint was collected using a recreational-grade GPS unit (WGS84 datum). We also recorded group size and behavior and took photographs for later evaluation (Fig. 3). An initial species identification was recorded based on visual cues observed through

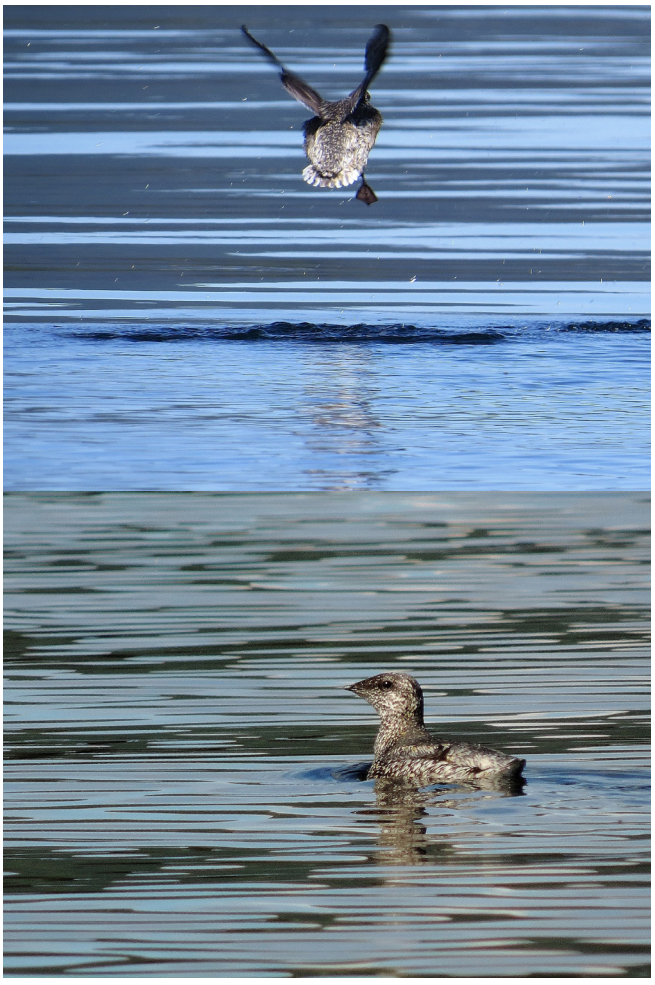

Fig. 3. Kittlitz's Murrelets recorded on Lake Aleknagik, Alaska, July–August, 2014. Photo credit: Rachel Ruden/USFWS.

long-range binoculars. When possible, we recorded a second waypoint at the approximate location of the group on the lake when it was first detected.

The presence/absence surveys on Lake Beverly and Togiak Lake on 31 July used a single route that ran the length of each lake. Murrelet observations on Lake Nerka were recorded opportunistically over the course of the study period.

Data processing

Distance sampling data from each survey were processed separately. The bearing (ø) refers to the angle at which a group was detected off of its respective transect leg. The bearing was calculated by taking the difference off true north of the group angle, measured with a compass, and the transect angle, measured in ArcMap 10.1. The perpendicular distance (x) of the group from the transect could then be solved for using the equation $x = r \sin ø$, where r equals the distance estimated by the observer (Buckland *et al.* 1993). When two waypoints were available, an off-transect distance was calculated by taking the perpendicular distance of the second waypoint from the transect. This was measured using the ruler tool in ArcMap 10.1.

Detections from all survey days on Lake Aleknagik were combined and imported into Distance 6.2 Release 1 (Thomas *et al.* 2010) to develop a detection function. This detection function was then applied to the data to estimate murrelet density and abundance per survey. A separate detection function was developed using distances estimated with the off-transect method. The function was then applied to the second data set for comparison of the density and abundance estimates. Finally, each group's location was assessed according to water depth using a bathymetric layer of the lake in ArcMap 10.1 (Fig. 4).

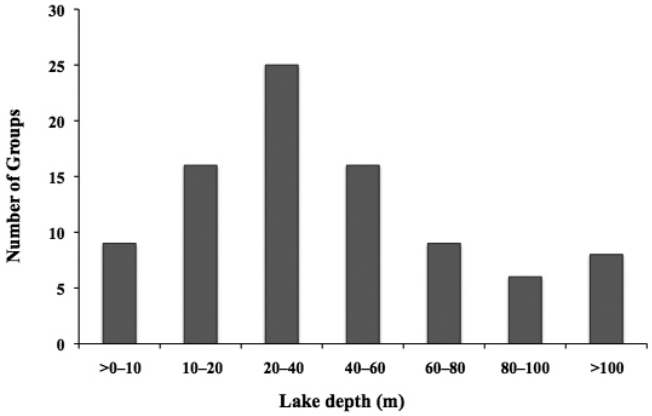

Fig. 4. Distribution of Kittlitz's Murrelet groups by water depth on Lake Aleknagik, Alaska, July–August 2014. Group location was evaluated using a bathymetric map of Lake Aleknagik imported as a layer into ArcMap 10.1.

TABLE 1
Results of Kittlitz's Murrelet surveys conducted on Lake Aleknagik, Alaska, in July–August 2014

Date	Total groups	Total birds	Mean group size
14 July	6	8	1.33
21 July	9	13	1.44
26 July	36	61	1.69
4 August[a]	40	66	1.65

[a] Data from 4 August were recorded during an opportunistic survey of the lake.

RESULTS

KIMUs were detected over a greater area of Lake Aleknagik than in 2013, with a fairly uniform spatial distribution (Fig. 2). Replicate surveys recorded eight adults (six groups) on 14 July, 13 adults (nine groups) on 21 July, and 61 adults (36 groups) on 26 July. In addition, we opportunistically surveyed the middle third of Lake Aleknagik for hatching-year birds on 4 August and recorded 66 adults (40 groups; Table 1). Interestingly, the first KIMU sighting on Lake Aleknagik was reported on 21 June, three weeks before formal surveys began.

The distance sampling method used on Lake Aleknagik resulted in 17 detections (15 m intervals, truncation after 240 m), from which a detection function was created. The off-transect method resulted in 15 valid detections (20 m intervals, truncation after 225 m). A second waypoint was not collected during the second survey, resulting in a lower number of detections in the combined pool used to create the second detection function (Table 2).

Of note, KIMU distribution by lake depth followed a bell-shaped curve that ranged from >0 to >100 m, with the largest number of groups detected within the 20–40 m depth interval (Fig. 4). Group size also changed over the study period. Although single adults were the most frequent group detected, the largest group size encountered increased over time, from two individuals on 14 July to six individuals on 4 August.

We did not detect any groups on Lake Beverly or Togiak Lake. Although a formal survey could not be conducted on Lake Nerka, Daniel Schindler of the University of Washington's Fisheries Research Institute recorded KIMUs in a range of locations on Lake Nerka and Little Togiak Lake. Locations included the point on upper River Arm, the heads of Anvil and Ott Bays, the islands near the outlet of Little Togiak Lake, and the northwest end of Little Togiak Lake (Appendix 1, available online).

TABLE 2
Density and abundance estimates for Kittlitz's Murrelets based on detection functions developed in Program DISTANCE

Date	Distance estimation		Off-transect	
	Density (95% CI)	Abundance (95% CI)	Density (95% CI)	Abundance (95% CI)
14 July	1.28 (0.38–4.28)	113 (34–376)	1.59 (0.25–9.93)	140 (22–875)
21 July	0.64 (0.08–5.18)	56 (7–456)	_[a]	_[a]
26 July	2.88 (1.13–7.31)	253 (100–644)	4.76 (0.95–23.77)	419 (84–2093)

[a] Off-transect data were not collected during the 21 July survey.

Perhaps the strongest evidence for nesting activity in the area came on 26 July, when a single adult was observed holding in its bill what appeared to be a sockeye salmon *Oncorhynchus nerka* fingerling, based on the fish's obvious parr marks.

DISCUSSION

KIMUs were recorded on Lakes Aleknagik and Nerka during the 2014 late nesting and early post-nesting periods, but they were not observed on Lake Beverly or Togiak Lake. Distance from the ocean may explain the observed distribution of KIMU on lakes in the Wood River lake system. Lake Aleknagik ranges 50–75 km inland, and Lake Nerka ranges 65–100 km inland (Brown 2005), whereas Lake Beverly and Togiak Lake surpass the upper extent of this seabird's hypothesized inland nesting range (Day *et al*. 1999) at 80–100 km and 75–95 km (MacDonald 1996), respectively. As one nest site has been recorded 75 km inland (Murphy *et al.* 1984), such distances may be plausible but do not appear to be typical.

Our survey efforts focused on Lake Aleknagik because of the number of KIMUs encountered there during the 2013 pilot survey. Subsequently, results from the 2014 surveys were consistent with known indicators of nesting activity, suggesting that a local breeding population may reside here despite our inability to detect hatching-year birds on the water. KIMUs were observed on the lake as early as 21 June 2014, the number of birds detected increased over the study period, and an adult was seen holding a fish. A fourth survey planned for 5–15 August could not be completed due to adverse survey conditions. Unfortunately, this may have been a critical window for chicks in the area to fledge and reach the lake, eliminating our opportunity to detect fledglings. Because it takes an average of 55 d from incubation to fledge, an adult would have to lay an egg by 10 June, at the latest, for a chick to be encountered as a fledgling on 4 August. This laying date would be early in the context of nest initiations across Alaska; egg occupancy can be protracted by more than a month from southeastern Alaska (15 May–14 June) to the Chukchi Sea (≤16–28 June) (Day 1996).

We provide a rough estimate of KIMU population density and abundance based on distance sampling. It is widely accepted that 60–80 observations are needed to develop a reliable detection function (Buckland *et al.* 1993). However, in consultation for this project, M. Kirchhoff suggested that our target be 30 observations (pers. comm., 18 June 2014). Both the distance estimation and off-transect methods used to collect distance data fell below this minimal threshold, at 17 and 15 detections, respectively. Because each detection function was created from the combined pool of valid detections per survey day, a fourth survey completed during the peak plateau of abundance may have satisfied the minimum. Extrapolating information from a limited data set is a concern when assessing such a small and elusive sample unit (Thompson 2004); however, strip transects would have resulted in a smaller and less accurate population estimate than that achieved by distance sampling.

Fish-holding behavior is widely accepted as an indication of chick-rearing by adult MAMU (Carter and Sealy 1987). The observation of an adult KIMU holding a young salmonid on Lake Aleknagik in 2014 is significant for two reasons. First, it fulfills our third objective: to record indicators of a breeding population. Second, salmon is likely a novel food source for this species. KIMUs at sea are known to forage on capelin *Mallotus villosus*, Pacific herring *Clupea pallasii* and Pacific sandlance *Ammodytes hexapterus* in the summer (Day *et al.* 1999, Day & Nigro 2000). Lake Aleknagik supports a myriad of fish species, including threespine stickleback *Gasterosteus aculeatus*, ninespine stickleback *Pungitius pungitius* and slimy sculpin *Cottus cognatus*, and it provides nursery habitat for sockeye salmon *Oncorhynchus nerka* and arctic char *Salvelinus alpinus* (Rogers 1973).

In Prince William Sound, adult KIMU target fish between 30 and 120 mm in length (Day and Nigro 2000). The salmon present in Lake Aleknagik span a range of developmental stages, with sockeye fry measuring 25–60 mm in length and sockeye fingerlings measuring 45–118 mm in length (Rogers 1973). Therefore, both stages fall within the size class of fish species taken by KIMUs elsewhere in Alaska. The stickleback species present in Lake Aleknagik also fall within this size class, consistent with the fish-holding observation recorded previously (Walsh 2013).

The closely related MAMU has been known to forage more than 100 km from its nest site (Bradley *et al.* 2004). Although fish-holding is an important observation, it does not confirm breeding on the talus slopes surrounding Lake Aleknagik. Nonetheless, our repeated observations suggest that the lake may support a breeding population of KIMU in the low hundreds. The population counts showed a sharp peak in late July, sustained into early August, when we would expect both adults of a nesting pair to be free of the nest and provisioning their chick (Day *et al.* 1999).

The proximity of the Wood River lake system to talus fields is consistent with KIMU nesting preferences (Day *et al.* 1999, Lawonn *et al.* 2011). Moreover, there is strong evidence of breeding by MAMU in the area, which are known to use similar talus slopes when ground-nesting (Barbaree *et al.* 2014). A deceased hatching-year MAMU was found on Lake Aleknagik 21 August 2013 (Walsh 2013). In addition, outside of this study, a smaller deceased hatching-year KIMU was found on the north end of the Goodnews Lake, roughly 75 km inland within Togiak National Wildlife Refuge, on 25 July 2014. Both individuals had retained egg teeth, an indication that they were recent fledglings from nearby nest sites. The occasional use of lakes may be an unrecognized facet of KIMU behavior, or perhaps these elusive seabirds are adaptable in the face of changing habitat. The use of freshwater resources within 100 km of marine waters is a novel addition to KIMU life history that warrants further investigation.

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