



# Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve

## *2019 Annual Report*

Natural Resource Report NPS/SEAN/NRR—2020/2063





**ON THIS PAGE**

Sea otter.

Image credit: NPS/ STEVEN HOEKMAN

**ON THE COVER**

Lamplugh Glacier, a tidewater glacier in Johns Hopkins Inlet.

Image credit: NPS/ STEVEN HOEKMAN

---

# **Monitoring Kittlitz's and Marbled Murrelets in Glacier Bay National Park and Preserve**

## *2019 Annual Report*

Natural Resource Report NPS/SEAN/NRR—2020/2063

Steven T. Hoekman<sup>1</sup>, William F. Johnson<sup>2</sup>

<sup>1</sup>Wild Ginger Consulting  
P.O. Box 182  
Langley, WA 98260

<sup>2</sup>National Park Service  
Southeast Alaska Network, Inventory and Monitoring Program  
3100 National Park Road  
Juneau, AK 99801

January 2020

U.S. Department of the Interior  
National Park Service  
Natural Resource Stewardship and Science  
Fort Collins, Colorado

The National Park Service, Natural Resource Stewardship and Science office in Fort Collins, Colorado, publishes a range of reports that address natural resource topics. These reports are of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Report Series is used to disseminate comprehensive information and analysis about natural resources and related topics concerning lands managed by the National Park Service. The series supports the advancement of science, informed decision-making, and the achievement of the National Park Service mission. The series also provides a forum for presenting more lengthy results that may not be accepted by publications with page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

Views, statements, findings, conclusions, recommendations, and data in this report do not necessarily reflect views and policies of the National Park Service, U.S. Department of the Interior. Mention of trade names or commercial products does not constitute endorsement or recommendation for use by the U.S. Government.

This report is available in digital format from the [Southeast Alaska Network website](#) and the [Natural Resource Publications Management website](#). If you have difficulty accessing information in this publication, particularly if using assistive technology, please email [irma@nps.gov](mailto:irma@nps.gov).

Please cite this publication as:

Hoekman, S. T., and W. F. Johnson. 2020. Monitoring Kittlitz's and marbled murrelets in Glacier Bay National Park and Preserve: 2019 annual report. Natural Resource Report NPS/SEAN/NRR—2020/2063. National Park Service, Fort Collins, Colorado.

# Contents

|                                           | Page |
|-------------------------------------------|------|
| Figures.....                              | iv   |
| Tables.....                               | iv   |
| Executive Summary .....                   | v    |
| Acknowledgments.....                      | vi   |
| Introduction.....                         | 1    |
| Methods.....                              | 2    |
| Study Area .....                          | 2    |
| Survey Design .....                       | 2    |
| Survey Methods.....                       | 4    |
| Abundance Estimation.....                 | 4    |
| Distance Calibration .....                | 4    |
| Results.....                              | 6    |
| Detection Function .....                  | 6    |
| Density and Abundance.....                | 8    |
| Spatial Distributions .....               | 10   |
| Distance Calibration .....                | 12   |
| Discussion and Recommendations .....      | 14   |
| Abundance and Spatial Distributions ..... | 14   |
| Distance Calibration .....                | 15   |
| Recommendations .....                     | 16   |
| Literature Cited .....                    | 17   |

## Figures

|                                                                                                                                                                                                                                                                                                               | Page |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| <b>Figure 1.</b> Line transects surveyed for murrelets during July 2019 in Glacier Bay. Permanent (red lines, numbered $\leq 25$ ) and rotating panel one (green, numbered $>100$ ) transects were surveyed as part of an augmented, serially alternating panel design with a three-year rotating panel ..... | 3    |
| <b>Figure 2.</b> Estimated detection function for murrelets from line transect surveys in Glacier Bay during July 2019, illustrating estimated detection probability of murrelet groups relative to perpendicular distance from the transect center line.....                                                 | 6    |
| <b>Figure 3.</b> Estimated density (individuals/km <sup>2</sup> ) of Kittlitz's (KIMU, vermilion) and marbled murrelets (MAMU, yellow) in Glacier Bay during July across survey years 2009-2019 .....                                                                                                         | 10   |
| <b>Figure 4.</b> Spatial distribution of Kittlitz's murrelets (KIMU) observed during line transect surveys in Glacier Bay during July 2019 .....                                                                                                                                                              | 11   |
| <b>Figure 5.</b> Spatial distribution of marbled murrelets (MAMU) observed during line transect surveys in Glacier Bay during July 2019.....                                                                                                                                                                  | 12   |
| <b>Figure 6.</b> Percent error in estimated distances relative to true distances during distance calibration assessments during July 2019 .....                                                                                                                                                               | 13   |

## Tables

|                                                                                                                                                                                          | Page |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| <b>Table 1.</b> Component parameter values used to estimate on-water density and abundance of Kittlitz's and marbled murrelets in Glacier Bay during July 2019 .....                     | 7    |
| <b>Table 2.</b> Estimates of on-water population density and abundance of Kittlitz's and marbled murrelets in the Glacier Bay survey area during July across survey years 2009-2019..... | 9    |
| <b>Table 3.</b> Average encounter rates (groups/km) for KIMU in Glacier Bay during July 2019 versus July 2010-2019 on transects in six density groups .....                              | 10   |

## Executive Summary

Since 2009, the National Park Service's Southeast Alaska Network (SEAN) has monitored abundance and spatial distribution of Kittlitz's (*Brachyramphus brevirostris*, "KIMU") and marbled murrelets (*B. marmoratus*, "MAMU") in Glacier Bay National Park and Preserve, an important summer residence for both species. The design of the monitoring program focuses on KIMU, with secondary consideration of MAMU. The SEAN uses vessel-based line transect surveys to estimate species-specific, on-water density and abundance of murrelets, accounting for detection probability and partial identification (identification only to genus *Brachyramphus*).

We surveyed 40 transects totaling 206.6 km from 6-13 July 2019 across the 1,170 km<sup>2</sup> survey area in Glacier Bay proper. We estimated an abundance of 4,155 KIMU (SE = 934) and 64,868 MAMU (SE = 12,725). Estimated MAMU abundance was 24% lower than 2018 and near the 11-year monitoring average. In contrast, estimated KIMU abundance was 60% lower than 2018 and, at <40% of the 11-year average, the lowest during SEAN monitoring.

The spatial distribution of KIMU was also atypical. Few to no KIMU were observed in upper fjords of the East and West Arms, including historically consistently-used areas in Reid Inlet, around Russell Island, and in the Hugh Miller-Scidmore Area. Instead, KIMU aggregated almost exclusively near the mouth of Muir Inlet and on the east side of the Central Bay. Consistent with prior results, MAMU congregated in the Central and Lower Bay. However, MAMU mirrored KIMU in decreased use (relative to prior surveys) of the East and West Arms and of the Hugh Miller-Scidmore Area and in increased use of the upper east side of the Central Bay, suggesting common ecological drivers to spatial distributions.

Causes of low estimated abundance and altered spatial distribution for KIMU in 2019 are unknown, and these data should be interpreted cautiously. Large annual fluctuations in abundance estimates of both species have quickly reversed transient changes, and future estimates will inform interpretation of 2019 results. Fluctuations likely reflect multiple factors, including: imprecision of estimates, potential bias in estimates resulting from infrequent but pervasive misidentification of these similar species, and true change in populations due to demographic factors such as survival, reproduction, and regional movements among alternative summering areas. Recent advances in sampling and analytic methods have highlighted challenges presented by misidentification, but also offer opportunity for enhancing monitoring methods to minimize misidentification and consequent degraded capacity to meet objectives of monitoring abundance and trend. Glacier Bay continues to house a significant fraction of the global population of each species.

Line transect methods require accurate distance estimates to animals to accurately estimate abundance. Distance calibration, which develops proficiency of survey observers in distance estimation, was improved by new binocular rangefinders allowing quick target acquisition (both buoys and murrelets) at previously under-represented longer distances (125–200 m) that are commonly used during surveys. These capabilities increased realism of distance calibration and demonstrated that observers met performance objectives, even at longer distances.

## Acknowledgments

We could not accomplish these surveys without the help of motivated and talented volunteers: M. Kirchhoff assisted with 2019 field observations. Surveys also rely on the support of SEAN Program Manager M. Bower, who along with J. Womble provided useful critique of versions of this report. R. Sarwas has been integral to maintaining the iOS-based survey software *Park Observer*. R. Swanson piloted the R/V *Fog Lark*. The Glacier Bay National Park and Preserve Visitor Information Station oversaw boating logistics. Glacier Bay staff, especially W. Bredow, T. Bruno, R. Swanson, L. Etherington, E. Johnson, B. McDonough, and J. Todd, facilitated our research and travel logistics in the park.

## Introduction

Since 2009, the National Park Service's Southeast Alaska Network (SEAN) has monitored the abundance of Kittlitz's murrelets (*Brachyramphus brevirostris*, hereafter "KIMU") and marbled murrelets (*B. marmoratus*, hereafter "MAMU") in Glacier Bay National Park and Preserve during early July. The program arose from concern over potential global and local population declines of these rare species (Piatt et al. 2007, 2011, U. S. Fish and Wildlife Service 2013, Kirchhoff et al. 2014) and the hypothesis that murrelet populations respond to fluctuations in Glacier Bay marine and terrestrial ecosystems (Moynahan et al. 2008). As part of its Vital Signs Monitoring Program, the SEAN designated KIMU as a priority vital sign with specific objectives of monitoring status, trend, and spatial distribution of the Glacier Bay population.

The KIMU is a seabird endemic to Alaska and northeastern Russia, with the highest breeding population densities in the northern Gulf of Alaska (Day et al. 2017). KIMU in summer are often associated with tidewater glacier and glacial fjord habitats, but also occur in non-glacially influenced areas (Arimitsu et al. 2011, Kissling et al. 2011, Madison et al. 2011, Day et al. 2017). KIMU often forage in proximity to glacier outflows (Day and Nigro 2000, Kuletz et al. 2003) and nest in recently de-glaciated areas with sparse vegetation (Day 1995, Felis et al. 2016). As a summer resident, open-water, pursuit forager, KIMU populations are likely to be closely linked to fluctuations in marine and terrestrial ecosystems (Moynahan et al. 2008).

The SEAN long-term Kittlitz's murrelet monitoring protocol (hereafter, the "Protocol"; Hoekman et al. 2013) focuses on estimating population abundance and trend, primarily for KIMU and secondarily for MAMU. Sampling effort was spatially allocated to increase precision of KIMU abundance estimates (see *Survey Design* below). Several challenges inherent to Glacier Bay and its murrelet populations complicate monitoring: uncertain identification (species misidentification and partial identification, which is identification only to genus) for these morphologically-similar species, incomplete detection of murrelets along transects, large spatial and temporal variation in populations, and convoluted topography that complicates survey transect placement. The 2009 and 2010 annual reports, in conjunction with the Protocol and an associated publication, fully describe methods developed to address these challenges (Hoekman et al. 2011a, 2011b, 2011c, 2013).

Annual reports, including the present report, concisely deliver results related to abundance and spatial distributions. Synthesis reports at roughly six-year intervals include more in-depth analyses. The first synthesis report assessed program performance and concluded the Protocol is largely functioning as designed, but uncertain identification likely has degraded capacity to meet objectives of monitoring abundance and trend (Hoekman 2019). Most recommendations are beyond the scope of this report, but upgraded equipment allowed us to pursue recommended enhancements to distance calibration assessments (see Standard Operating Procedure 9, hereafter "SOP", in Hoekman et al. 2013) by including longer distances and estimating distances to murrelets in addition to target buoys.

In 2019 field work, our objectives were to conduct vessel-based line transect surveys to estimate abundance and spatial distribution of murrelets in Glacier Bay and to explore enhancements to distance calibration assessment methods.

## Methods

This section includes a brief overview of survey design, survey methods, and analytic approach. Full details can be found in the Protocol (Hoekman et al. 2013); we reference relevant sections below.

### Study Area

Glacier Bay is a narrow, tidewater glacier fjord located in southeastern Alaska. The survey area encompassed 1,170 km<sup>2</sup> of waters north of Icy Strait and excluded some non-motorized waters or areas that did not allow safe survey vessel passage (Figure 1; Figure 2.1 in Hoekman et al. 2013). Pilot surveys during July 2009 used slightly different methods and a slightly smaller study area (Hoekman et al. 2011a).

### Survey Design

We used a generalized random tessellation stratified sampling design (GRTS; Stevens and Olsen 2004) to minimize deleterious effects of large spatial variation in murrelet abundance (Drew et al. 2008, Hoekman et al. 2011a, 2013) by providing a random, spatially-balanced sample. We allocated survey effort relative to expected densities of KIMU using unequal probability sampling (Stevens and Olsen 2004). To avoid placing transects parallel to the observed density gradient of murrelets (Drew et al. 2008, Kirchhoff et al. 2010) and to provide representative coverage across water depths, we oriented linear transects perpendicular to the local prevailing shoreline. In more enclosed waters we used shore-to-shore zigzag transects to avoid undesirably short transects. Transects are sampled using an augmented, serially alternating panel design (McDonald 2003), where one permanent panel (set of transects) with highest expected densities of KIMU is sampled annually and three others are visited on a three-year rotation, with 2019 including panel one (Figure 1). Chapter 2 and Appendix B of the Protocol provide additional detail (Hoekman et al. 2013).

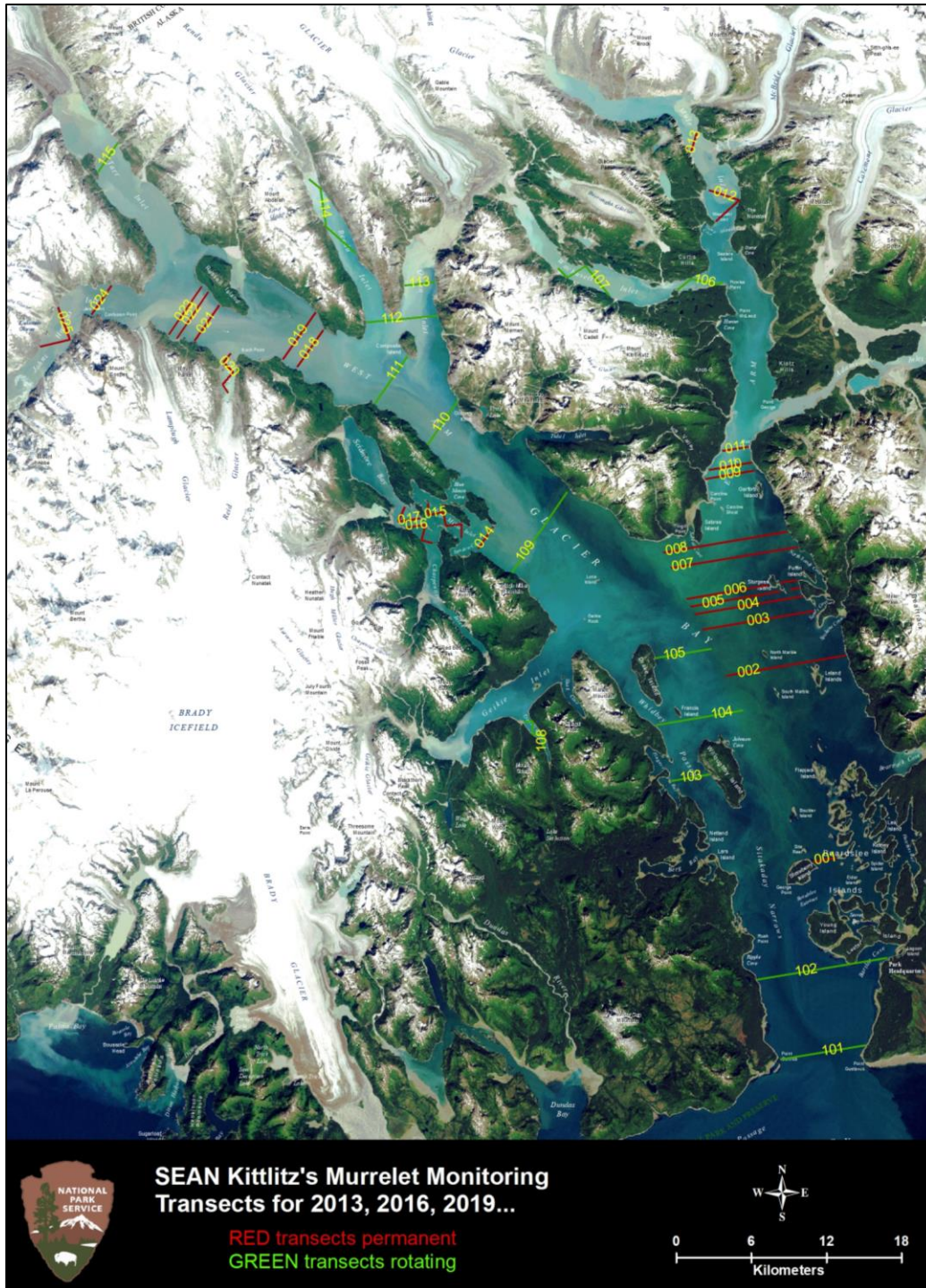


**Figure 1.** Line transects surveyed for murrelets during July 2019 in Glacier Bay. Permanent (red lines, numbered  $\leq 25$ ) and rotating panel one (green, numbered  $>100$ ) transects were surveyed as part of an augmented, serially alternating panel design with a three-year rotating panel. Linear transects were used in open waters ( $>2.5$  km wide) and zigzag transects were used in more restricted waters. Transects extended from shore to shore, except a few truncated at mid-point of the Central Bay to maintain optimal transect length. Linear transects were oriented perpendicular to the local prevailing shoreline. The angle of zigzag transects relative to shore was determined by the width of each area.

## Survey Methods

We conducted vessel-based line transect surveys (Buckland et al. 2001) at a speed of  $\leq 10$  km/h aboard the R/V *Fog Lark*, a 9 m landing craft with a large front deck that provided a viewing height of  $\sim 3$  m above the water for two observers. For all groups (closely associated murrelets of one species class within 5 m of others) initially located on the water, observers recorded group size, species class (KIMU, MAMU, or genus *Brachyramphus* murrelet), and estimated distance and angle (relative to the boat path) to the group. The allowable Beaufort sea state was  $\leq 2$ . Program *Park Observer* (R. Sarwas and W. Johnson, National Park Service), iOS-based software used to record observations of murrelets and associated GPS-based date/time/location stamps, was modified in 2019 to include identity of the survey observer associated with each record. This change can improve abundance estimation by applying statistical modeling of performance (e.g., detection function, uncertain species identification) of individual observers. The Protocol (Chapter 3, SOPs 1, 2, 3, and 9, and Appendix F) provides additional detail (Hoekman et al. 2013), but has not been updated with operational details specific to *Park Observer*.

## Abundance Estimation

We estimated detection probability and group size using Program DISTANCE version 6.2 (Thomas et al. 2010) and species-specific abundance using statistical software R version 3.3.1 (R Core Team 2019) following recommended distance sampling methods (Buckland et al. 2001) and Protocol SOP 12 (Hoekman et al. 2013). Distance sampling methods were modified to account for incomplete detection near the transect center line and partial identification. Adjustments for partial identification assumed correct species identification and identical proportions of each species in the identified and partial identified classes, which is further discussed in Hoekman (2019). Density estimates were based on several component parameters: detection probability across the transect width, detection probability near the center line, group size for each species class, and encounter rates (groups/km of transect) for each species class. We estimated abundance by multiplying total study area (1,170 km<sup>2</sup>) by estimated densities. See Hoekman et al. (2011c) and the Protocol (Hoekman et al. 2013; Appendices A and D, SOPs 11 and 12) for more detail.

## Distance Calibration

SEAN's recent upgrade to more capable laser range-finding binoculars (Leica Geovid HD-B, Leica Camera, Inc., Allendale, New Jersey) offered opportunity to overcome limitations of prior monocular laser range-finding optics in quickly and reliably acquiring true distances to buoy targets and to murrelets. Distance calibration in 2019 emphasized longer distances (125 – 200 m), which had previously been under-represented. Line transect methods are sensitive to systematic bias in estimated distances, with percent bias in estimated distances ("percent bias," calculated as  $100 * \{[\text{estimated distance} - \text{true distance}] / \text{true distance}\}$ ) roughly inversely proportional to percent bias in abundance estimates (Buckland et al. 2001). Because sparse prior data suggested increased under-estimation of longer true distances (Figs. 5, 6 in Hoekman 2019), we compared mean percent bias for longer (125 – 200 m) versus shorter ( $< 125$  m) true distances.

One distance calibration training session used murrelets as targets. Standard methods were altered as follows: The boat travelled in a straight line at  $\sim 5$  km/hour in an area with moderate murrelet density

(near Leland Island, Figs. 1, 4, 5), periodically altering course to encounter murrelets. Participants searched for and pointed out murrelet groups to others. After a group was located by all, the Session Sergeant leading the session (typically the Data Manager) verbally indicated when true distance was acquired *via* rangefinder, and each observer immediately and privately recorded their distance estimate. To assess efficacy of targeting murrelets versus buoys, we compared differences in 1) distributions of true distances, 2) mean percent bias, and 3) sampling rate (i.e., number of estimated distances per observer per minute).

## Results

We surveyed 206.6 km along all 40 permanent and first-year panel transects during 6-13 July 2019; however, transect 025 in Johns Hopkins Inlet was not completed due to drift ice that prevented safe navigation (Figure 1). Hazy, smoky skies (80% of records with >50% cloud cover, none with precipitation or fog) and calm seas (77% and 22% of records with Beaufort force 0 and 1) characterized weather conditions during surveys. Observers recorded 3,734 murrelets in 1,219 on-water groups, of which 13% were classified as KIMU, 70% as MAMU, and 17% as (partially-identified) genus *Brachyramphus* murrelets.

Protocol methods limit murrelet groups (defined above) to one species class. However, when closely associated murrelets include individuals of more than one species class, such mixed groups are denoted by assigning identical time and location data to separate records for each species class. “Mixed-species groups” (containing individual(s) of both species classes) have been infrequent in Glacier Bay (Hoekman 2019), but were common in 2019. Of all KIMU groups, 61% occurred in mixed-species groups with MAMU. For MAMU, 11% of groups were in association with KIMU.

### Detection Function

A hazard rate function was selected to enforce a flat shoulder on the estimated detection function (Figure 2) and to mitigate effects of the high frequency of detections very near the transect center line (Buckland et al. 2001). Away from the transect center line, detection probability declined steadily, but remained relatively high at large perpendicular distances. A wide transect width (right-truncation distance of 200 m) in combination with moderately high detection probability (Table 1) within this width resulted in a high estimated effective strip half-width (126 m).

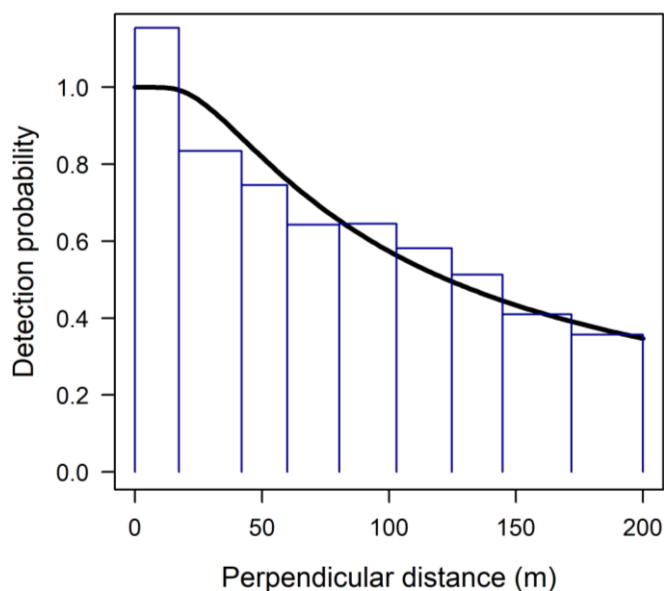


**Figure 2.** Estimated detection function for murrelets from line transect surveys in Glacier Bay during July 2019, illustrating estimated detection probability of murrelet groups relative to perpendicular distance from the transect center line.

**Table 1.** Component parameter values used to estimate on-water density and abundance of Kittlitz's and marbled murrelets in Glacier Bay during July 2019. Group sizes were estimated as averages for each species class. See SOP 11 of the Protocol (Hoekman et al. 2013) for more detail.

| Parameter                                        | Species                                          | Estimate | SE   | P-value | Degrees of freedom |
|--------------------------------------------------|--------------------------------------------------|----------|------|---------|--------------------|
| Detection across transect width                  | All species                                      | 0.63     | 0.04 | —       | 1,188              |
| Detection near transect center line <sup>A</sup> | All species                                      | 0.94     | 0.03 | —       | 66                 |
| Group size: Average                              | Kittlitz's murrelet <sup>B</sup>                 | 1.70     | 0.08 | —       | 160                |
|                                                  | Marbled murrelet <sup>B</sup>                    | 2.96     | 0.10 | —       | 842                |
|                                                  | Genus <i>Brachyramphus</i> murrelet <sup>B</sup> | 4.42     | 0.40 | —       | 185                |
| Group size: Regression estimate                  | Kittlitz's murrelet                              | 1.66     | 0.04 | 0.42    | 159                |
|                                                  | Marbled murrelet                                 | 2.71     | 0.03 | 0.06    | 841                |
|                                                  | Genus <i>Brachyramphus</i> murrelet              | 3.99     | 0.08 | 0.30    | 184                |
| Encounter rate (groups/km)                       | Kittlitz's murrelet                              | 0.40     | 0.08 | —       | 38                 |
|                                                  | Marbled murrelet                                 | 3.57     | 0.66 | —       | 38                 |
|                                                  | Genus <i>Brachyramphus</i> murrelet              | 0.61     | 0.12 | —       | 38                 |

<sup>A</sup> Estimate from Hoekman et al. 2011c.

<sup>B</sup> Estimate selected for estimation of density and abundance.

## **Density and Abundance**

Relatively larger group sizes and much higher encounter rates for MAMU resulted in estimates of on-water density and abundance ~15 times greater than for KIMU (Tables 1, 2). Relatively high variation in encounter rates among transects resulted in relatively low precision of estimates (coefficient of variation or CV; estimated standard error divided by estimated abundance) for KIMU (CV = 0.22) and MAMU (0.20). Estimated density and abundance for MAMU were near the eleven-year average and 24% higher than 2018 (Table 2, Figure 3). However, KIMU estimates were the lowest to date, 60% lower than 2018. Relative to long-term averages, encounter rates for KIMU were elevated in areas with highest expected densities but greatly reduced in all other areas, which cover most of the survey area (Table 3). Transects with no recorded KIMU were much more frequent in 2019 (58%) than other years (range 15-40%).

**Table 2.** Estimates of on-water population density and abundance of Kittlitz's and marbled murrelets in the Glacier Bay survey area during July across survey years 2009-2019. Methods and survey area for pilot surveys in 2009 differed slightly from other years (Hoekman et al. 2011a).

| Year       | Kittlitz's murrelet |            |              |              | Marbled murrelet |            |               |              |
|------------|---------------------|------------|--------------|--------------|------------------|------------|---------------|--------------|
|            | Density A           | SE         | Abundance    | SE           | Density A        | SE         | Abundance     | SE           |
| 2019       | 3.6                 | 0.8        | 4,155        | 934          | 55.4             | 10.9       | 64,868        | 12,725       |
| 2018       | 9.0                 | 2.3        | 10,517       | 2,655        | 44.7             | 6.6        | 52,302        | 7,752        |
| 2017       | 7.5                 | 1.3        | 8,810        | 1,513        | 50.5             | 7.2        | 59,126        | 8,390        |
| 2016       | 6.0                 | 1.1        | 7,026        | 1,345        | 51.8             | 10.3       | 60,624        | 12,018       |
| 2015       | 9.2                 | 2.2        | 10,778       | 2,598        | 71.6             | 10.3       | 83,793        | 12,044       |
| 2014       | 8.9                 | 1.3        | 10,422       | 1,522        | 35.4             | 3.4        | 41,474        | 3,998        |
| 2013       | 6.2                 | 1.7        | 7,210        | 2,046        | 72.2             | 13.2       | 84,428        | 15,394       |
| 2012       | 14.1                | 2.2        | 16,469       | 2,581        | 44.9             | 4.5        | 52,560        | 5,216        |
| 2011       | 6.4                 | 1.0        | 7,477        | 1,119        | 63.1             | 6.0        | 73,766        | 7,055        |
| 2010       | 11.4                | 1.2        | 13,308       | 1,357        | 52.7             | 4.6        | 61,717        | 5,372        |
| 2009       | 12.0                | 3.7        | 13,124 B     | 4,062        | 26.5             | 3.7        | 28,978 B      | 4,077        |
| <b>All</b> | <b>8.6</b>          | <b>1.0</b> | <b>9,961</b> | <b>1,096</b> | <b>51.8</b>      | <b>4.3</b> | <b>60,417</b> | <b>5,167</b> |

<sup>A</sup> Individuals/km<sup>2</sup>

<sup>B</sup> Abundance extrapolated over the 1,092 km<sup>2</sup> survey area; all others extrapolated over 1,170 km<sup>2</sup>.

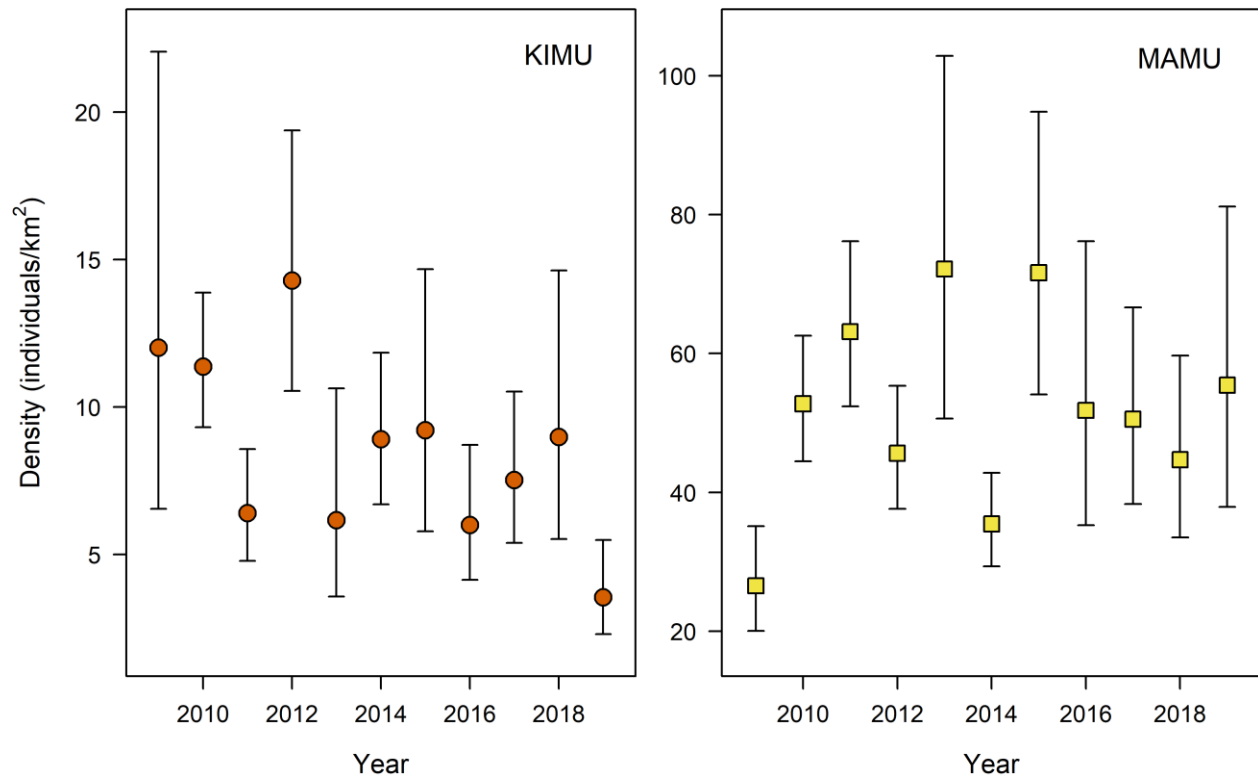


**Figure 3.** Estimated density (individuals/km<sup>2</sup>) of Kittlitz's (KIMU, vermilion) and marbled murrelets (MAMU, yellow) in Glacier Bay during July across survey years 2009-2019. Error bars are 95% confidence intervals. Note differing y-axis scales. Pilot survey methods (Hoekman 2011a) and survey area for 2009 (1,092 km<sup>2</sup>) differed slightly from other years (1,170 km<sup>2</sup>).

**Table 3.** Average encounter rates (groups/km) for KIMU in Glacier Bay during July 2019 versus July 2010-2019 on transects in six density groups. Ordered density groups included transects with lowest (group 1) to highest (5 and 6) expected densities of KIMU. See Hoekman et al. (2013) Appendix B for additional detail.

| Transect<br>Density Groups | Percent of<br>Survey Area | Year(s) |           |
|----------------------------|---------------------------|---------|-----------|
|                            |                           | 2019    | 2010-2019 |
| 1 and 2                    | 60%                       | 0.05    | 0.61      |
| 3 and 4                    | 27%                       | 0.68    | 1.24      |
| 5 and 6                    | 13%                       | 1.57    | 1.31      |

## Spatial Distributions

Murrelet observations were most concentrated in the east side of the Central Bay, extending north from North Marble Island to the mouth of Muir Inlet. Observations of KIMU (Figure 4) were densest in the mouth of Muir Inlet, moderate in the upper east side of the Central Bay, and sparse elsewhere. For MAMU (Figure 5), observations were dense in the mouth of Muir Inlet, the upper east side of the Central Bay, and the Lower Bay; elsewhere, densities were uniformly low.

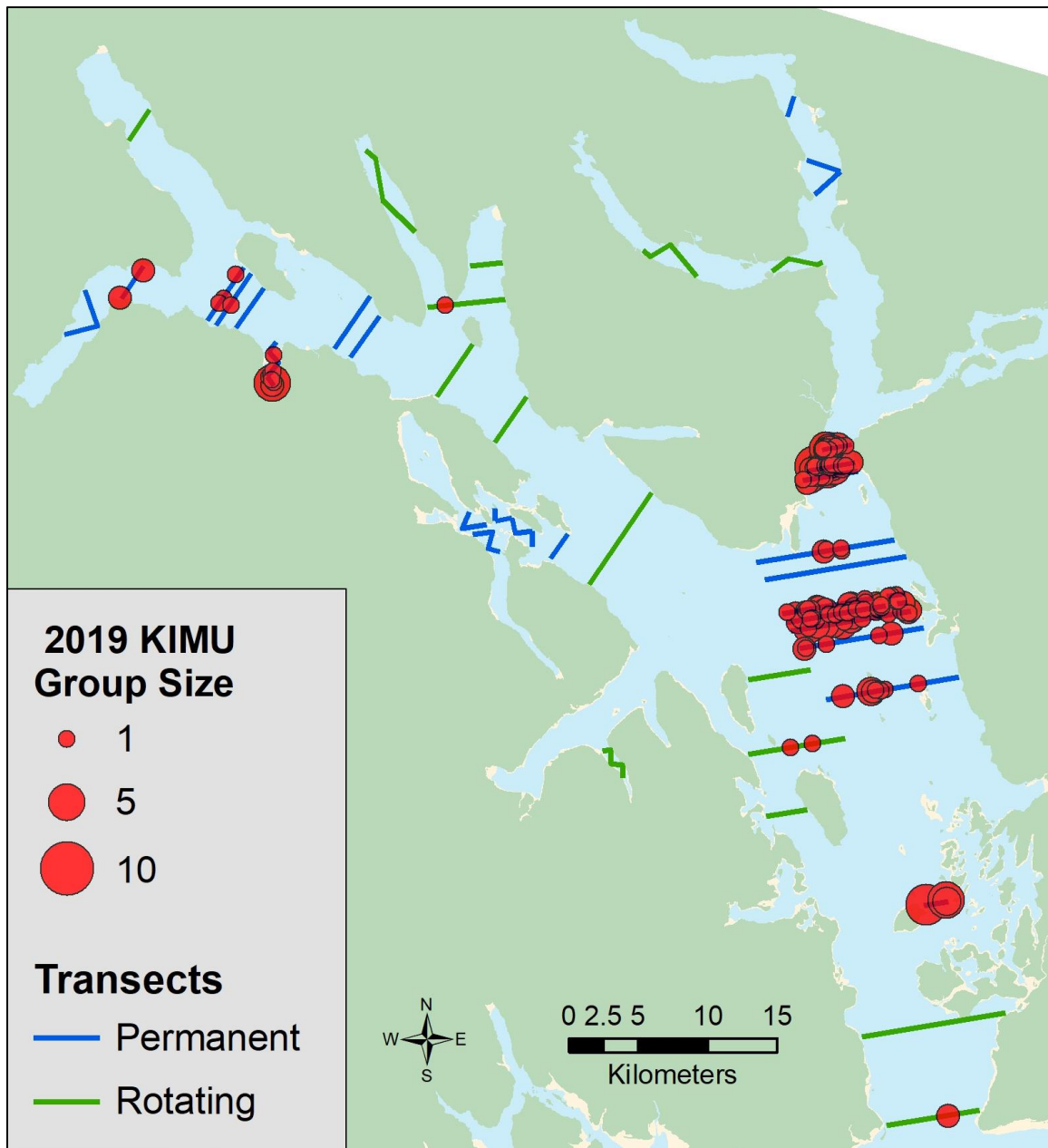


**Figure 4.** Spatial distribution of Kittlitz's murrelets (KIMU) observed during line transect surveys in Glacier Bay during July 2019. Permanent transects (blue) are sampled annually, while rotating panel transects (green) are from panel one of a three-year rotation. Area of circles is proportional to group size.

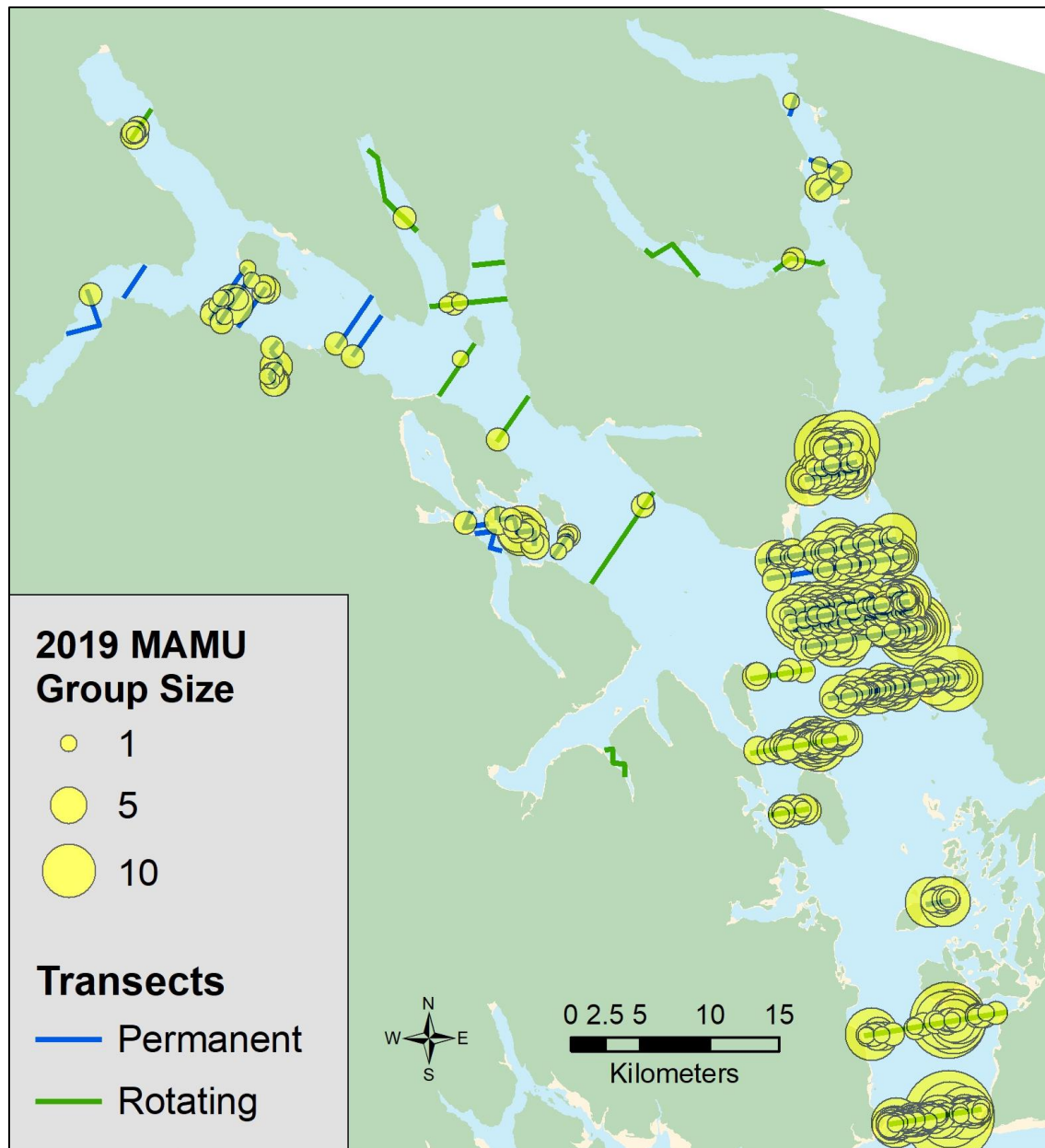


**Figure 5.** Spatial distribution of marbled murrelets (MAMU) observed during line transect surveys in Glacier Bay during July 2019. Permanent transects (blue) are sampled annually, while rotating panel transects (green) are from panel one of a three-year rotation. Area of circles is proportional to group size.

### Distance Calibration

During distance calibration assessments, range-finding binoculars were generally successful in acquiring buoy targets at distances <250 m, although seas were calm (80% and 20% with Beaufort force of 0 and 1). True distances >250 m ( $n = 4$ ) were censored from analyses. Percent error of distances estimates did not differ strongly for shorter (<125 m, mean  $\pm$  SE,  $-0.048\% \pm 0.020$ ) relative to longer (range 125 – 240 m,  $-0.055\% \pm 0.016$ ) true distances, although estimates for true distances >175 m tended to more consistently under-estimate true distances (Figure 6). Comparison of buoys

versus murrelets as targets during distance calibration training sessions did not support meaningful differences in true distances (buoys,  $112 \text{ m} \pm 3.7$ , maximum = 277 m; murrelets,  $118 \text{ m} \pm 11.3$ , maximum = 163 m) or in percent error in estimates (buoys,  $-0.022\% \pm 0.013$ ; murrelets,  $-0.029\% \pm 0.027$ ). Sampling rate (estimates per observer per minute) was much lower when targeting murrelets (0.40,  $n = 24$  estimates) versus buoys (1.66,  $n = 176$ ).

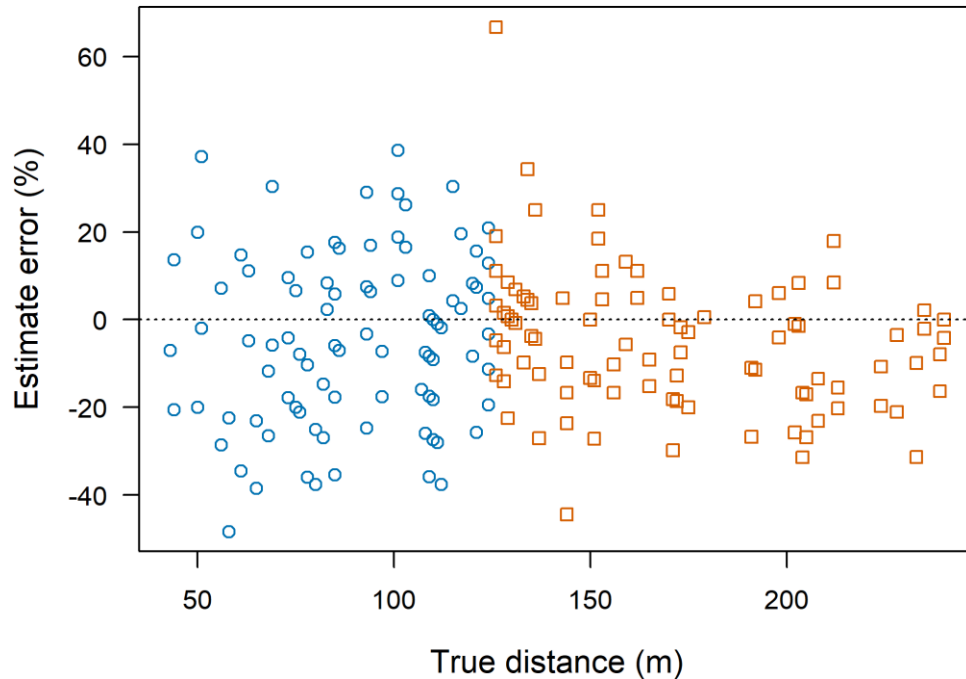


**Figure 6.** Percent error in estimated distances relative to true distances during distance calibration assessments during July 2019. Blue circles and vermilion squares denote true distances  $<125 \text{ m}$  or  $\geq 125 \text{ m}$ . The dotted reference line displays error = 0.

## Discussion and Recommendations

### Abundance and Spatial Distributions

Estimated density and abundance (hereafter, we refer only to abundance) and observed spatial distribution for MAMU in Glacier Bay were largely consistent with results since 2009; however, results for KIMU were atypical. Considerable annual variation in abundance estimates for both species since 2009 likely reflects a combination of factors, including: imprecision in estimates (resulting from high spatial variation in murrelet encounter rates), potential bias in estimates resulting from uncertain identification (Hoekman 2019), and variation in true populations. In Glacier Bay and other summer population centers, annual fluctuations in abundance estimates appear larger than can be explained by intrinsic population growth (i.e., reproduction and survival), and regional movements likely have contributed to this variation (Kissling et al. 2015, Bertram et al. 2015, Hoekman 2019).

MAMU abundance in Glacier Bay since 2010 has been high but variable, with 2019 abundance near the long-term average. Annual fluctuations in abundance likely are influenced by regional movements, by numbers of local “day-commuters” arriving to forage in Glacier Bay, and northward migration by post-breeding birds (Kirchhoff 2008, Bertram et al. 2016). In contrast, estimated 2019 KIMU abundance was lower than for any comparable survey since 2007 (Kirchhoff 2008). Differences in methods hinder comparison to earlier surveys (Drew et al. 2008, Hoekman 2019).

Low estimated KIMU abundance in 2019 coincided with contraction and concentration of their spatial distribution. Previously, KIMU consistently made moderate to high use of upper fjord areas in the East and West Arms, but in each year also aggregated in a few of several consistently-used areas scattered across Glacier Bay (Drew et al. 2008, Hoekman 2019). In 2019, KIMU almost exclusively concentrated in the east side of the Central Bay: from North Boulder Island to the mouth of Muir Inlet (Figure 4) and also in the Beardslee Entrance north to Flapjack Island (personal observation). A similar distribution has only been observed in 2003 (Drew et al. 2008), and near-average abundance in 2003 (relative to comparable surveys during 1999-2003) suggested no association with low abundance. Despite their restricted spatial distribution in 2019, prevalence of KIMU in high density transect groups (Table 3) indicated that unequal probability sampling effectively elevated sampling intensity in areas of KIMU concentration, increasing precision and reliability of estimated abundance.

MAMU observations typically have been widely dispersed across Glacier Bay during summer, with densities increasing in proximity to the mouth of Glacier Bay (Drew et al. 2008, Hoekman 2019). Consistent with prior results, in 2019 most congregated in the Central and Lower Bay (Figure 5). However, MAMU mirrored KIMU in increased use (relative to prior surveys) of the upper east side of the Central Bay and decreased use of Hugh Miller-Scidmore Area and the East and West Arms, suggesting common ecological drivers to similar spatial distributions.

Causes of low estimated KIMU abundance and altered spatial distribution are unknown. Results may reflect both population demography and accuracy (reflecting error from bias and imprecision) of estimates and should be interpreted cautiously. Large annual fluctuations in abundance estimates of

both species have quickly reversed transient changes, and future estimates will inform interpretation of 2019 results. Kissling et al. (2015) noted low annual fidelity to summering areas and low breeding propensity of KIMU in Icy Bay, and periodic use of alternate summering areas and variation in breeding effort could plausibly contribute to large annual fluctuations in estimated abundance in Glacier Bay. Under these scenarios, population fluctuations could reflect either effects of wintering habitat resources on body condition of pre-breeding KIMU or available resources (e.g. nesting and food) at Glacier Bay. However, continued high MAMU abundance suggested adequate food availability in Glacier Bay.

Interpretation is also complicated by infrequent but pervasive species misidentification that likely has introduced substantive positive bias to KIMU abundance estimates, with bias varying annually relative to observer experience and rarity of KIMU relative to MAMU (Schaefer et al. 2015, Hoekman 2019). Mixed-species groups, although typically rare (Hoekman 2019), comprised the majority of KIMU groups in 2019, likely reflecting rarity of KIMU and their high spatial overlap with MAMU. Frequent mixing heightens risk of misidentification, which likely was mitigated by experienced survey observers in 2019, and necessitates that methods for estimating uncertain identification accommodate mixed-species groups. Recent advances in field and analytic methods for estimating uncertain identification highlight both its prevalence and its consequences for murrelet monitoring in Glacier Bay and also offer opportunity to mitigate risks by enhancing future monitoring methods and by improving analyses and interpretation of existing data (Schaefer et al. 2015, Hoekman 2019). Despite low estimated KIMU abundance in 2019, Glacier Bay continues to house an important fraction of the global population of each species (Piatt et al. 2007, U. S. Fish and Wildlife Service 2013).

### **Distance Calibration**

Distance sampling requires accurate estimation of distances to animals to avoid bias in abundance estimates (Buckland et al. 2001). Hoekman (2019) concluded distance calibration assessments successfully developed proficiency of observers in distance estimation, but were hindered by under-representation of longer distances (125 – 200 m) that have been common during surveys (Figure 7 in Hoekman 2019). Recommendations included increased assessment at longer distances and enhancing realism by using murrelets instead of buoys as targets. Binocular laser rangefinders outperformed previous equipment during distance calibration and were generally successful in quickly acquiring distances to targets, even at longer distances. However, evaluation of performance with increased wind speed and with precipitation is needed. Assessment data provided evidence that performance in distance estimation did not degrade at true distances up to ~175 m. Binocular rangefinders generally successfully targeted murrelets at satisfactory distances, but benefits of increased realism of targeting murrelet should be weighed against reduced sampling rate. Focusing on areas with high murrelet densities may mitigate this drawback. Using buoys as targets maximizes repetition and may be ideal for inexperienced observers, while enhanced realism with murrelets may most benefit experienced observers.

## **Recommendations**

Monitor murrelets in Glacier Bay to assess if low estimated KIMU abundance and altered spatial distributions in 2019 constitute transient or persistent changes. If changes persist, local and regional oceanographic and climatic data may be useful to develop and assess explanatory hypotheses. During the upcoming Vital Signs program review for murrelet monitoring, explore enhancing the Protocol to minimize uncertain species identification and its risks to achieving monitoring objectives.

Continue to include longer distances (125 – 200 m) during distance calibration assessments, and validate performance of equipment and observers with increased wind and precipitation. Further develop distance calibration using murrelets as targets by 1) assessing sampling rate relative to murrelet density, 2) assessing target acquisition at longer distances (125 – 200 m), 3) comparing distance estimation performance using murrelets versus buoys, and 4) standardizing distance calibration methods (e.g., boat speed, data acquisition methods, etc.). Distance calibration using murrelets likely is best applied with high murrelet density and proficient observers.

## Literature Cited

- Arimitsu, M. L., J. F. Piatt, M. D. Romano, and T. I. Van Pelt. 2011. Status and distribution of the Kittlitz's Murrelet in Kenai Fjords, Alaska. *Marine Ornithology* 39:13–22.
- Bertram, D. F., M. C. Drever, M. K. McAllister, B. K. Schroeder, D. J. Lindsay, and D. A. Faust. 2015. Estimation of coast-wide population trends of marbled murrelets in Canada using a Bayesian hierarchical model. *PLOS ONE* 10:e0134891.
- Bertram, D. F., C. A. MacDonald, P. D. O'Hara, and J. L. Cragg. 2016. Marbled murrelet *Brachyramphus marmoratus* movements and marine habitat use near proposed tanker routes to Kitimat, BC, Canada. *Marine Ornithology* 44:3–9.
- Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: Estimating abundance of biological populations. Oxford, New York, New York.
- Day, R. H. 1995. New information on Kittlitz's murrelet nests. *Condor* 97:271–273.
- Day, R. H., M. L. Kissling, K. J. Kuletz, D. A. Nigro, and P. Pyle. 2017. Kittlitz's murrelet (*Brachyramphus brevirostris*), version 2.0. In P. G. Rodewald, editor. The Birds of North America Online. Cornell Lab of Ornithology. Ithaca, New York. Available at: <https://birdsna.org/Species-Account/bna/species/kitmur> (Accessed 28 June 2018).
- Day, R. H., and D. A. Nigro. 2000. Feeding ecology of Kittlitz's and Marbled Murrelets in Prince William Sound, Alaska. *Waterbirds* 23:1–14.
- Drew, G. S., S. Speckman, J. F. Piatt, J. M. Burgos, and J. Bodkin. 2008. Survey design considerations for monitoring marine predator populations in Glacier Bay, Alaska: Results and post-hoc analyses of surveys conducted in 1999–2003. Administrative report. U. S. Department of the Interior, U. S. Geological Survey, Reston, Virginia.
- Felis, J. J., M. L. Kissling, R. S. A. Kaler, L. A. Kenney, and M. J. Lawonn. 2016. Identifying Kittlitz's murrelet nesting habitat in North America at the landscape scale. *Journal of Fish and Wildlife Management* 7:323–333.
- Hoekman, S. T. 2019. Kittlitz's murrelet monitoring in Glacier Bay National Park and Preserve 2010–2018: Synthesis and program review. Natural Resource Report NPS/SEAN/NRR-2019/1957. National Park Service, Fort Collins, Colorado.
- Hoekman, S. T., B. J. Moynahan, W. F. Johnson, and C. J. Sergeant. 2013. Glacier Bay National Park and Preserve Kittlitz's murrelet monitoring protocol: Version KM-2012.1. Natural Resource Report NPS/SEAN/NRR—2013/735. National Park Service, Fort Collins, Colorado.

- Hoekman, S. T., B. J. Moynahan, and M. S. Lindberg. 2011a. Monitoring Kittlitz's and marbled murrelets in Glacier Bay National Park: 2009 annual report. Natural Resource Technical Report NPS/SEAN/NRTR—2011/440. National Park Service, Fort Collins, Colorado.
- Hoekman, S. T., B. J. Moynahan, and M. S. Lindberg. 2011b. Monitoring Kittlitz's and marbled murrelets in Glacier Bay National Park: 2010 annual report. Natural Resource Technical Report NPS/SEAN/NRTR—2011/441. National Park Service, Fort Collins, Colorado.
- Hoekman, S. T., B. J. Moynahan, M. S. Lindberg, L. C. Sharman, and W. F. Johnson. 2011c. Line transect sampling for murrelets: Accounting for incomplete detection and identification. *Marine Ornithology* 39:35–44.
- Kirchhoff, M. D. 2008. Methodological considerations for at-sea monitoring of *Brachyramphus* murrelets in Glacier Bay, Alaska. Alaska Department of Fish and Game, Douglas, Alaska.
- Kirchhoff, M. D., J. R. Lindell, and J. I. Hodges. 2014. From critically endangered to least concern?—A revised population trend for Kittlitz's murrelet in Glacier Bay, Alaska. *Condor: Ornithological Applications* 116:24–34.
- Kirchhoff, M. D., M. Smith, and S. Wright. 2010. Abundance, population trend, and distribution of marbled murrelets and Kittlitz's murrelets in Glacier Bay National Park. Audubon Alaska, Anchorage, Alaska.
- Kissling, M. L., S. M. Gende, S. B. Lewis, and P. M. Lukacs. 2015. Reproductive performance of Kittlitz's murrelet in a glaciated landscape, Icy Bay, Alaska, USA. *The Condor: Ornithological Applications* 117:237–248.
- Kissling, M. L., P. M. Lukacs, S. B. Lewis, S. M. Gende, K. J. Kuletz, N. R. Hatch, S. K. Schoen, and S. Oehlers. 2011. Distribution and abundance of the Kittlitz's murrelet in selected areas of southeastern Alaska. *Marine Ornithology* 39:3–11.
- Kuletz, K. J., S. W. Stephensen, D. B. Irons, E. A. Labunski, and K. M. Brenneman. 2003. Changes in distribution and abundance of Kittlitz's murrelets *Brachyramphus brevirostris* relative to glacial recession in Prince William Sound, Alaska. *Marine Ornithology* 31:133–140.
- Madison, E. N., J. F. Piatt, M. L. Arimitsu, M. D. Romano, T. I. Van Pelt, S. K. Nelson, J. C. Williams, and A. R. Degange. 2011. Status and distribution of the Kittlitz's murrelet *Brachyramphus brevirostris* along the Alaska Peninsula and Kodiak and Aleutian islands, Alaska. *Marine Ornithology* 39:111–122.
- McDonald, T. L. 2003. Review of environmental monitoring methods: Survey designs. *Environmental Monitoring and Assessment* 85:277–292.
- Moynahan, B. J., W. F. Johnson, D. W. Shirokauer, L. C. Sharman, G. Smith, and S. M. Gende. 2008. Vital signs monitoring plan: Southeast Alaska network. U. S. National Park Service, Fort Collins, Colorado.

- Piatt, J. F., M. L. Arimitsu, G. S. Drew, E. N. Madison, J. L. Bodkin, and M. D. Romano. 2011. Status and trend of the Kittlitz's murrelet *Brachyramphus brevirostris* in Glacier Bay, Alaska. *Marine Ornithology* 39:65–75.
- Piatt, J. F., K. J. Kuletz, A. E. Burger, S. A. Hatch, V. L. Friesen, T. P. Birt, M. L. Arimitsu, G. S. Drew, A. M. A. Harding, and K. S. Bixler. 2007. Status review of the Marbled murrelet (*Brachyramphus marmoratus*) in Alaska and British Columbia. U. S. Geological Survey Open-File Report 2006-1387. Reston, Virginia.
- R Core Team. 2019. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.
- Schaefer, A. L., P. M. Lukacs, and M. L. Kissling. 2015. Testing factors influencing identification rates of similar species during abundance surveys. *Condor: Ornithological Applications* 117:460–472.
- Stevens, D. L., and A. R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99:262–278.
- Thomas, L., S. T. Buckland, E. A. Rexstad, J. L. Laake, S. Strindberg, S. L. Hedley, J. R. B. Bishop, T. A. Marques, and K. P. Burnham. 2010. Distance software: Design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology* 47:5–14.
- U. S. Fish and Wildlife Service. 2013. 12-month finding on a petition to list Kittlitz's Murrelet as an endangered or threatened species. *Federal Register* 78:61764.



The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

NPS 132/166717, January 2020

National Park Service  
U.S. Department of the Interior



---

[Natural Resource Stewardship and Science](#)

1201 Oakridge Drive, Suite 150

Fort Collins, CO 80525