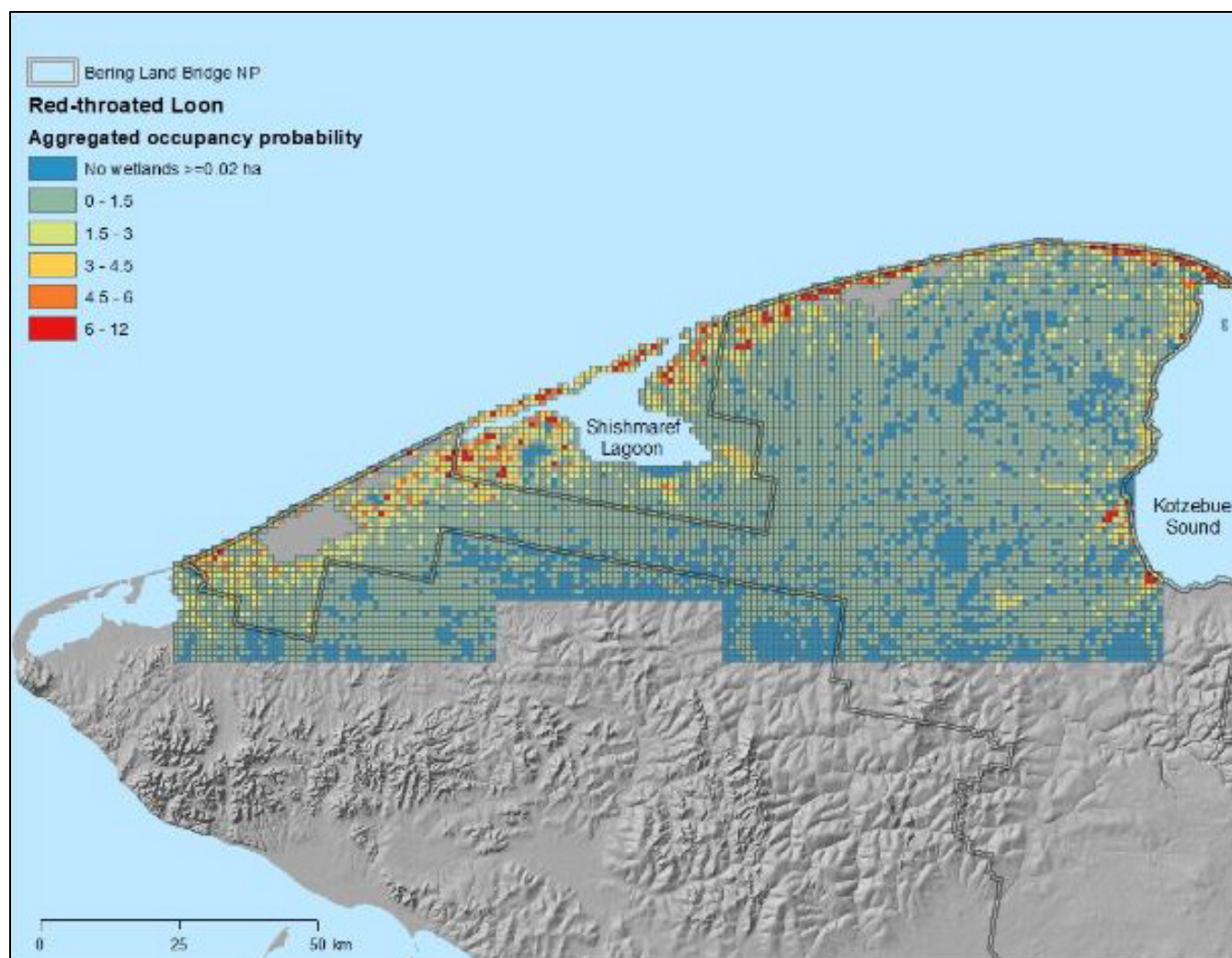




Loon occupancy dynamics in Western Arctic Parklands, Alaska, 2011–2018

Natural Resource Report NPS/ARC/NRR—2021/2280



ON THE COVER

Predicted Red-throated Loon aggregated occupancy probability for a 1 km grid cell

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Natural Resource Report NPS/ARCN/NRR—2021/2280

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Executive Summary

We investigated lake occupancy dynamics for Yellow-billed (*Gavia adamsii*), Pacific (*Gavia pacifica*), and Red-throated Loons (*Gavia stellata*) in Western Arctic National Parklands (WEAR) and assessed habitat predictors of occupancy for all three species using aerial survey data from 2011–2018. Annual estimates for the number of lakes occupied by Red-throated Loon ranged from 841.45–957.99 from 2016–2018. Breeding probability was apparently stable for Yellow-billed and Pacific Loon from 2011–2018. Lake area was a strong positive predictor of Yellow-billed Loon breeding probability, while both lake area and connectivity (the presence or absence of a connecting stream) were strong positive predictors of Pacific Loon breeding probability. Red-throated Loon occupancy probability declined with lake area and increased with proximity to the coastline and with shoreline complexity. We found that the probability of a lake persisting in the breeding or occupied state from one year to another was relatively high for all three loon species, suggesting that nesting habitat in the study area is likely nearly saturated by their combined populations. In addition, breeding density across the loon assemblage appears to be higher in near-coastal areas and in the area surrounding Shishmaref Lagoon.

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Introduction

From 1977–1993, Alaska’s breeding population of Red-throated Loons (*Gavia stellata*) has declined by an estimated 53% (Groves et al. 1996). Presently, reliable data on the population status of Red-throated Loon in western Alaska is limited (ADFG 2006). Due to its high trophic level and reliance on marine fish for rearing young, Red-throated Loon has been proposed as an indicator of change in nearshore systems (Dickson 1992). The strength of this marine association is unique among North American loons. Yellow-billed (*Gavia adamsii*), Pacific (*Gavia pacifica*), Arctic (*Gavia arctica*), and Common Loons (*Gavia immer*) rely to a greater degree or exclusively on obtaining freshwater fish from within the nesting territory to feed young (North 1994). The nearshore association of Red-throated Loon makes its highly vulnerable to population-level effects from oil spills (Dickson 1992). Vessel traffic in the Chukchi and Beaufort Seas is expected to increase dramatically with the decreasing extent of sea ice along the Northern Sea Route and the implementation of plans for offshore oil and gas development and deepwater port construction. Thus, knowledge of the Red-throated Loon distribution and that of other Gaviformes along the Chukchi coastline is critical for understanding potential impacts from offshore oil and gas development and for the development of resource protection strategies.

Previous efforts for monitoring loons in WEAR have focused on Yellow-billed Loon and have restricted sampling to lakes ≥ 7 ha based upon work documenting negligible use of lakes < 7 ha by this species (Earnst et al. 2006, Mallek et al. 2006, Schmidt et al. 2014). Concurrent with these Yellow-billed Loon focused surveys (hereafter, the targeted survey), we implemented a second aerial survey with a broader habitat scope (hereafter, the area search survey) in order to provide a more complete assessment of the population status and distribution of Red-throated, Arctic, and Pacific Loon, species which regularly nest and forage on wetlands smaller than < 7 ha (Reimchen and Douglas 1984, Douglas and Reimchen 1988, Eberl and Picman 1993). We used the combined data from the area search survey (2016–2018) and targeted survey (2011–2018) to: 1) assess the occupancy dynamics for Yellow-billed, Pacific/Arctic, and Red-throated Loon in WEAR (Western Arctic National Parklands); and 2) assess habitat predictors of occupancy for all three species.

Methods

Study area

The study area is located along the southeastern Chukchi coastline on the northwestern end of the Seward Peninsula (Fig. 1). The region is characterized by permafrost lowlands interspersed with thermokarst lakes formed through a process by which the thermal equilibrium of the ground is disturbed resulting in permafrost thaw, surface subsidence, and eventual water impoundment (van Everdingen 1998, Grosse et al. 2013). Subsequently, thermokarst lakes exhibit dynamic expansion and retraction of waters and subject to drainage through local permafrost degradation (Jones et al. 2011, Grosse et al. 2013).

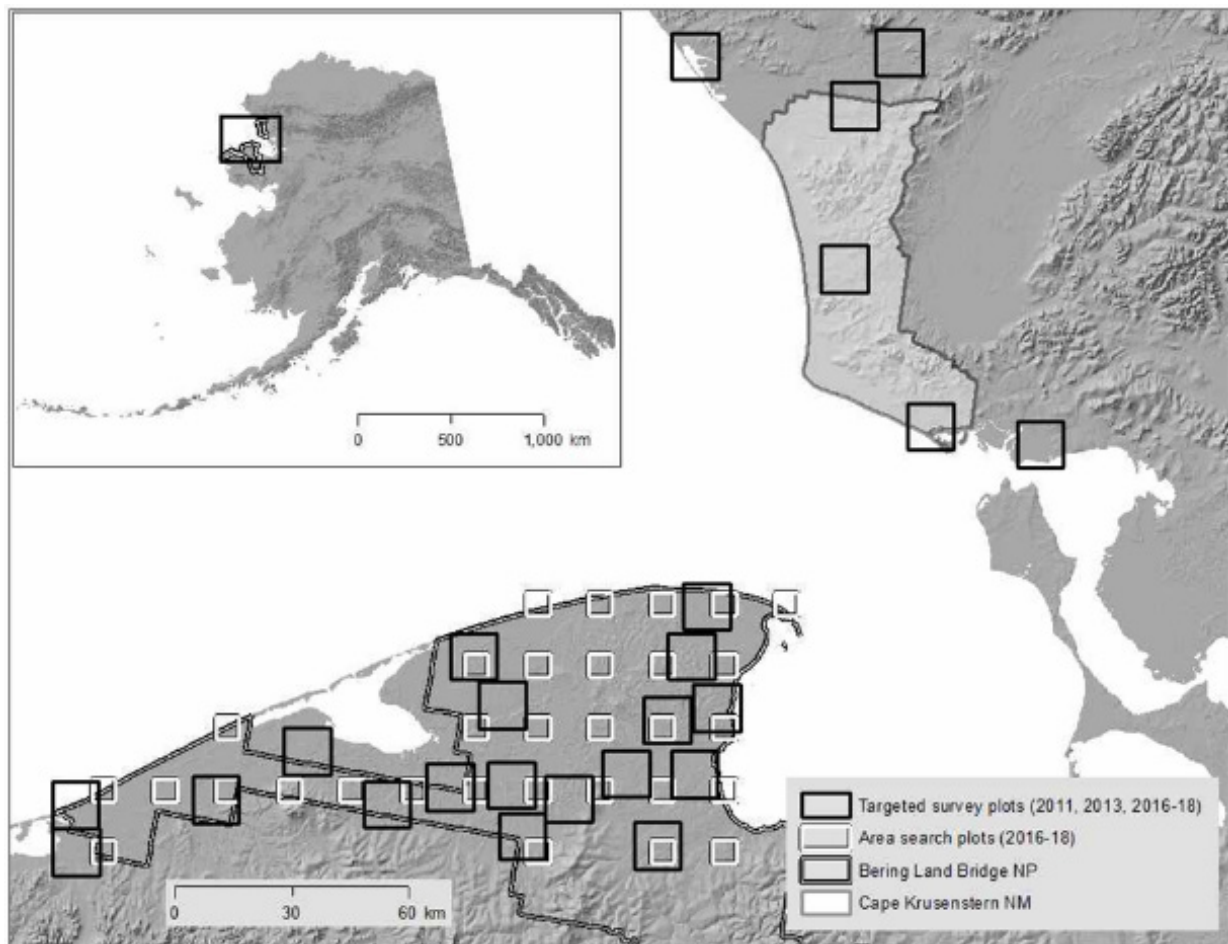


Figure 1. Study area located in Western Arctic Parklands, Alaska, 2011–2018.

The study area supports all five loon species, although Common Loon is a rare breeder and was excluded from our analyses. We lumped Arctic and Pacific Loon for analysis because of the difficulty of distinguishing the two species from the air. These two species have similar ecological requirements and are likely to interact with Yellow-billed and Red-throated Loon in a similar manner, and hereafter we use the term Pacific Loon to refer to both Arctic and Pacific Loon due to

the predominance of the latter. Lastly, Yellow-billed Loon, the largest of the Gaviformes, appears to often exclude Pacific Loon in the competition for lake resources (Haynes et al. 2014, Schmidt et al. 2014), suggesting that a dominance hierarchy of Yellow-billed, Pacific, and Red-throated Loon, in this order, may partly govern patterns of lake occupancy where habitat preferences overlap.

Sampling methods

We conducted two spatially and temporally overlapping surveys; a targeted survey restricted to lakes ≥ 7 ha and an area search survey with inference to all wetlands in the sampling frame. The targeted survey was conducted in 2011, 2013, and concurrent with the area search survey in 2016–2018. The targeted survey was conducted within 24, 12 x 12 km plots centered on randomly selected points throughout the study area (Fig. 1). The area search survey was conducted within 31, 6 x 6 km plots located systematically across Bering Land Bridge National Preserve on the Seward Peninsula where the highest density of lakes and loons in the study area are found (Fig. 1). Both surveys were conducted during June 21–30 in each year, at a time when most breeders would be expected to have initiated nests, but prior to the onset of hatching. We conducted an average of two repeat aerial surveys of each plot within 4–48 hours of each other. We used different pilot-observer teams on each visit to ensure that observations were independent. Surveys were conducted from a tandem seat fixed-wing aircraft (e.g., Aviat Husky or Piper Super Cub) flown at ~45–60 m above ground level at ~174 km hr⁻¹. In general, we circled each lake, searching the shoreline, islands, and water, and recording all loons and nest locations using paper maps and GPS units (2011 and 2013) or a tablet-based moving map application (2016–2018). During the area search surveys, some wetlands were too small to circle and were covered in one or more passes. While the teams conducting the targeted survey were given a list of individual lakes to survey, the area search teams were instructed to cover all wetland habitat within plots. Pilot-observer teams used their trackline and satellite imagery of lakes through the moving map application to ensure complete plot coverage and assign observed loons and nests to individual wetlands. Further details of the survey design for the targeted survey can be found in Mallek et al. (2006) and Schmidt et al. (2014).

During the course of surveys, we also recorded observations of tern species. Additional details about these data can be found in the Appendix A.

Previously, Schmidt et al. (2014) used a multi-state framework for inference about Yellow-billed and Pacific Loon occupancy in our study area from 2011–2013. Under this framework, lakes existed in one of three mutually exclusive states: 1) unoccupied; 2) occupied without breeding; and 3) occupied with breeding. Inference about the second state is analogous to quantifying use due to the presence of temporary emigration (e.g., movement on and off of lakes between survey visits). Exploratory analyses using a multi-state model and the full dataset (2011–2018) showed evidence of a decline in the probability of detecting use over time for both Yellow-billed and Pacific Loon (Appendix B). We suspect this pattern may ultimately be due to transient use of lakes by non-breeding individuals. That is, when the number of non-breeding individuals present in the study area remains high over both survey visits, the habitat is saturated and detection of use at the lake-level is high regardless of transient use of lakes by individuals. When non-breeders are present in low densities during one of the visits and are high in the other, transient use of lakes by individuals is evident as a steep decline

in the detection of use. Although we know relatively little about the movement patterns of non-breeding loons, inter-annual fluctuation in their density during the survey period could arise through variation in their arrival and migration phenology. Earnst et al. (2005) and Schmutz et al. (2014) observed a large non-breeding component of the Yellow-billed Loon population on the Arctic Coastal Plain (~50% of the total population) that arrives in late June after most nests have already been initiated. Surveys in WEAR are conducted in late June near the transition from nest initiation phase to the period of non-breeder arrival, suggesting that modest shifts in non-breeder arrival timing coupled with their transient movements could be realized as apparent variation in the probability of detecting use. In addition, survey effort was higher when the target and area search surveys overlapped (2016–2018), with many lakes receiving >2 visits. Additional visits meant greater opportunity to detect occupancy at infrequently used lakes, suggesting that the lack of closure at the lake-level was more evident with increased visitation.

Thus, we focused on making inference to the breeding population as opposed to using a multi-state framework with inference to use and breeding. For Yellow-billed and Pacific Loon, inference was to two occupancy states, unoccupied and breeding, and the observed nest locations were collapsed to detection/non-detection of breeding on lake $j = 1, 2, \dots, J$, on visit $k = 1, 2, \dots, K$, and in year $t = 1, 2, \dots, T$. Due to very low detection rates of Red-throated Loon nests, the bird and nest locations were collapsed to detection/non-detection of ≥ 1 individual including those associated with nests, leading to two occupancy states, unoccupied and occupied. The presence of Red-throated Loon on wetlands generally corresponded to territorial and/or breeding activity given its predominantly marine foraging strategy. Thus, we expect that occupancy for this species may approximate breeding population size.

By virtue of integrating the area search survey, the sampling frame included a relatively wide distribution of lake sizes including a number of relatively small lakes for which Yellow-billed and Pacific Loon occupancy probability was negligible. Thus, it was computationally expedient to truncate the data used in analyses to the species-specific set of lakes for which occupancy probability was non-negligible including $J = 519$ lakes ≥ 7 ha, $J = 1083$ lakes ≥ 1 ha, and $J = 4187$ lakes ≥ 0.02 ha for Yellow-billed, Pacific, and Red-throated Loon, respectively. To delineate all waterbodies ≥ 0.02 ha, we extracted water pixels from SPOT 5 imagery with 5 m resolution using a threshold approach.

Analysis

We constructed a series of species-specific models which described the occupancy state in years $t > 1$ as a first-order Markov process (i.e., dependent on the state in $t - 1$) and explicitly addressed imperfect detection (MacKenzie et al. 2003, Royle and Kéry 2007). The observations y_{jkt} for each species were Bernoulli outcomes of detection probability p conditional on the true occupancy states z_{jt} :

$$y_{jkt} \sim \text{Bern}(z_{jt} * p)$$

For Yellow-billed and Pacific Loon, we shared detection probability p , assuming that detection of nests from a fixed-wing platform was similar for these species. For Red-throated Loon, we specified

a logit-linear model for p that included the effects of linear and quadratic lake area, assuming that some small wetlands may not have been exposed to sampling during area search surveys.

The true occupancy states were Bernoulli random variables with probability ψ_{jt} :

$$z_{jt} \sim \text{Bern}(\psi_{jt})$$

For all three species, we specified a logit-linear model for initial occupancy probability ψ_{j1} that included the effects of lake area, shoreline complexity (i.e., perimeter/(4*sqrt(area))), distance from the coastline, and connectivity (i.e., the presence of ≥ 1 intersecting stream channel) (Zuck et al. 2017). For Red-throated Loon, we added the quadratic effect of lake area to accommodate non-linear variation in occupancy probability over the wide distribution of lakes sizes on which they were found. Occupancy probability in subsequent years was equal to the persistence probability $\phi_{s_{t-1}}$, given the lake was occupied in the previous year, or the colonization probability $\gamma_{s_{t-1}}$, given the lake was unoccupied in the previous year:

$$\psi_{jt} = z_{jt-1}\phi_{s_{t-1}} + (1 - z_{jt-1})\gamma_{s_{t-1}}$$

where the persistence and colonization probabilities were given time specificity using the subscript s_{t-1} which indexes three different time periods, $s = 1, 2$, and 3 for 2013, 2016, and 2017–2018, respectively. For Red-throated Loon, we only had sufficient data for analysis from 2016–2018, coinciding with implementation of the area search survey. Therefore, for this species, we only estimated one persistence and colonization probability for the period 2017–2018.

We also used the species interaction factor (SIF; see MacKenzie et al. 2006, Richmond et al. 2010) to quantify the extent of competitive exclusion of the subordinate species B by the dominant species A in both of our pairings of interacting species (i.e., Yellow-billed/Pacific Loon and Pacific/Red-throated Loon):

$$SIF = \frac{\psi^A \psi^{BA}}{\psi^A (\psi^A \psi^{BA} + (1 - \psi^A) \psi^{Ba})}$$

where values < 1 suggest some level of competitive exclusion and values near 1 indicate that the species are distributed independently.

We fit all models in a Bayesian framework using JAGS version 4.3 (Plummer 2003). We specified vague normal priors for all regression coefficients, vague uniform priors for all probability-scale and detection function parameters, and $U(0,100)$ priors for the standard deviations of the random effects. We log-transformed lake area to reduce right skewness and scaled all covariates to improve convergence.

Results and discussion

Annual estimates for the number of lakes within survey plots that were occupied by Red-throated Loon ranged from 841–958 from 2016–2018. Breeding probability was apparently stable for Yellow-billed and Pacific Loon from 2011–2018 (Fig. 2). Lake area was a strong positive predictor of Yellow-billed Loon breeding probability, while both lake area and connectivity (the presence or absence of a connecting stream) were strong positive predictors of Pacific Loon breeding probability (Table 1). Red-throated Loon occupancy probability declined with lake area and increased with proximity to the coastline and with shoreline complexity (Table 1; Fig. 3). Species interaction factors for Yellow-billed/Pacific Loon and Pacific/Red-throated Loon were near 0, indicating almost complete competitive exclusion by the dominant species in these pairings (Table 1). That is, it was a rare occurrence in which congeners nested on the same lake in a given year. This was also true for conspecifics based on a limited number of lakes observed with >1 nest for any species. This distributional pattern was to be expected given the relatively small sizes of the lakes in our study area compared to the Arctic Coastal Plain where apparently larger lake sizes may mediate competition between Yellow-billed and Pacific Loon (Haynes et al. 2014, D. Nigro unpublished data).

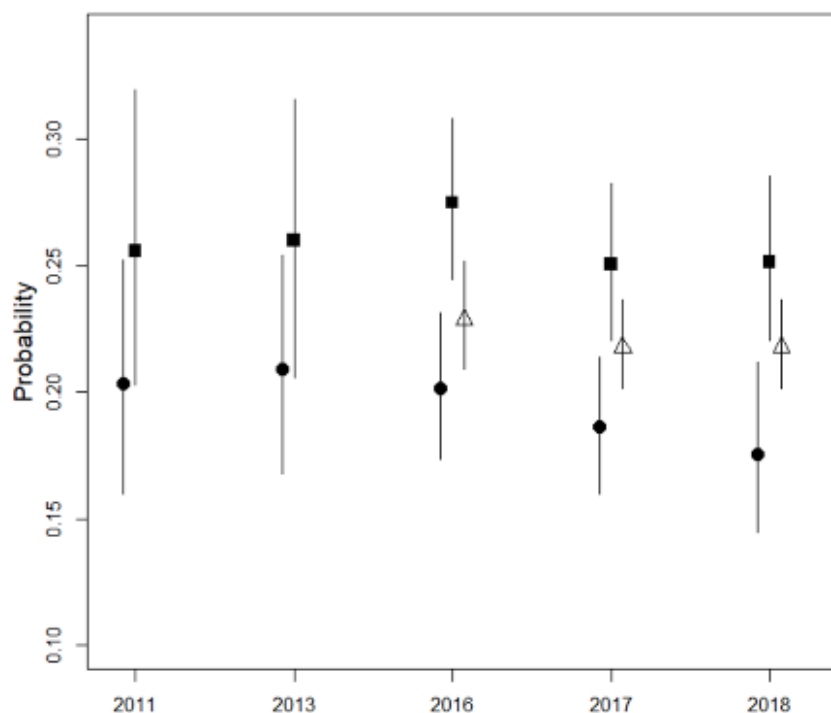


Figure 2. Posterior means and 95% credible intervals for Yellow-billed (filled circles) and Pacific Loon (filled squares) breeding probability and Red-throated Loon (open triangles) occupancy probability for lakes in Western Arctic Parklands, 2011–2018. Estimates for Red-throated Loon are only shown for those years in which sufficient data permitted analysis (i.e., 2016–2018). Probabilities correspond to $J = 519$ lakes ≥ 7 ha, $J = 1083$ lakes ≥ 1 ha, and $J = 4187$ lakes ≥ 0.02 ha for Yellow-billed, Pacific, and Red-throated Loons, respectively.

Table 1. Parameter estimates from monitoring of Yellow-billed (Y superscript), Pacific (P superscript), and Red-throated Loon (R superscript) occupancy in Western Arctic Parklands, Alaska, USA, 2011, 2013, and 2016–2018. For Yellow-billed and Pacific Loon, we considered the states, unoccupied and breeding. For Red-throated Loon, occupancy refers to use by ≥ 1 individual including those associated with nests.

Parameter	Parameter description	mean	SD	95% CI
α_0^Y	Intercept for initial breeding probability	-1.54	0.47	-2.54, -0.69
$\alpha_1^{Y area_j}$	Area effect on initial breeding probability	0.74*	0.22*	0.36*, 1.21*
$\alpha_2^{Y shoreline_j}$	Shoreline effect on initial breeding probability	-0.05	0.19	-0.45, 0.30
$\alpha_3^{Y coastline_j}$	Distance to coastline effect on initial breeding probability	0.22	0.16	-0.09, 0.55
$\alpha_4^{Y connectivity_j}$	Connectivity effect on initial breeding probability	0.02	0.50	-0.90, 1.06
ϕ_1^Y	Persistence probability for 2011–2013	0.82	0.09	0.62, 0.98
ϕ_2^Y	Persistence probability for 2013–2016	0.84	0.08	0.67, 0.98
ϕ_3^Y	Persistence probability for 2016–2018	0.85	0.06	0.72, 0.96
γ_1^Y	Colonization probability for 2011–2013	0.05	0.03	0.01, 0.12
γ_2^Y	Colonization probability for 2013–2016	0.03	0.02	0.00, 0.08
γ_3^Y	Colonization probability for 2016–2018	0.02	0.01	0.00, 0.04
p^n	Probability of detecting breeding for both Y and P	0.29	0.02	0.26, 0.32
α_0^P	Intercept for initial breeding probability	-2.28	0.53	-3.44, -1.36

* Habitat covariates with 95% credible intervals (CI) that do not cover 0, also shown in bold text.

Table 1 (continued). Parameter estimates from monitoring of Yellow-billed (Y superscript), Pacific (P superscript), and Red-throated Loon (R superscript) occupancy in Western Arctic Parklands, Alaska, USA, 2011, 2013, and 2016–2018. For Yellow-billed and Pacific Loon, we considered the states, unoccupied and breeding. For Red-throated Loon, occupancy refers to use by ≥ 1 individual including those associated with nests.

Parameter	Parameter description	mean	SD	95% CI
α_0^P	Intercept for initial breeding probability	-2.28	0.53	-3.44, -1.36
$\alpha_1^P area_j$	Area effect on initial breeding probability	0.47*	0.14*	0.22*, 0.76*
$\alpha_2^P shoreline_j$	Shoreline effect on initial breeding probability	0.18	0.14	-0.08, 0.47
$\alpha_3^P coastline_j$	Distance to coastline effect on initial breeding probability	-0.05	0.14	-0.33, 0.22
$\alpha_4^P connectivity_j$	Connectivity effect on initial breeding probability	1.41*	0.54*	0.47*, 2.57*
ϕ_1^P	Persistence probability for 2011–2013	0.72	0.08	0.57, 0.88
ϕ_2^P	Persistence probability for 2013–2016	0.90	0.06	0.76, 0.99
ϕ_3^P	Persistence probability for 2016–2018	0.75	0.05	0.66, 0.84
γ_1^P	Colonization probability for 2011–2013	0.10	0.04	0.03, 0.18
γ_2^P	Colonization probability for 2013–2016	0.06	0.03	0.01, 0.12
γ_3^P	Colonization probability for 2016–2018	0.07	0.01	0.05, 0.10
α_{01}^R	Intercept on initial occupancy probability	-1.14	0.08	-1.30, -0.97

* Habitat covariates with 95% credible intervals (CI) that do not cover 0, also shown in bold text.

Table 1 (continued). Parameter estimates from monitoring of Yellow-billed (Y superscript), Pacific (P superscript), and Red-throated Loon (R superscript) occupancy in Western Arctic Parklands, Alaska, USA, 2011, 2013, and 2016–2018. For Yellow-billed and Pacific Loon, we considered the states, unoccupied and breeding. For Red-throated Loon, occupancy refers to use by ≥ 1 individual including those associated with nests.

Parameter	Parameter description	mean	SD	95% CI
$\alpha_1^R area_j$	Linear area effect on initial occupancy probability	0.08	0.05	−0.03, 0.18
$\alpha_2^R area_j^2$	Quadratic area effect on initial occupancy probability	−0.07*	0.02*	−0.11*, −0.04*
$\alpha_3^R shoreline_j$	Shoreline effect on initial occupancy probability	0.10*	0.05*	0.00*, 0.20*
$\alpha_4^R coastline_j$	Distance to coastline effect on initial occupancy probability	−0.90*	0.07*	−1.05*, −0.75*
ϕ^R	Persistence probability	0.81	0.03	0.76, 0.85
γ^R	Colonization probability	0.04	0.01	0.03, 0.05
β_0^R	Intercept for detection probability	−0.80	0.06	−0.91, −0.70
$\beta_1^R area_j$	Linear area effect on detection probability	0.33	0.04	0.25, 0.41
$\beta_2^R area_j^2$	Quadratic area effect on detection probability	−0.06	0.01	−0.08, −0.04
SIF^{YP}	Species interaction factor; Y is dominant and P subordinate	0.12	0.02	0.09, 0.16
SIF^{PR}	Species interaction factor; P is dominant and R subordinate	0.06	0.01	0.05, 0.08

* Habitat covariates with 95% credible intervals (CI) that do not cover 0, also shown in bold text.

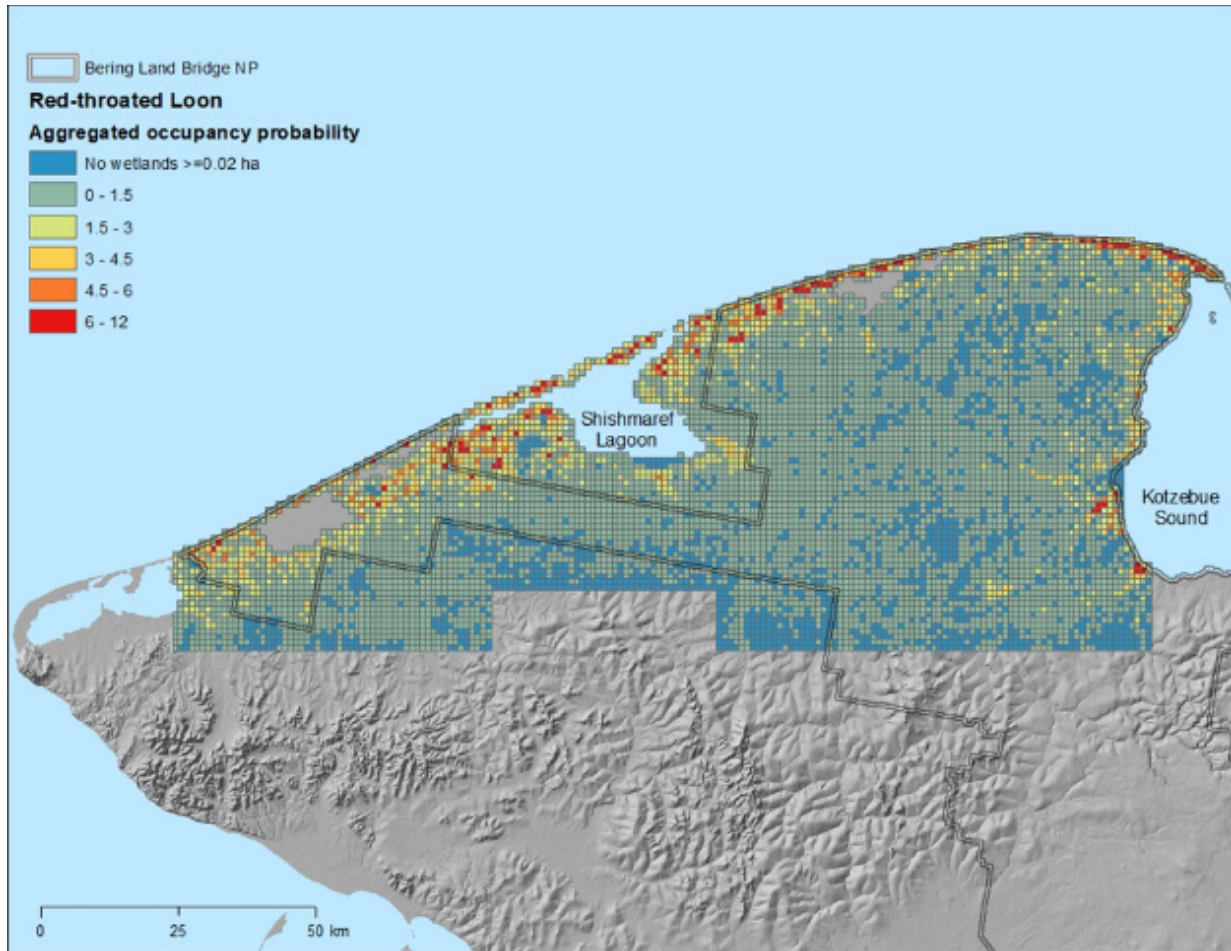


Figure 3. Predicted Red-throated Loon occupancy aggregated at a 1 km cell size within a grid overlaying our study area in Bering Land Bridge National Preserve, 2016–2018. Aggregate occupancy was derived by summing the predicted occupancy probabilities of all lakes with their centroids lying within a cell. Given its predominantly marine foraging strategy and the relatively small size of nestling lakes, the presence of Red-throated Loon on wetlands generally corresponded to a single territorial and/or breeding pair. Thus, we expect that the aggregated occupancy for this species may serve as an index of breeding pair abundance.

We found that the probability of a lake persisting in the breeding state from one year to another for Yellow-billed Loon was much higher (0.82–0.85; Table 1) relative to estimates reported for the Arctic Coastal Plain (posterior mean = 0.50, 95% CI = 0.38, 0.64; D. Nigro unpublished data). We also found high persistence probability for Pacific Loon breeding and Red-throated Loon occupancy (0.72–0.90 across all years and species; Table 1). Loon populations generally contain a large number of floaters that are prospecting for territories, leading to rapid turnover of any vacant nesting territories (Earnst et al. 2006, Schmutz et al. 2014).

Overall, our findings suggest that nesting habitat in the study area is likely nearly saturated by the combined populations of Red-throated, Pacific, Arctic, and Yellow-billed Loon. In addition, breeding density across the loon assemblage appears to be higher in near-coastal areas and in the area surrounding Shishmaref Lagoon (Figs. 3–6).

Continued monitoring will be necessary to understand the response of these populations to changes in broad-scale climate. The life history characteristics of seabirds, including their position atop marine trophic systems, longevity, low fecundity, and deferred maturity, are manifested in the sensitivity of their vital rates to climate-driven changes in prey abundance and distribution (e.g., Gaillard and Yoccoz 2003, Sandvik et al. 2005, Velarde and Ezcurra 2018). In addition, permafrost degradation under continued warming could upset the balance between lake drainage and expansion that has characterized historic thermokarst lake dynamics in arctic and subarctic Alaska (Jones et al. 2011, Jones and Arp 2015, Swanson 2019). A shift towards drainage-dominant dynamics could impact the structure of loon assemblages by altering lake-size distributions via the loss of large, deep lakes coupled with a gain in their smaller remnants (Swanson 2019). Knowledge of loon-habitat relationships and patterns of co-occurrence will likely be critical for understanding the future trajectories of these populations across these changing landscapes.

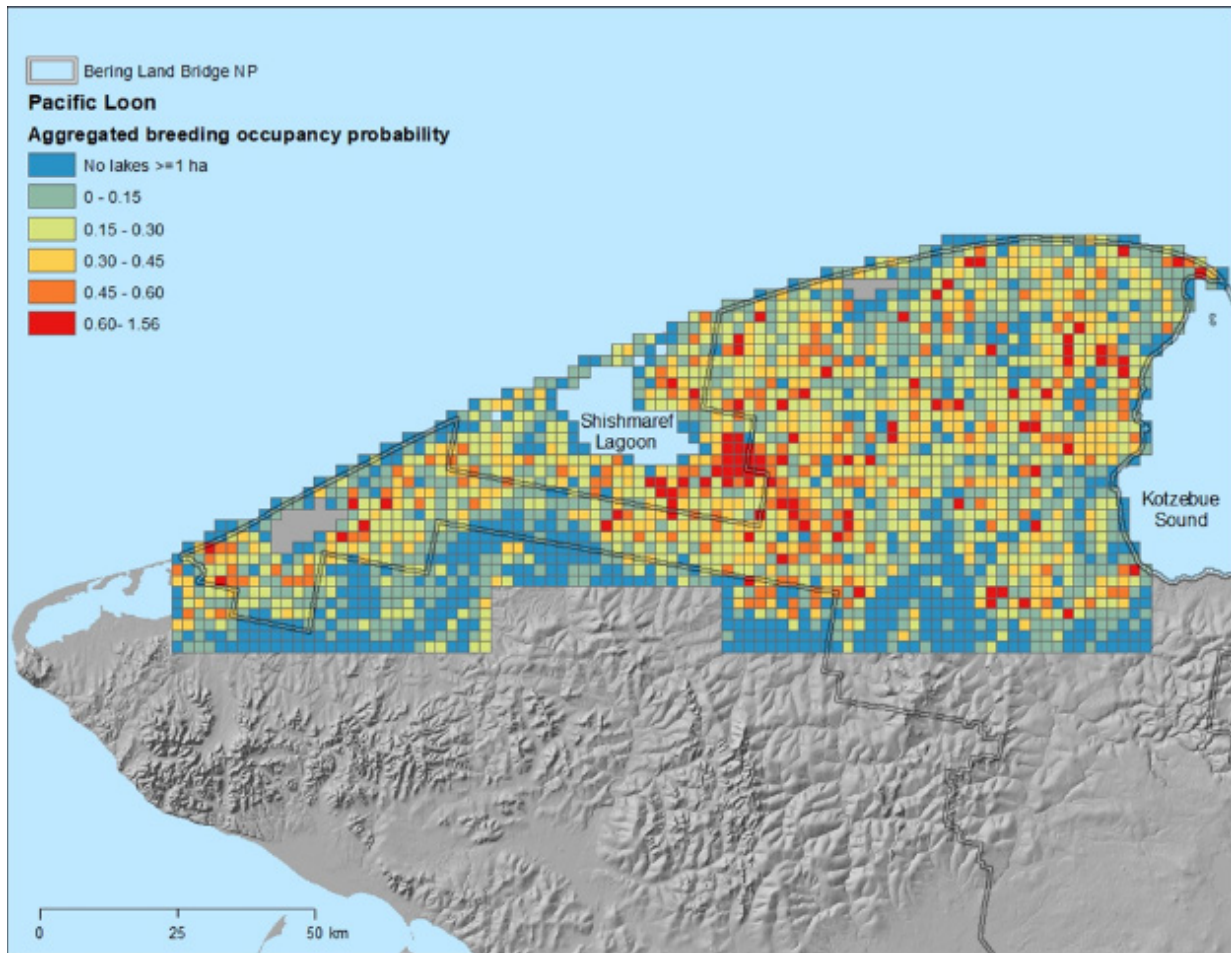


Figure 4. Predicted Pacific Loon breeding occupancy aggregated at a 2 km cell size within a grid overlaying our study area in Bering Land Bridge National Preserve, 2016–2018. Aggregate breeding occupancy was derived by summing the predicted breeding occupancy probabilities of all lakes with their centroids lying within a cell. Given that lakes rarely contained >1 nest, we expect that the aggregated occupancy for this species may serve as an index of breeding pair abundance.

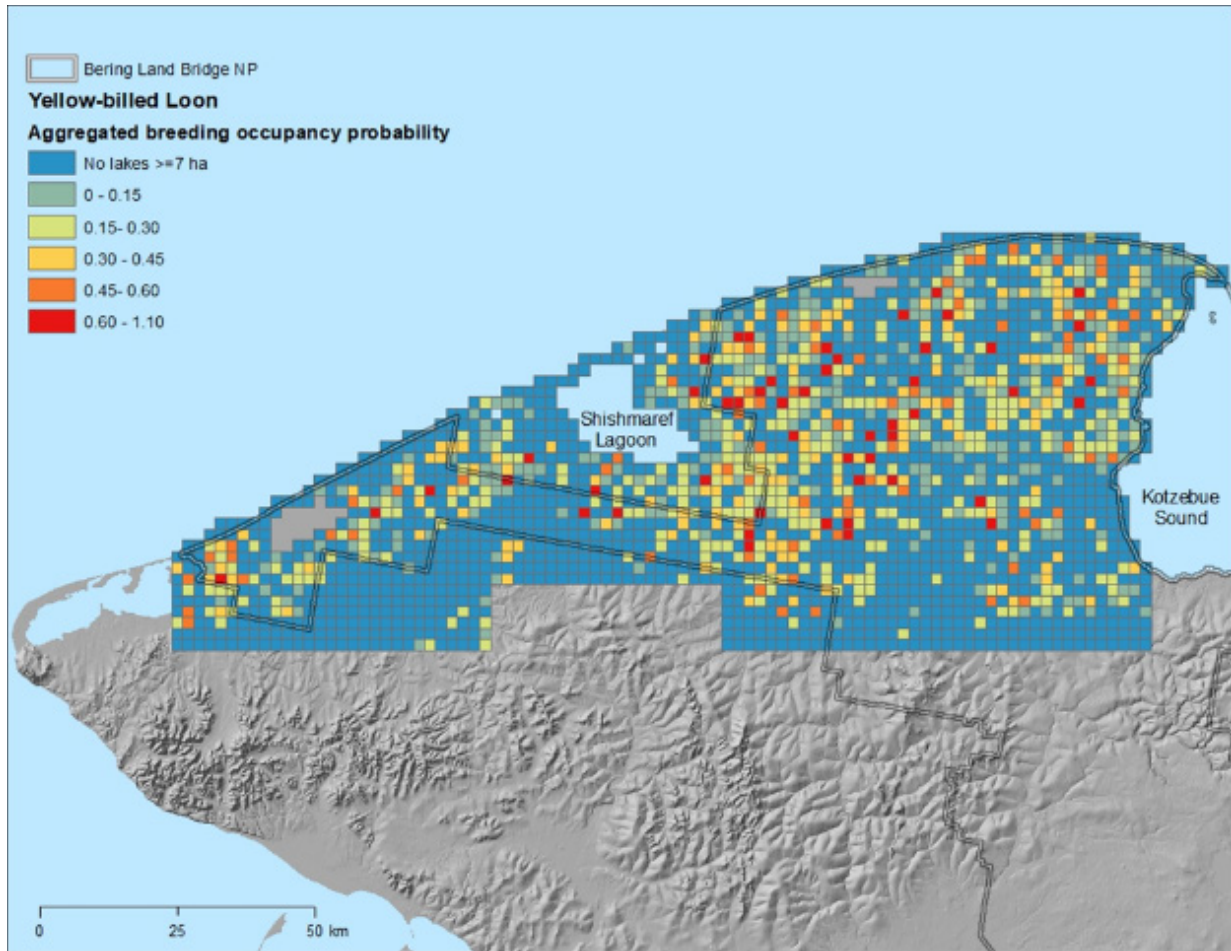


Figure 5. Predicted Yellow-billed Loon breeding occupancy aggregated at a 2 km cell size within a grid overlaying our study area in Bering Land Bridge National Preserve, 2016–2018. Aggregate breeding occupancy was derived by summing the predicted breeding occupancy probabilities of all lakes with their centroids lying within a cell. Given that lakes rarely contained >1 nest, we expect that the aggregated occupancy for this species may serve as an index of breeding pair abundance.

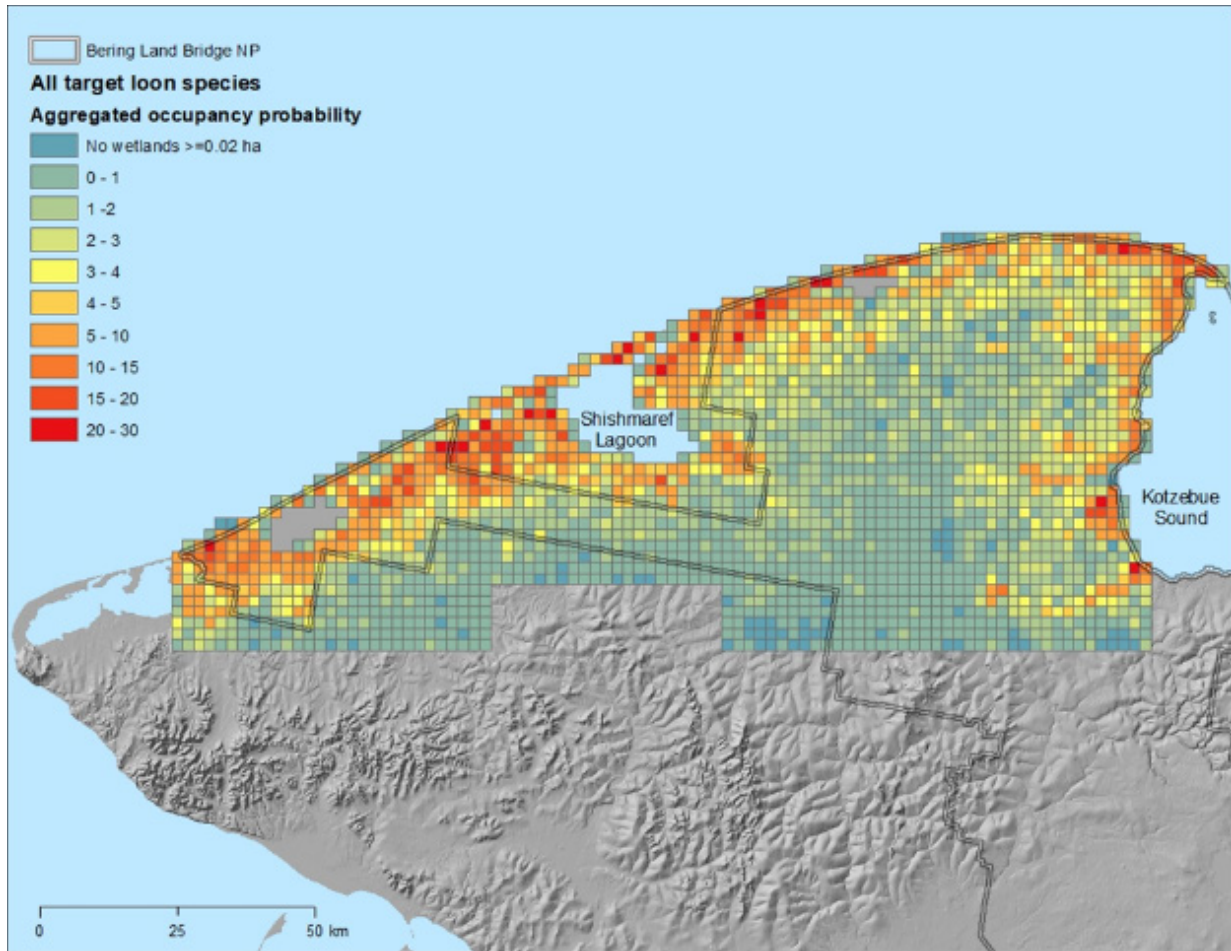


Figure 6. Predicted occupancy of all four target loon species aggregated at a 2 km cell size within a grid overlaying our study area in Bering Land Bridge National Preserve, 2016–2018. Aggregate occupancy of the loon assemblage was derived by summing the predicted breeding occupancy probabilities for Red-throated, Arctic/Pacific, and Yellow-billed Loons on all lakes with their centroids lying within a cell. Given that lakes rarely contained >1 nest, we expect that the aggregated occupancy may serve as an index of breeding pair abundance.

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Appendix A. Observations of tern species in Western Arctic Parklands, 2016–2018.

The global population of Aleutian Terns (*Onychoprion aleuticus*) was previously estimated at 32,000 individuals with approximately 9,000–12,000 of those breeding in Alaska and the remainder in eastern Siberia (North 1997). Recent observations at historical colonies indicate potentially severe declines (Denlinger 2006). The drivers of these population declines are poorly understood but anthropogenic factors (e.g., habitat loss and degradation, eggging and harvest, and human disturbance) are likely involved (North 1997). Most of the historical Aleutian Tern colonies located along the Chukchi coast, the northern limit of their range, were identified over 30 years ago. There has been no consistent effort to monitor colonies along the Chukchi coastline or to document Aleutian Tern distribution beyond these historical locations.

With the objective of documenting Arctic (*Sterna paradisaea*) and Aleutian Tern distribution in WEAR, we recorded observations of these species during the course of aerial loon surveys. All observations were recorded as ‘tern spp.’ because we were unable to distinguish these species with certainty from the air. We recorded a waypoint and count for each observed individual or group and noted whether the observation was of a suspected breeding colony. We observed 79 tern groups from 2016–2018, ranging in size from 1–51 individuals, and documented 6 suspected colony locations (Fig. A1).

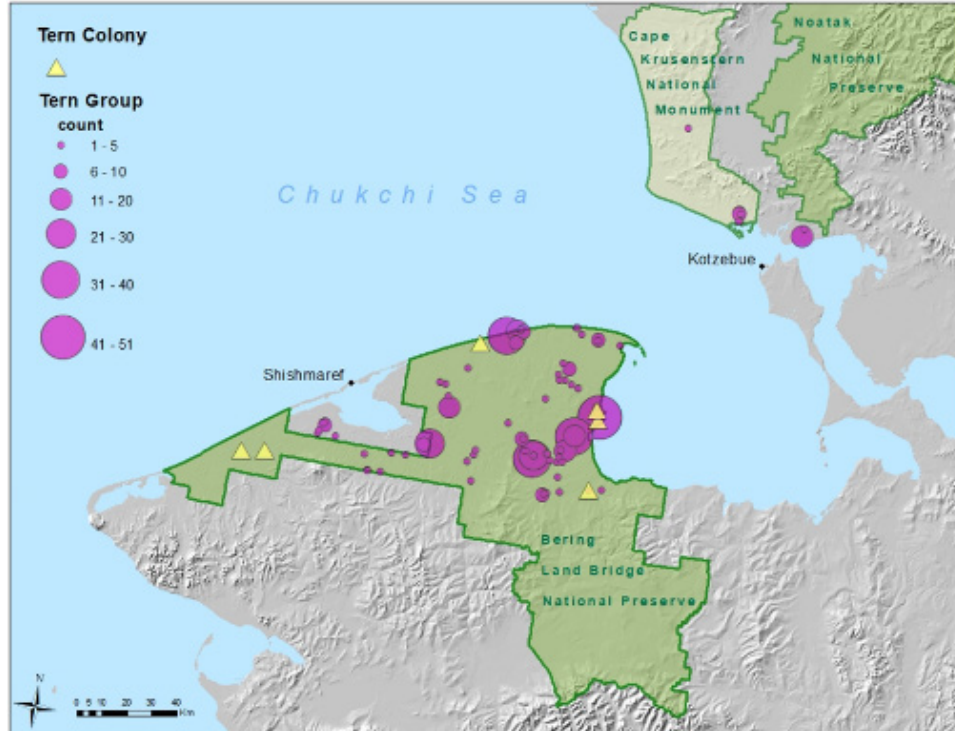


Figure A1. Observations of tern species recorded during aerial loon surveys in Western Arctic Parklands, 2016–2018.

Appendix B. Trend in the probability of detecting use in a multi-state framework.

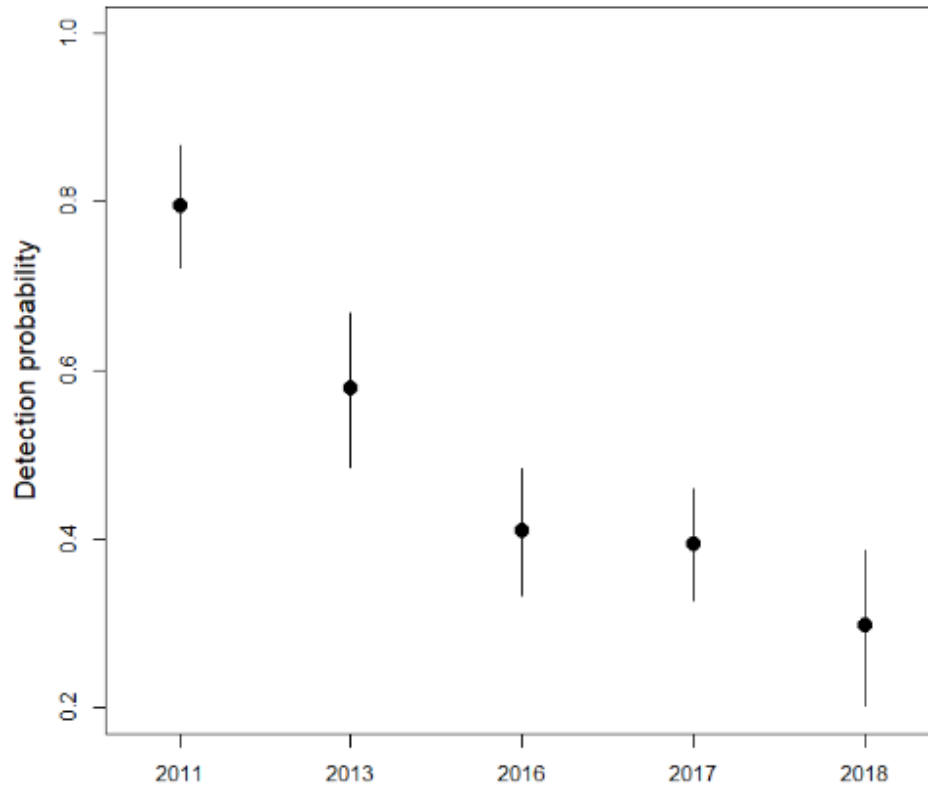


Figure B1. Posterior means and 95% credible intervals for the probability of detecting use by Yellow-billed and Pacific Loon. Estimates are from exploratory modeling using an intercept-only version of the implicit dynamics multi-state model in which the probability of detecting use was shared between both loon species.

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.

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