FIRST INSIGHTS INTO THAYER'S GULL *LARUS GLAUCOIDES THAYERI* MIGRATORY AND OVERWINTER PATTERNS ALONG THE NORTHEAST PACIFIC COAST

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ABSTRACT

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Investigating the seasonal movements of migratory seabirds is essential to our understanding of their basic life history and conservation needs. Using satellite telemetry, we studied the migration and non-breeding distribution of Thayer's Gulls *Larus glaucoides thayeri*, a little known North American gull. Four adult birds that were tracked from a colony in the Canadian high Arctic migrated south overland, crossing multiple mountain ranges to arrive at the coast between southeast Alaska and northwest British Columbia. The subsequent wintering distribution differed greatly among individuals occupying ranges as far north as Yakutat Bay, Alaska (59.7°N) and as far south as Monterey Bay, California (36.7°N). Gulls spent 62%–82% of the overwinter period in waters overlying the inner continental shelf (mean sea surface temperature 8.4–11.7°C; mean distance to coast 2.6–8.8 km, mean depth 19–102 m), in areas of generally low human activity. Their remaining time was spent primarily onshore in coastal (15%–20%) or inland areas (4%–23%) composed of natural vegetated habitat with low human population density. Little time was spent in agricultural (0%–5%) or urban (0%–1.5%) environments. Our tracking study provides new insights into the basic natural history of this species. This knowledge should help in the development of conservation strategies for the management of Thayer's Gull populations.

Key words: Iceland Gull, Thayer's Gull, *Larus*, migration, biologging, arctic, overwinter

INTRODUCTION

Migratory birds can travel extensive distances to avoid unfavourable conditions and seek abundant resources (Alerstam & Lindström 1990). Studying these movements is an essential component of our understanding of a species' basic life history. Assessing the extent to which distributions overlap with potential threats from either direct or indirect impacts of human activities is only possible when paired with complete knowledge of year-round spatiotemporal distribution and movement patterns (Calvert *et al*. 2009, Martin *et al*. 2007, Runge *et al*. 2014).

Arctic breeding species are faced with a complex array of challenges and potential threats as they move through their annual cycle. At high latitudes, the nesting season is temporally constrained (e.g., Mallory & Forbes 2007), and rapid climate change is altering the environment at an unprecedented rate (Wauchope *et al*. 2017). Along migratory routes and at overwinter sites, historic staging and wintering areas are degrading or presenting "temporal mismatches" with critical prey (e.g., McGowan *et al*. 2011, Murray *et al*. 2014). For most migratory bird species, and for many Arctic-nesters in particular, insights into the consequences of non-breeding movement ecology have only recently occurred due to advances in biologging technology.

The Thayer's Gull *Larus glaucoides thayeri* is among the least known of all North American gull species. This lack of knowledge can be attributed, at least partially, to the difficulty of studying high-Arctic, low-density, cliff-nesting seabirds, and perhaps partially to a confused and disputed taxonomic history. Thayer's Gull is presently considered one of three sub-species of Iceland Gull. The total breeding population is estimated at around 6300 nesting pairs, occupying scattered nesting sites throughout the Canadian Arctic Archipelago (Snell *et al*. 2018). Definitive data capturing migratory and overwinter movements of individuals of known origin are nearly non-existent. Banding and recovery data for Thayer's Gulls are extremely sparse (e.g., Allard *et al*. 2010), and prior to this study, Iceland Gulls of any sub-species had not been tracked through the non-breeding period.

The objective of the current study was to document the non-breeding movements of Thayer's Gulls using satellite tracking, complemented by a summary of reported band encounters. We present details of southbound migratory routes for four adult Thayer's Gulls that were tracked from a high Arctic breeding colony in northern Canada, and we describe overwinter movement patterns and habitat characteristics for this enigmatic species.

STUDY AREA AND METHODS

St. Helena Island lies 8 km northeast of Cape Vera on the northwestern arm of Devon Island (89.15°N, 76.28°W; Fig. 1). It is a small (1.25 × 0.5 km) island that consists mostly of a low, rocky shelf with an east-facing cliff near the island's center. The colony of Thayer's Gull is small, usually supporting about 20 nests annually (Allard *et al*. 2010, Mallory & Gilchrist 2005).

We trapped five adult breeding Thayer's Gulls on their nests using spring-loaded bownets in July 2016. A 12-g, solar-powered satellite transmitter (Microwave Telemetry Inc.) was then attached to each gull with a teflon tube harness and was positioned using a leg-loop design on the lower back, anterior to the uropygial gland (Mallory & Gilbert 2008). These transmitters sent at least one signal daily, which was captured by the ARGOS satellite system and then sent by email to the research team.

In addition to tracking data, banding and recovery records for all Thayer's Gulls banded or encountered in North America as of 14 March 2019 were obtained from the North American Bird Banding Program database through the Government of Canada (https://www.canada.ca/en/environment-climate-change/services/bird-banding) and from Allard *et al*. (2010).

Following Yurkowski *et al*. (2018) and Anderson *et al*. (2019), we filtered ARGOS-derived position data using a Bayesian state-space model (SSM) to describe movement paths from location data and provide more precise location estimates at a regular 24-h interval. Great-circle distances (km) between each pair of daily locations were calculated using custom-built routines in the software Matlab (MathWorks Inc, USA). To delineate the beginning of the overwintering period, we visualized tracks for each bird, noting the date on which southbound migration ceased (indicated by an abrupt break in the direction of travel and the distance travelled per day after reaching the Pacific coast). Although this was a subjective delineation, the descriptive nature of the work was not affected by these distinctions. The extent of the wintering areas for each individual bird was visualized as the contours of the 90% kernel density utilization distribution, generated using ArcMap (ESRI ArcGIS 10.5. search radius 100 km, output cell size 5 km). The resulting polygons are presented only as a visual aid to general overwinter distributions for each bird and were not used in determining movement or habitat metrics.

Environmental data extraction

Overwinter daily positions were designated as offshore, coastal, or inland based on proximity to the coastline. Positions within 500 m of the coastline were considered coastal, whether onshore or offshore. The proportion of the overwinter period associated with each designation was determined for each bird as the number of daily positions in this category divided by the total number of overwinter daily positions. Overwinter positions located onshore, whether coastal or inland, were also assigned to four land cover classes: wetland/tundra, natural vegetated, agricultural, and urban. Terrestrial habitat classification data were obtained from the 2010 North American Land Cover database at a spatial resolution of 250 m (Latifovic *et al*. 2012). All remaining locations positioned over ocean were assigned as a fifth class: marine. The proportion of the overwintering period associated with each of the five classes was determined as above.

Human population density in the vicinity of each onshore overwinter position was estimated from the publicly-available Gridded Population of the World (GPWv3) dataset (CIESIN 2016) and was represented as people per km^2 based on 2010 census data at a 2.5 arc-minute (or ~0.05°, ~5 km at the equator) grid cell resolution. Each onshore overwinter position was assigned the population density of the 5 × 5-km grid cell within which it fell.

Potential human impacts in locations of marine overwinter positions were estimated from the publicly-available Human Impact on Marine Ecosystems dataset (Halpern *et al*. 2015, 2008). This dataset predicts human impact, at a 1-km^2 grid cell resolution, as a cumulative impact score out of six categories ranging from very low to very high impact

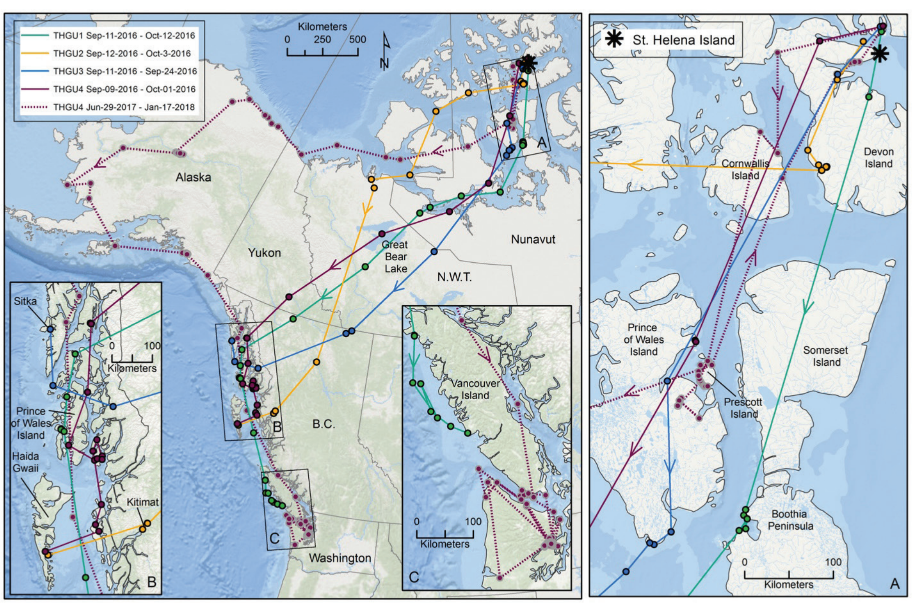

Fig. 1. Southbound migratory routes of four Platform Transmitter Terminal (PTT) satellite-tracked Thayer's Gulls from St. Helena Island, Nunavut in 2016. In 2017, the summer movements and subsequent second southbound migratory route of one of the four birds is also shown.

(very low: < 1.4, low: 1.4–4.95, medium: 4.95–8.47, medium high: 8.47–12, high: 12–15.52, very high: > 15.52) based on 17 different anthropogenic drivers of ecological change (e.g., fishing, pollution, oil rigs, climate change, invasive species, shipping, and nutrient inputs). Each marine overwinter position was assigned the maximum and mean impact score of the grid cells within a 2.5 km radius.

Marine habitat was further characterized by assessing bathymetry (in m; NOAA ETOPO1 Global Relied Model, 0.01° spatial resolution), sea surface temperature (°C, NASA Aqua MODIS 8-day composite, 0.025° spatial resolution, ± 1 °C nominal accuracy), and sea surface chlorophyll *a* concentration (mg/m^3, NASA Aqua MODIS 8-day composite, 0.025° spatial resolution, ± 40% nominal accuracy) as the mean value within 5-km grid cells surrounding each position. Data were extracted from the CoastWatch website using the "xtractomatic routine" developed for R software (https://coastwatch.pfeg.noaa.gov/xtracto). A 5-km buffer for assessing environmental variables was chosen because this is likely to capture local variation in variables due to the limited daily movements made by birds when associating with an overwinter site. Mean ± standard deviation is reported throughout the text. Measurements to determine sex were not available.

RESULTS

One deployed device stopped transmitting prior to the bird commencing its southbound migration. The remaining four devices captured southbound migration and ≥ 4 mo of the overwinter period (between 113 and 267 d). One device continued transmitting for 565 d, capturing a complete 254-d overwinter period, northbound migration, breeding period, subsequent second southbound migration, and the first 93 d of the second overwinter period.

TABLE 1
Movement summary of southbound migration and overwinter period for four satellite-tracked Thayer's Gulls from St. Helena Island, Nunavut

Bird ID	Southbound departure date	Total migration distance (km)	Duration southbound migration (d)	Migration travel rate (km/d)	Max. migration travel rate (km/d)	Duration of tracked overwinter period (d)	Overwinter travel rate (km/d)	Overwinter days with travel rate < 5 km/d (%)
THGU1	11 Sept 2016	4293	31	138.5 ± 183	606.0	267	43.0 ± 71.4	31
THGU2	12 Sept 2016	3644	21	165.6 ± 291	1253.5	113	7.1 ± 6.4	47
THGU3	11 Sept 2016	3247	12	270.6 ± 313	835.9	156	26.8 ± 51.1	42
THGU4	09 Sept 2016	2870	21	410.0 ± 230	769.7	254	28.7 ± 80.2	48

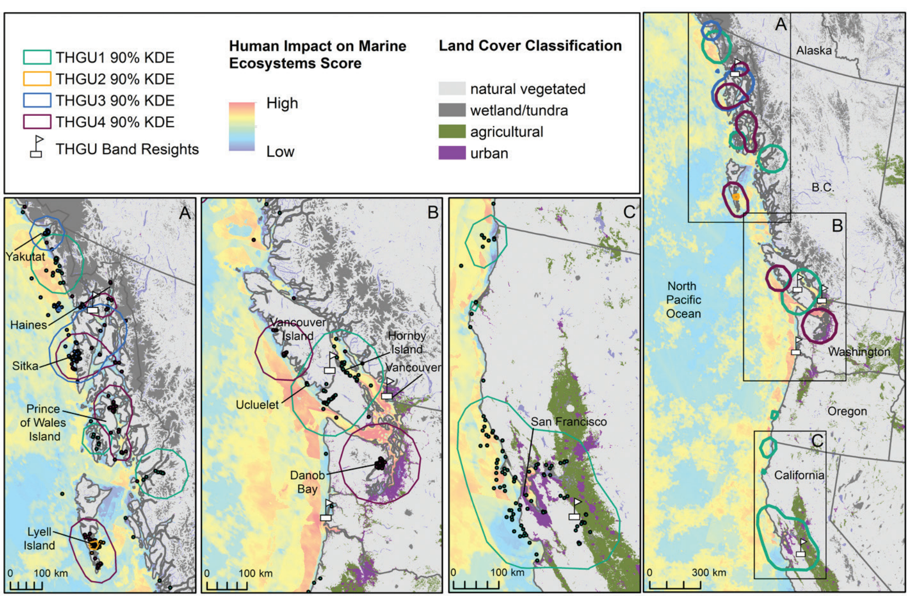

Fig. 2. Overwinter distributions (September–June) of four Platform Transmitter Terminal (PTT) satellite-tracked Thayer's Gulls, shown by individual 90% kernel density estimation (KDE) contours as well as individual daily locations in panes A–C. Five reported resightings of banded Arctic breeding Thayer's Gulls are also shown.

Migration timing and routes

All four tracked birds initiated their southbound post-breeding migration within a 4-d period in September 2016 (Table 1). Birds arrived at the first overwinter destination 12–31 d after leaving St. Helena Island, making one to three distinct stops of 3–7 d each along the migratory route (Fig. 1). Southbound migratory routes differed somewhat among the birds (described in greater detail in Fig. 1 and Appendix 1, available on the website), although all four routes traversed southwest across the Northwest Territories, with three birds crossing Great Bear Lake (Fig. 1). All four birds first reached the Pacific Ocean within a 530 km stretch of coastline between southwestern Alaska and northwestern British Columbia. On their southbound migration, they travelled a mean distance of 3513 ± 608 km at a mean rate of 245 ± 123 km/d (Table 1). Southbound, they reached a maximum travel rate of 606–1254 km/d (Table 1).

Overwinter movements and distributions

Overwinter movement patterns and destinations differed greatly between individuals, with birds settling into wintering areas as far north as Yakutat Bay, Alaska (59.7°N) and as far south as Monterey Bay, California (36.7°N; Fig. 2). Tracking duration also varied, and it is possible that some birds moved farther south later in the winter season after their transmitters had ceased working. However, the individual with the shortest tracking duration (THGU2, 113 d) made only localized movements within a 30-km radius around Lyell Island of Haida Gwaii, British Columbia, for the first 4 mo of the overwinter period (Fig. 2). In contrast, the individual with the longest overwinter tracking duration (THGU1; 267 d) moved extensively within the first 4 mo, first arriving north of THGU2 in southeast Alaska, then immediately moving south to spend a month on Vancouver Island, British Columbia, and finally moving farther south to the San Francisco, California area (Fig. 2). THGU4 also moved south after an initial stay near Lyell Island, British Columbia, and then spent November to March within an 11 km radius around Dabob Bay, Washington. Unlike the other birds that moved south, THGU3 remained within a 2.87° latitudinal range in the far north of the range for 5 mo.

Following the first 4 mo of the overwinter period, two gulls exhibited different movement patterns. THGU4 moved from Washington to Alaska, following a coastal route (Fig. 2), where it spent 3 mo before migrating farther north on 12 June 2017. In contrast, THGU1 moved inland from coastal California, stopping at many human-altered habitats (landfills, reservoirs) before moving north to Vancouver Island and eventually to Alaska, where its transmitter stopped functioning on 05 June 2017 (detailed in Appendix 2, available on the website).

Winter habitat associations and human impact exposure

All four birds spent the vast majority of their time in coastal areas (Table 2); the mean proportion of overwinter locations in areas classified as marine was 77% ± 4.7%. The remainder of overwinter locations were primarily classified as natural vegetated areas (16% ± 7.4%; Table 2). Three birds spent a small proportion

TABLE 2
Proportional overwinter habitat associations for four satellite-tracked Thayer's Gulls from St. Helena Island, Nunavut

Bird ID	% marine	% natural veg.	% wetland/ tundra	% agricult.	% urban	% offshore	% coastal	% inland	Distance to coast (km)	Distance offshore (km)	Max. distance offshore (km)	Max. distance inland (km)
THGU1	73	11	8	5	2	62	15	23	13.81 ± 25.1	7.96 ± 13.1	101.7	38.6
THGU2	75	25	0	0	0	65	19	16	2.7 ± 2.7	3.27 ± 2.8	19.6	6.81
THGU3	84	9	6	0	0	82	5	4	8.17 ± 16.1	8.78 ± 16.7	93.5	5.56
THGU4	77	19	4	0	0	64	20	16	2.07 ± 3.0	2.64 ± 3.5	27.8	6.59

TABLE 3
Overwinter habitat characteristics for four satellite-tracked Thayer's Gulls from St. Helena Island, Nunavut for onshore and marine locations[a]

Bird ID	Onshore human population density (people/km^2)	Human Impact on Marine Ecosystems score[b]	Max. Human Impact on Marine Ecosystems score	Bathymetry (depth, m)	Sea surface temperature (°C)
THGU1	49 ± 187	3.25 ± 1.67	7.76	88 ± 234	11.7 ± 1.8
THGU2	0.2 ± 0	2.88 ± 0.62	3.98	19 ± 27	10.1 ± 0.9
THGU3	12 ± 62	3.58 ± 0.93	4.96	102 ± 318	8.4 ± 1.7
THGU4	3 ± 15	4.24 ± 1.26	6.28	76 ± 73	9.0 ± 2.0

[a] All values determined based on a 5-km buffer around overwinter period locations.
[b] Cumulative impact score ranging from very low (< 1.4) to very high (> 15.52) impact.

of the overwinter period in areas classified as wetland or tundra (4%–8%), while only one bird (THGU1) had any overwinter locations classified as agricultural or urban areas (Table 2). The mean proportion of daily overwinter locations within 500 m of the coastline was 15% ± 6.6%; however, THGU3 spent more of the overwinter period in locations classified as offshore (> 500 m from the coastline) than the other three birds (Table 2). For all overwinter locations, gulls were typically within 6.7 ± 5.5 km (Table 2) of the coast. The mean maximum distance travelled inland from the coast across birds was 14.4 ± 16.1 km, but only THGU1 travelled more than 7 km inland (Table 2). When offshore, the mean distance from the coast across birds was 5.7 ± 3.1 km, with maximum distances from shore varying between birds, from 19.6–101.7 km (Table 2).

When in areas classified as marine, whether offshore or coastal, gulls were found over water that had a mean depth of 71 ± 35 m, although bathymetry varied considerably (Table 3). Sea surface temperature also varied, both within and between birds (Table 3). The marine areas used by all four birds were generally considered 'low impact' from human activities, based on mean Human Impacts on Marine Ecosystems scores (Table 3). Maximum impact scores that were encountered ranged from 'low impact' to 'medium impact' (Table 3), where THGU1 and THGU4 overlapped in areas of higher impact around the Salish Sea and coastal California (Fig. 2).

When onshore, three birds spent most of the overwinter period in areas with low human population densities (mean < 12 people/km^2; Table 3). For these birds, the maximum population density that was encountered ranged from 0.21–325 people/km^2. Only one bird (THGU4) spent time in areas with a nearby high population density (mean 49 ± 187 people/km^2, maximum 1873 people/km^2), primarily along the California coast (Fig. 2). Despite residing in this generally densely populated area of California for 153 d, THGU4 only spent 2% and 5% of the overwinter period in areas classified as urban or agricultural, respectively.

Fidelity to migratory timing, routes, and wintering sites

The transmitter on THGU4 continued to function for an additional annual cycle, revealing a return trip in 2017 to the Canadian Arctic Archipelago but not to the breeding colony at St. Helena Island. This bird departed the wintering area in mid-June, moving across the Northwest Territories and Great Bear Lake northwest to Prince of Wales Island, Nunavut. It remained in this area for 1 mo and did not return to the breeding colony until mid-August (Fig. 1). It headed back south within 5 d of the date it left the previous year. However, it followed a different route than in 2016. Rather than moving southwest across the continent, in 2017, THGU4 moved west to Alaska along the continental coastline, then southwest across the state to the Pacific coast, where it followed a coastal route south, eventually returning again to Dabob Bay, Washington for the winter until the transmitter stopped functioning 93 d later (see Appendix 3 for a detailed description, available on the website).

History and distribution of band recovery encounters

Since 1962, a total of 178 Thayer's Gulls have been banded, of which 64 were banded within the non-breeding range. Only one of these birds has been resighted, < 1 mo after banding and at the same location, in Victoria, British Columbia. The remaining 114 birds were banded within the breeding range in the Canadian high Arctic, and five have been encountered during the non-breeding period: one in Alaska, two in British Columbia, one in Washington, and one in California (Fig. 2). One after-hatch-year Thayer's Gull was banded near Cambridge Bay, Nunavut, and resighted 3 mo later in October, in Glen Park, Vancouver, British Columbia. The remaining resighted banded birds were all banded at St. Helena Island, Nunavut. One bird, banded as an after-second-year, was resighted 5 y later on Vancouver Island, British Columbia, inland from Courtenay. A second after-hatch-year bird from Cape Vera was resighted 9 y later in January, in agricultural fields in California, near to areas used by THGU1. The fourth resighted bird was banded as a flightless chick on St. Helena Island, and was encountered 6 mo later in February at Long Beach, Washington. The fifth was also banded as a chick, resighted 10 mo later in June near Gustavus, Alaska.

DISCUSSION

Prior to our study, little was known about the migration and non-breeding distribution of Thayer's Gulls. Most information was anecdotal or outdated, with very few band recoveries (e.g., Allard *et al*. 2010). Despite a limited sample size of four individuals, our findings reveal that at least a portion of Thayer's Gulls from the Canadian Arctic Archipelago engage in an impressive, direct, overland migration, crossing multiple mountain ranges en route to the northeast Pacific coastline. Once birds arrive at the coast, they exhibit remarkably high variability in overwinter movement strategies and habitat use, spanning the coastline from remote Alaskan shores to human-dominated landscapes of northern California. Moreover, from just four tracked birds, a high degree of individual variation in overwinter movement strategies was apparent, with the overwinter period composed of varying degrees of residency and itinerancy both within and between birds. Our results corroborate the scant reported observations and band resightings and highlight the potential importance of remote areas in northern British Columbia and Alaska throughout the non-breeding period. Clearly, tracking more birds would have provided further insight.

All four tracked Thayer's Gulls completed a direct overland migration in 2016, crossing through areas of Nunavut, Northwest Territories, Yukon, and northern British Columbia, all of which are rarely or sparsely occupied by human observers. It has been suggested that some Thayer's Gulls may migrate inland; however, the sparsity of inland records was thought to indicate limited overland migration (Snell *et al*. 2018). Thayer's Gulls have been reported as very rare in the Barrow Strait, Nunavut, in August (Nettleship & Gaston 1978), but this was based on aerial census data that was collected prior to fall migration (which occurs in September, as observed in this study). One other documented observation from Lancaster Sound reported only a few gulls seen from a ship in early September 1950 (Wynne-Edwards 1952). Additional evidence contradicting overland migration was reported by Macpherson & Manning (1959), who did not observe migrating birds in the Adelaide Peninsula area in Nunavut, despite this area being on the presumed migratory route. We found, however, that three of four birds crossed southbound through the Barrow Strait or western Lancaster Sound, and all four tracked birds took routes northwest of the Adelaide Peninsula, instead crossing Victoria Island then passing southbound over the northern coasts of Nunavut and the Northwest Territories.

Our limited results suggest that the interior of the Northwest Territories, and Great Bear Lake in particular, likely encompass the migratory route of more birds than previously recognized. This applies to birds breeding on St. Helena Island, and possibly to birds breeding at other sites as well. Thayer's Gull had been reported as a 'rare transient or wanderer' at Great Slave Lake in the Northwest Territories (Sirois et al. 1995) and in interior British Columbia (Campbell *et al*. 1990). Interestingly, this species had not been reported previously at Great Bear Lake on any local species inventories (MacDonald, 2004) or via the citizen-based bird observation network eBird (eBird 2019). Perhaps this is not surprising because birds do not linger at these sites; southbound tracked birds stopped for one day or less, and one northbound bird stopped for 3–4 d. Given that Great Bear Lake is the largest lake residing entirely within Canada, with a surface area of over 31 000 km^2 and lying close to the northern tree limit (MacDonald 2004), this feature may provide a visual landmark on the landscape for navigating birds on migration. All four tracked birds exhibited direct and rapid overland routes in 2016, apparently minimizing migration duration and distance. Following the crossing of Canada's northern interior, the tracked birds accomplished a remarkable transit through multiple ranges of the Interior Mountains of northern British Columbia and southern Yukon, followed by crossing the coastal mountains en route to the remote Pacific coast.

Apparent bottlenecks exist for migrating Thayer's Gulls for both arrival at, and departure from, the Pacific coast. These bottlenecks occur in northwest British Columbia around Kitimat and the Haida Gwaii, and in southeast Alaska along the Alexander Archipelago in the Eastern Gulf of Alaska. It is likely that staging for northbound departure is timed to coincide with the local spring spawning run of the highly energy-dense eulachon *Thaleichtys pacificus*. One account of abundant Thayer's Gulls near Juneau, Alaska, at Berners Bay, supports this idea, with thousands of birds reported over a few days in May 1995 and again in May 1996 (Snell *et al*. 2018, Tobish 1995), consistent with our tracking results. The two gulls tracked through the entire overwinter period returned to this northern region by April, and one band recovery is also known from this area in June (Allard *et al*. 2010). Similarly, in spring in Iceland, increases in Iceland Gull (*glaucoides* or *kumlieni*) abundance have been noted in association with the local migration of capelin *Mallotus villosus*, another energy-dense schooling fish (Ingolfsson 1967). In autumn, all four tracked Thayer's Gulls arrived first at this contracted stretch of shoreline from their southbound overland migration, within 530 km of one another. For Thayer's Gulls, these productive coastal meadows and intertidal estuarine habitats may provide a temporary pre- or post-migration stopover for some individuals, while others elect to remain for an extended stay, at least in the first half of the overwinter period.

Our tracked birds support previous observations that Thayer's Gulls are seasonally abundant on the coast of British Columbia north to Haida Gwaii; in coastal northwestern Washington, Oregon; in inland areas of the Cascade Range on lawns, agricultural lands, and garbage dumps; and south through California (Brooks 1937, Campbell *et al*. 1990, Gilligan *et al*. 1994, Lehman 1980, Morgan *et al*. 1991, Snell *et al*. 2018, Taylor & Harper 1986, Vermeer & Morgan 1997). Taken together, the four gulls tracked here visited the entire reported overwintering range of this sub-species. However, birds frequented coastal islands and estuaries throughout the range, particularly at higher latitudes, and spent more time than we expected, based on prior knowledge, within the northern reaches of the overwinter distribution.

Our results support previous assertions that Thayer's Gulls are almost exclusively maritime or coastal south of their breeding areas (Snell *et al*. 2018), albeit after an overland migration. The four tracked birds were closely associated with the warmer and shallower waters along the coast and nearshore continental shelf during the overwinter period. Gulls spent little time far offshore (two birds travelled ~100 km offshore once) or far inland. Therefore, tracking data were consistent with previous at-sea surveys, which showed that Thayer's Gulls are common over the continental shelf off the west coast of British Columbia and Oregon during the overwinter period, occasionally venturing far offshore (presumably attracted by fishing fleets; Morgan *et al*. 1991). Nonetheless, we found that some birds did visit marine areas with higher Human Marine Impact Scores, although their use of these areas tended to be more transitory; periods of longer residence, or true overwinter destinations, occurred in regions with lower impact scores. Further research could assess how the degree and nature of fisheries or human-affected marine areas affect the overwintering of Thayer's Gulls.

Only one of the four gulls that we tracked spent time during the overwinter period in highly human-altered habitats such as large urban cities, landfills, and agricultural areas; one band recovery was also resighted in an agricultural field, and one was resighted in an urban park. Interestingly, a recent study by Anderson *et al*. (2019) showed that Arctic-breeding Herring Gulls *L. argentatus* similarly use principally marine 'natural' habitats during the winter, far more than southern nesting conspecifics that use urban and agricultural areas during non-breeding seasons. However, Peck *et al*. (2016) showed that Thayer's Gull eggs still contain many organohalogenated contaminants. Therefore, while they may not feed heavily in human-altered habitats during the winter or migration, their higher position in the food web still exposes them to contamination.

Most other high Arctic-breeding gull species are primarily pelagic or pagophilic in their overwinter distribution, such as Sabine's Gull *Xema sabini* (Gilg *et al*. 2013, Davis *et al*. 2016), Ivory Gull *Pagophila burnean* (Spencer *et al*. 2014), Ross's Gull *Rhodostethia rosea* (Maftei *et al*. 2015), and interestingly, the two other sub-species of Iceland Gull (Snell *et al*. 2018). While the wintering range and movements of Iceland Gulls are generally not well understood, most *L. g. glaucoides* and, in all likelihood, many *L. g. kumlieni*, are thought to be intraregional Arctic migrants, overwintering in open leads and polynyas (Snell *et al*. 2018). While it is possible that some Thayer's Gulls may also overwinter in polynyas in the north, the four gulls tracked from St. Helena Island did not do so. In contrast, our results support the idea that some Thayer's Gulls overwinter entirely in the more southerly coastal Northeast Pacific, exhibiting a distinctly different non-breeding strategy than most other Arctic-breeding gulls and even closely related sub-species.

Although multi-year tracking data are only available for a single Thayer's Gull, this bird exhibited extreme variation in its southbound migratory route paired with remarkable fidelity to a particular overwinter destination in Puget Sound, which was visited in two consecutive overwinter periods. Both high individual consistency and flexibility in non-breeding movement patterns have been identified in other seabirds (e.g., Dias *et al*. 2011, Orben *et al*. 2015). For Long-tailed Skuas *Stercorarius longicauda* tracked through multiple years of migratory journeys across hemispheres, individuals could be highly consistent between two consecutive years and flexible between other years (Van Bemmelen *et al*. 2017).

Our limited sample size prevents further interpretation, but the observed behavior warrants further investigation into the degree of flexibility and consistency in individual Thayer's Gull migratory and overwinter movements, which can be achieved through future tracking efforts.

The Thayer's Gull is not currently considered a species of conservation concern, but it undoubtedly faces a challenging future, with habitat alterations anticipated in both its breeding and non-breeding range due to accelerating climate change and anthropogenic pressures. It is widely recognized that a major driver of bird population declines is habitat loss and degradation in wintering areas, and management efforts can be more effective when non-breeding movement ecology is considered in decision-making (e.g., Morrison *et al*. 2013, Rushing *et al*. 2016). In the northern breeding range of the high Canadian Arctic Archipelago, both historical and anticipated future warming is, on average, twice the magnitude of global warming trends, with broad ecological consequences (Bush & Lemmen 2019). In light of the immense environmental challenges ahead, we must have a thorough understanding of the year-round distribution and population trends of Arctic birds. To ensure the development of impactful management practices and policies going forward, it will be crucial to encourage tracking research efforts which seek to identify the habitat requirements and movement patterns of migratory species (e.g., Hays *et al*. 2019, Sequeira *et al*. 2018).

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