Inter-individual variation in the migratory behaviour of a generalist seabird, the herring gull (Larus smithsoniansus), from the Canadian Arctic

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Abstract: The Arctic is warming three times faster than the rest of the globe, causing rapid transformational changes in Arctic ecosystems. As these changes increase, understanding seabird movements will be important for predicting how they respond to climate change, and thus how we plan for conservation. Moreover, as most Arctic-breeding seabirds only spend the breeding season in the Arctic, climate change may also affect them through habitat changes in their non-breeding range. We used Global Location Sensors (GLS) to provide new insights on the movement of Arctic-breeding herring gulls (Larus smithsoniansus) in North America. We tracked gulls that wintered in the Gulf of Mexico (n = 7) or the Great Lakes (n = 1), and found that migratory routes and stopover sites varied between individuals, and between southbound and northbound migration. This inter-individual variation suggests that herring gulls, as a generalist species, can make use of an array of regions during migration, but may be more susceptible to climate change impacts in their overwintering locations than during migration. However, due to our limited sample size, future, multi-year studies are recommended to better understand the impacts of climate change on this Arctic-breeding seabird.

Keywords: animal movement; Climate change; geolocator; migration; seabirds

1 Introduction

Advancements in tracking technologies have facilitated new understanding of seabird movement patterns that were previously unknown, as seabirds spend most of their life at sea [1]. Such spatial information is crucial for our understanding of seabird ecology and life-history traits, and can be used to inform conservation [2]. Importantly, migration routes and wintering locations can vary among colonies and individuals within a population due to a multitude of factors, including genetics, natal colonies, competition and environmental stressors [3–8]. Thus, knowledge of both population and individual-level movements can provide important insights for conservation and management.

In the Arctic, ocean temperatures are warming three times faster than the rest of the globe, and Arctic ecosystems are experiencing rapid transformational changes [9]. Further, most Arctic-breeding seabirds spend only a portion of their annual cycle at high latitudes, thus climate change impacts are not localized and may occur across a broad range of important areas and habitats throughout migration. As these impacts continue to increase in frequency and intensity [9, 10], understanding seabird movements is critical both for conservation planning (e.g. understanding threats during the non-breeding period or informing marine protected areas) [2, 11] and predicting how marine fauna will respond to these environmental changes [12].
Despite the need for this information, the migratory movements of many Arctic-breeding seabirds, particularly gulls, are not well understood. Several studies have shown that Arctic-breeding gulls exhibit individual variation in migration routes and wintering areas but return to the same breeding sites each year [13–15]. Gulls that use a wide range of stopovers and wintering areas during migration may be less sensitive to certain stressors, such as habitat loss or climate change, than specialists that are constrained to a certain habitat or diet during migration [16]. Thus, understanding individual movements is integral to our understanding of how these stressors may impact the population as a whole.

American herring gulls (Larus smithsonianus; hereafter herring gulls) are opportunistic seabirds that migrate both short and long-distances to diverse overwintering areas [17, 18]. As a generalist species, herring gulls can exploit resources in marine, freshwater, terrestrial and anthropogenic habitats [17, 19], and are thus distributed across inland and coastal areas across the northern hemisphere [20]. This flexibility allows herring gulls to thrive in a range of habitats and climatic conditions throughout their annual cycle, and as a result, provides a unique opportunity to monitor how individual generalists alter their migratory behaviour in an increasingly changing climate [9, 10].

Information on the migratory behaviour of Arctic-breeding herring gulls has only recently been revealed [17, 18]. Herring gulls from the Canadian Arctic exhibit variation in migration and habitat use among colonies, including relatively prominent migratory connectivity between regional colonies and specific wintering areas [17, 18]. For example, previous research indicates that herring gulls from the eastern Canadian Arctic largely overwinter in the Gulf of Mexico, while gulls from the Great Lakes mostly remain in the Great Lakes region throughout the winter [17, 18]. Interestingly, individuals within these populations seemed to use different routes to reach their respective wintering areas [18], yet analyses of within-population variation are scarce. Here, we compare to, and expand upon, previous research [17, 18] by providing new insights on individual differences in migratory routes, stopover sites and overwintering areas of a herring gull population from the eastern Canadian Arctic. As generalist omnivores known for individual behavioral variation [20], we expected to observe considerable variation in migratory pathways and timing, as seen in ivory gull (Pagophila eburnea) [21] and long-tailed skua (Stercorarius longicaudus) migrations [14, 22], before arriving at the general wintering area. We then expected individuals from the same colony to converge in the same wintering areas, as reported in previous studies [17, 18].

2 Methods

2.1 Study area

The East Bay (Qaqsauqtuq) Migratory Birds Sanctuary (hereafter “East Bay”; 64°01 N, 81°47 W; Fig. 1) where GLS tags were deployed is located on Southampton Island in Kivalliq Region, Nunavut, Canada. This sanctuary is an 112,811 ha area that supports a vast array of migratory Arctic breeding birds, including various species of gulls, ducks, geese and shorebirds. Several mammals, such as Arctic foxes (Vulpes lagopus) and polar bears (Ursus maritimus), also use the area [23–25] and take advantage of the abundance of seabird eggs and young as a food source [26]. Due to its importance as a nesting site for a variety of migratory birds, East Bay and the surrounding area has been designated as an Important Bird Area [27], and listed as a key migratory bird terrestrial habitat site by the Canadian Wildlife Service [23]. The colony of herring gulls on Mitivik Island (Fig. 1) in East Bay is small, approximately 15-20 breeding pairs and is thought to be stable (H.G. Gilchrist pers. comm) [28].

2.2 Tag deployment and recapture

We captured adult herring gulls using a self-triggering wire mesh drop box trap over their nest in late-June or early July in 2007 (n = 2), 2009 (n = 10) and 2010 (n = 15). At the time of capture, we attached a stainless steel band to the right tarsus, a light level Global Location Sensor (GLS; Lotek LAT2500, 3.8 g, or LAT2900, 2.1 g) to the left tarsus and recorded mass (g) of the adult. GLS tags represented <1% of adult herring gull body mass, well under the recommended 3% maximum for seabirds [29]. The following year, we recaptured gulls as described above, removed the GLS and recorded mass (g) again.

2.3 Data processing

We downloaded data for the GLS units, and then processed and analyzed light-level data using R v 4.0.2 [30]. We restricted data to the known range of herring gulls [20], thus removing locations outside of 0°N – 72°N and 45°W – 130°W, and applied a speed filter of 100 km/h
We segmented the time series of an individual when there were gaps >7 days and removed segments with <7 successive daily locations. We then used a state-space model (SSM) to model herring gull movement paths, which reduces location error (from approximately 200 km [29, 38], to 43 km [39]) and produces a single location estimate per 24 h [17, 40, 41]. The SSM did not predict locations for gaps >7 days, and we removed five birds that had partial tracks (i.e., large portions of southbound and/or northbound migration were missing). Based on visual inspection of the SSM-locations, we removed data from one week before and three weeks after the vernal equinox and all data between May 31 and October 15 (which includes the autumnal equinox, June solstice and movements at the breeding colony) to exclude locations that cannot be accurately estimated at high latitudes [42, 43]. An additional two weeks of data before the vernal equinox were removed for one individual (gull 4) due to unrealistic movements.

2.4 Data analysis

We followed methods in Anderson et al. [18] to determine distance travelled per day (km/d), total distance travelled (km), travel speed (total distance travelled per travel day divided by the number of travel days; km/d), and the

Figure 1: Location of Mitivik Island (A) in the East Bay Migratory Birds Sanctuary on Southampton Island (B) in Kivalliq Region, Nunavut, Canada, where GLS tags were deployed on herring gulls (Larus smithsonianus) from 2007 – 2008; 2009 – 2010, and 2010 – 2011.
Inter-individual variation in the migratory behaviour of a generalist seabird ... number and length of travel and stopover days. Briefly, locations were categorized as travel days if the bird moved > 75 km in a single day or > 0.3° latitude in the same direction for two of three successive days, and if not, locations were categorized as stopover days [18]. It is important to note that we present minimum values for the information we collected (e.g., distance travelled per day, total travel distance, stopover length), given the gaps in our data due to the fall and spring equinoxes. Individual birds are numbered (1 – 8) and the results for each individual are described by their number. We report means ± one standard deviation unless otherwise indicated.

3 Results

We recovered 13 of 27 loggers deployed (48%) and all deployments lasted one year. After data processing, we had complete tracks from 8 individuals (2007-2008: n = 1; 2009-2010: n = 1; 2010-2011: n = 6). All tracks start on October 15 (after the fall equinox) and end on May 31 (to avoid localized movements around the colony before breeding), with a gap from March 13 to April 10 due to the spring equinox (February 27 to April 10 for gull 4). For gulls tagged from 2010-2011 (n = 6), mean mass did not significantly differ between tag deployment and recapture (paired t-test: t5 = 0.34, p = 0.75).

3.1 Southbound migration and overwintering grounds

Due to the gap in data during the breeding season and fall equinox, we lacked southbound migration tracks for two birds (1, 6) that were already at their wintering grounds (Great Lakes: 1; Gulf of Mexico: 6) when tracks began. The remaining six birds (2 – 5, 7, 8) had partial routes (i.e., southbound migration began before or during the fall equinox, thus data at the beginning of southbound migration were missing). The gulls we tracked were either already located off the northeastern coast of the United States (US; gull 4), or were stopped on land in Québec near Hudson Bay (2, 3, 5) or in Hudson Bay/James Bay (7, 8; Fig. 2a). After this stopover, the southbound migration routes of gulls diverged (estimated routes spread 2,300 km east
to west), where gulls either travelled to locations off the coast of northeastern US (2), moved off the coast of northeastern Canada then the Gulf of Maine (7) before reaching their main wintering grounds in the Gulf of Mexico, or travelled directly to the Gulf of Mexico (3 – 5, 8), arriving in mid-November to mid-December. Gulls overwintered in the Gulf of Mexico for an average of 102 ± 29 days (range 48 to 143 days) with 2-10 travel days in between. The gulls wintering in the Great Lakes (1) remained in this region for the duration of the wintering period before beginning northbound migration (Fig. 2a).

Across the five gulls with partial tracks, the mean daily distance travelled during southbound migration was 113 ± 99 km/d (range 0 – 393 km) and the mean total distance travelled was 4833 ± 1753 km (range 1913 – 6998 km; Table 1). Mean travel speed was 183 ± 30 km/d (range 147 – 228 km/d). Mean stopover length was 15 ± 9 days (range 3 – 30 days; Table 1), whereas mean overwintering length was 109 ± 37 days (range 53 – 179 days; Table 2). During overwintering, the maximum daily distance travelled was 218 km.

### 3.2 Northbound migration

Due to the spring equinox, we lack data from March 13 to April 10 (February 27 to April 10 for gull 4), thus have partial northbound routes and duration for most individuals (i.e., northbound migration began during the spring equinox, thus data at the beginning of northbound migration are missing). The only gull with a full northbound migration track was the gull that overwintered in the Great Lakes (1; Fig. 2b). It began northbound migration on May 14 and travelled across Canada and Hudson Bay for two weeks until returning to the colony in late May. Gulls that overwintered in the Gulf of Mexico had different northbound migration routes (Fig. 2b), and stopped along the northeastern coast of the US (5), inland US (6), the Gulf of Maine (2, 4, 8), the Gulf of St. Lawrence (4), the Grand Banks (3, 7), and/or the Labrador Sea (2), before returning to colony in mid-late May. Overall, gulls used a combination of coastal and overland routes across northeastern Canada and US during northbound migration, diverging by up to 3,000 km east-west, and had limited overlap between routes and stopover sites.

Across all gulls, the mean daily travel distance recorded during northbound migration was 79 ± 63 km/d (range 2 – 295 km), while the mean minimum total travel distance was 6423 ± 1754 km (range 3499 – 8422 km), recognizing that these total travel distances are likely an underestimate as we lack data due to the spring equinox. Mean travel speed was 265 ± 120 km/d (range 154 – 516 km/d), and mean stopover length was 15 ± 10 days (range 2 – 32 days).

### 3.3 Comparison between southbound and northbound migration

Over the entire non-breeding period, gulls travelled an average total of 13,735 ± 4269 km (range 7078 – 19910 km), or 9293 ± 4229 km (range 2780 – 15719 km) during travel days only (not including local movements at stopovers and wintering areas). The mean daily travel distance during northbound migration was significantly lower than for southbound migration (paired t-test, \( t_5=3.1, p=0.027 \)), and the mean minimum total travel distance was farther during northbound migration than southbound migration (paired t-test, \( t_5=3.6, p=0.015 \); Table 1). Mean travel speed was faster, but not significantly so, during northbound migration than southbound migration (paired t-test, \( t_5=2.1, p=0.093 \); similar results for non-parametric Wilcoxon test), and mean stopover length during northbound migration was similar to southbound migration (paired t-test, \( t_5=0.3, p=0.811 \); Table 1). Finally, migration routes and stopover sites varied considerably between individuals and between southbound and northbound migration (Fig. 2). For example, both gull 2 and 3 took an overland route across northeastern Canada during southbound migration, then a coastal route along the northeastern United States to their wintering grounds in the Gulf of Mexico. However, on northbound migration, both individuals took a more eastern coastal route around the Grand Banks and Labrador Sea before returning to the colony. Moreover, some gulls that did not stop on the southeastern coast of North America during southbound migration, did so during northbound migration (e.g., 5, 8).

### 4 Discussion

This research provides new insights on individual differences in herring gull migration from the Canadian Arctic. Despite earlier work suggesting high migratory connectivity in herring gulls [17, 18], we found that one gull migrated overland to winter in the Great Lakes, while the remainder migrated overland and then along the northeastern coast of North America to winter in the Gulf of Mexico, but migration routes and stopover sites differed markedly between individuals and between southbound and northbound migration. The majority of gulls wintered in
### Table 1. Summary of southbound and northbound migration routes of GLS-tracked herring gulls (Larus smithsonianus) from the East Bay Migratory Birds Sanctuary in Kivalliq, Nunavut, Canada during the 2007 – 2008, 2009 – 2010 and 2010 – 2011 non-breeding seasons. Migration starts on October 15 (after the fall equinox) and ends on May 31 (to avoid localized movements around the colony before breeding), with a gap from March 13 to April 10 (February 27 to April 10 for gull 4) due to the spring equinox.

| Migration route | ID   | Bird-year  | Number of stopovers | Total number of stopover days | Mean ± SD stopover length (d) | Total distance traveled during stopover days (km) | Number of travel days | Mean ± SD distance traveled per day (km/d) | Total distance traveled during travel days (km) | Travel speed during travel days (km/d) |
|----------------|------|------------|----------------------|-------------------------------|--------------------------------|--------------------------------------------------|----------------------|---------------------------------------------|-----------------------------------------------|------------------------------------------|
| Southbound     | 1    | 2007-2008  | NA                   | NA                            | NA                            | NA                                               | NA                   | NA                                          | NA                                            | NA                                       |
|                | 2    | 2009-2010  | 2                    | 29                            | 14.5 ± 2.12                   | 916                                              | 29                   | 97 ± 86                                     | 5609                                          | 212                                      |
|                | 3    | 2010-2011  | 1                    | 4                             | 4 ± NA                        | 171                                              | 30                   | 170 ± 104                                   | 5769                                          | 187                                      |
|                | 4    | 2010-2011  | 0                    | 0                             | NA                            | 2                                                | 13                   | 147 ± 67                                    | 1913                                          | 147                                      |
|                | 5    | 2010-2011  | 1                    | 30                            | 30 ± NA                       | 780                                              | 19                   | 96 ± 107                                    | 4691                                          | 206                                      |
|                | 6    | 2010-2011  | NA                   | NA                            | NA                            | NA                                               | NA                   | NA                                          | NA                                            | NA                                       |
|                | 7    | 2010-2011  | 3                    | 39                            | 13 ± 8.72                     | 1213                                             | 35                   | 95 ± 81                                     | 6998                                          | 165                                      |
|                | 8    | 2010-2011  | 1                    | 13                            | 13 ± NA                       | 609                                              | 15                   | 146 ± 129                                   | 4021                                          | 228                                      |
| Northbound     | 1    | 2007-2008  | 2                    | 36                            | 18 ± 19.80                    | 726                                              | 15                   | 61 ± 74                                     | 3499                                          | 185                                      |
|                | 2    | 2009-2010  | 4                    | 24                            | 6.67 ± 3.79                   | 1141                                             | 27                   | 85 ± 46                                     | 6854                                          | 162                                      |
|                | 3    | 2010-2011  | 2                    | 38                            | 19 ± 11.31                    | 1713                                             | 13                   | 70 ± 51                                     | 8423                                          | 516                                      |
|                | 4    | 2010-2011  | 4                    | 25                            | 7.67 ± 6.66                   | 965                                              | 35                   | 87 ± 57                                     | 6689                                          | 164                                      |
|                | 5    | 2010-2011  | 1                    | 30                            | 30 ± NA                       | 780                                              | 19                   | 96 ± 107                                    | 4691                                          | 206                                      |
|                | 6    | 2010-2011  | 2                    | 30                            | 15 ± 8.49                     | 986                                              | 21                   | 88 ± 82                                     | 4800                                          | 182                                      |
|                | 7    | 2010-2011  | 2                    | 30                            | 15 ± 15.56                    | 999                                              | 21                   | 79 ± 63                                     | 8354                                          | 350                                      |
|                | 8    | 2010-2011  | 2                    | 18                            | 9 ± 4.24                      | 601                                              | 33                   | 88 ± 50                                     | 7469                                          | 208                                      |
the Gulf of Mexico, similar to other studies of the same population in 2008 and 2013 – 2015 [17, 18]. The Gulf of Mexico is a highly productive area as a result of upwelling and river inputs [44, 45], and therefore has an abundance of fish and invertebrate species [46]. Consequently, this region hosts a variety of passerines, waterfowl, seabirds and shorebirds during migration [47–49], including ring-billed (Larus delawarensis) [50] and herring gulls [51–53]. The Gulf of Mexico has high levels of fishing activity and includes some of the top fisheries in the United States [54, 55], and herring gulls may also take advantage of discards from fishing vessels [56–58]. Compared to gulls from breeding colonies along the Atlantic Coast, Anderson et al. [17] showed that gulls from the Arctic spent proportionally more time at sea in the winter, presumably exploiting fisheries. However, herring gull diet during the non-breeding period is largely unknown, particularly in this region [52], thus future research on the non-breeding diet of herring gulls is encouraged.

Interestingly, one gull spent its entire overwintering period in the Great Lakes, which has been previously reported for one gull from this population through a band resighting [28], but has not been recorded in gulls tracked from this population [17, 18]. The Great Lakes is a stopover for many migratory birds [59] and also hosts herring gull populations year-round [51, 60]. This different overwintering location could be the result of movement between populations or historical colonization from a Great Lakes colony [13], as herring gulls often move between colonies in this region and have low natal fidelity [20, 50]. However, it is also likely that herring gulls exhibit some year-to-year variation in overwintering areas [61], similar to other Arctic migrants such as the long-tailed skua [14]. However, we lack multi-year tracking data for these individuals to test wintering site fidelity, and thus additional tracking studies to examine year-to-year variation are recommended. Importantly, with trends of less severe winters (i.e., less ice and snow cover) [62, 63] in the Great Lakes region, this area may be an increasingly viable overwintering location for the Arctic-breeding component of the American herring gull population.

While some gulls took largely the same route for southbound and northbound migration, others took a more eastern, coastal route during northbound migration (Fig. 2). Moreover, for all gulls with both southbound and northbound data, migration distances were longer on northbound than southbound migration. This is counter to general patterns observed for Thayer’s (Larus glaucoxides thayeri), Sabine’s (Xema sabini) and ivory gulls breeding in the Canadian Arctic, which had relatively longer and slower fall migration, and shorter, quicker spring migration [15, 21, 64]. In all of those studies, however, breeding birds nested close to polynyas, areas of recurrent, predictable open water that provide access to potential food supplies early in the season [65]. In contrast, herring gulls at East Bay migrate across extensive, heavy pack ice [66] to arrive before their main food source arrives (other bird eggs from local eider and goose colonies), and they must forage in shifting pack ice and coastal leads while they set up their breeding territories (H.G. Gilchrist, unpubl. data). Hence, if gulls arrive too early and sea ice covers most foraging areas, they would have to rely on endogenous reserves, which could affect reproduction [67]. Therefore, we speculate that annual variation in the phenology of sea ice break up constrains the timing of spring migration and arrival for herring gulls at this colony. Moreover, we note that while travelling longer distances can be more energetically costly, foraging along the coast might provide more predictable, high energy prey to increase energetic stores prior to breeding [18, 68]. It is also possible that gulls used

| ID | Bird-year | Overwinter location | Number of overwinter | Number of travel days in between overwinter days | Mean ± SD distance traveled per day (km/d) | Total distance traveled (km) during overwinter |
|----|-----------|---------------------|----------------------|-----------------------------------------------|-------------------------------------------|-----------------------------------------------|
| 1  | 2007-2008 | Great Lakes         | 179                  | 0                                             | 24 ± 12                                    | 3579                                          |
| 2  | 2009-2010 | Gulf of Mexico      | 89                   | 0                                             | 26 ± 15                                    | 2329                                          |
| 3  | 2010-2011 | Gulf of Mexico      | 100                  | 10                                            | 39 ± 27                                    | 4301                                          |
| 4  | 2010-2011 | Gulf of Mexico      | 109                  | 4                                             | 33 ± 22                                    | 3680                                          |
| 5  | 2010-2011 | Gulf of Mexico      | 95                   | 3                                             | 29 ± 18                                    | 2844                                          |
| 6  | 2010-2011 | Gulf of Mexico      | 135                  | 12                                            | 33 ± 30                                    | 4800                                          |
| 7  | 2010-2011 | Gulf of Mexico      | 53                   | 20                                            | 62 ± 46                                    | 4559                                          |
| 8  | 2010-2011 | Gulf of Mexico      | 112                  | 7                                             | 29 ± 21                                    | 3401                                          |
trans-equatorial migrants have to refuel for longer periods [69–71], however, wind-driven flyways in the Gulf of Mexico and Atlantic Ocean seem to shift most migratory birds farther west in spring, not east [49, 72], thus this relationship merits further study. Given the expectations for increased variability or occurrence in strong storms and hurricanes in the North Atlantic [73, 74] and the accompanying strong winds which greatly influence seabird movement routes and energetic costs [75, 76], Arctic-breeding herring gulls using the southern coastal migration route may experience more storm events that could influence migratory patterns in the future. At the same time, if sea ice in Hudson Bay continues to break up earlier than in the past, we should expect herring gulls to respond by arriving earlier at the colony, a pattern observed at a nearby colony of thick-billed murres (Uria lomvia) [77].

Stopover sites also varied between individuals, and included areas throughout northeastern Canada and USA, including the Labrador Sea, Grand Banks and Gulf of Maine. The Labrador Sea is a hotspot for many fish, seabird and marine mammal species [78], including gulls [3, 11, 79–82]. Similarly, both the Grand Banks and Gulf of Maine, with high productivity levels [83, 84] and a variety of fish and invertebrate species [85–89], are large aggregation areas for many seabirds [90–92], including herring gulls [17, 18, 51]. The differences in stopover areas may be partially explained by the flexible foraging behaviour of herring gulls as generalists [18, 20]. Previous reports of this breeding population showed no stopovers in the Labrador Sea and Grand Banks [18], which further emphasizes that this colony exhibits a wide range of individual behaviours, and possibly interannual variation for individuals.

Timing at overwintering and stopover sites also varied considerably; in fact, one gull was already at its wintering grounds when we started the tracking analysis in October. Herring gulls remained at wintering sites for an average of 109 days but wintering duration varied, similar to previous reports of this population and populations in more southern latitudes [17, 93]. However, due to missing data around the equinoxes, the duration of overwintering in our study is likely an underestimate. Stopovers also varied in length, but overall, herring gulls spent a relatively short time (mean 15 days for both southbound and northbound migration) at stopovers compared to overwintering sites, similar to more southern herring gull local populations [93]. In contrast, Sabine’s gulls from northeast Greenland spent an average of 45 and 19 days at stopover sites during southbound and northbound migration, respectively [71]. These longer stops of Sabine’s gulls are likely because trans-equatorial migrants have to refuel for longer periods to increase energetic stores for migration to more southern overwintering locations than those of the herring gulls. Indeed, Sabine’s gulls migrated an average of 32,000 km total during the non-breeding period [71], whereas herring gulls in our study migrated an average of 9,000 km. Note that the migration distances in our study are likely an underestimate due to the data gap around the equinoxes; previous studies of this population estimate that herring gulls travel an average of 7361 km during southbound migration alone [18], compared to 4833 km in our study. Still, these distances are much less than that of trans-equatorial migrants such as Sabine’s gulls. Future research using higher resolution tracking devices, such as Global Positioning System (GPS) tags, would allow us to analyze migration timing and distances in more detail.

Overall, this inter-individual variation during migration, but relatively similar overwintering distribution, was expected based on previous findings from this population [17, 18] and the ability of herring gulls to exploit a variety of habitats during migration as a generalist species. This behaviour has also been reported in lesser black-backed gulls (Larus fuscus) from the Netherlands, where gulls used multiple migration routes but largely overwinter in the same region in Spain [94]. Interestingly, another similar-sized, Arctic-breeding generalist gull, the Thayer’s gull, appears to use the opposite strategy; gulls tracked from the Canadian Arctic took similar routes on southbound migration but overwintered in different areas [15]. These contrasting strategies may impact these species in different ways in the face of a changing climate. For example, the strong inter-individual variation observed in herring gulls migrating to and from East Bay may benefit these gulls if prey abundance dramatically decreases in one stopover area, because only a portion of the overall colony would be affected.

Importantly, because gulls from East Bay migrate to the same overwintering grounds (i.e., the Gulf of Mexico), they may be more vulnerable to climate change impacts than Thayer’s gulls that overwinter in different regions. Indeed, in addition to the predicted increases in severe weather events along migration routes in the North Atlantic [73, 74], the Gulf of Mexico is predicted to experience increases in severe weather events and ocean temperatures [95] which can cause declines in fish and invertebrate populations [96, 97]. Moreover, an increase in storm frequency and intensity can increase the risk of oil spills [98], making herring gulls that overwinter in this region vulnerable to a variety of climate change impacts. In contrast, in the Great Lakes region, productivity is expected to increase as snow and ice cover decrease [62, 63] and we know at least some of the East Bay herring gulls winter in
this area. Thus, this region may become a more important overwintering location for Arctic-breeding gulls. Moreover, as herring gulls from East Bay spend the nonbreeding season in marine, freshwater and anthropogenic habitats [17], individuals may also be able to more easily adapt to new environments or exploit alternative food sources, such as fishing vessels [56–58] or other anthropogenic sources [19].

5 Conclusions

This research provides new insights on individual variation in herring gull migration from the Canadian Arctic. Herring gulls breeding at East Bay, Nunavut differed in their migration strategies, but largely overwintered in similar locations. This research shows that herring gulls, as an opportunistic species, are diverse in their migration strategies and make use of a suite of regions, but also highlights the importance of the Gulf of Mexico as a wintering area. Consequently, these Arctic-breeding gulls may be less susceptible to climate change impacts during migration compared to more specialized Arctic seabirds, but may be more susceptible during overwintering as most gulls overwinter in the same region. This provides a unique opportunity to monitor how this generalist species will shift its migratory behaviour in the face of climate change. Future, multiyear studies [14] are recommended to better understand year-to-year variation and climate change impacts on the migratory behaviours of this Arctic-breeding seabird.

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