FORAGING BEHAVIOUR OF GREAT BLACK-BACKED GULLS *LARUS MARINUS* NEAR AN URBAN CENTRE IN ATLANTIC CANADA: EVIDENCE OF INDIVIDUAL SPECIALIZATION FROM GPS TRACKING

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Received 19 June 2017, accepted 15 November 2017

ABSTRACT

MAYNARD, L.D. & RONCONI, R.A. 2018. Foraging behaviour of Great Black-blacked Gulls *Larus marinus* near an urban centre in Atlantic Canada: evidence of individual specialization from GPS tracking. *Marine Ornithology* 46: 27–32.

Researchers studying the feeding behaviour of large Laridae have focused primarily on dietary reconstructions and behavioural observations on feeding grounds, but little is known about individual-level foraging habits. The recent development of GPS tracking technologies has allowed new ways to quantify individual-level foraging behaviour. We provide the first known tracking data of Great Black-backed Gull *Larus marinus* using GPS devices deployed on three incubating adults on Devil's Island in Nova Scotia, Canada. Distance travelled and maximum foraging trip distance from the nest differed among individuals, and individuals showed differences in preference for habitat use. One individual visited coastal environments during 81% of its foraging trips, whereas the second visited urban areas during 71% of its foraging trips. The third individual did not display strong preference for any habitat relative to the other individuals but was the only tracked individual visiting salt marshes (24% of its trips). Calculation of core foraging/roosting area (50% utilization) using kernel density estimators also revealed different degrees of consistency in visited habitat and diversity of locations used among individuals. This study, although limited in sample size, suggests presence of variation in foraging behaviour among individuals. While dietary studies have presented Great Black-backed Gulls as generalists at the population level, telemetry data may reveal strong behavioural and habitat specialization at the individual level.

Key words: Great Black-backed Gull, *Larus marinus*, foraging ecology, individual specialization, GPS-tracking devices

RÉSUMÉ

Les précédentes études du comportement alimentaire des goélands sont principalement basées sur le régime alimentaire et le comportement observé aux sites d'alimentation. Cependant, peu d'informations sur le comportement au niveau individuel est connu à ce jour. Le récent développement de systèmes de localisation GPS a permis d'accéder à de nouvelles façons de quantifier ce comportement. La présente étude révèle les premiers résultats de suivi par GPS de trois Goélands marins *Larus marinus* nichant sur Devil's Island en Nouvelle-Écosse, Canada. La distance parcourue et la distance maximale du nid des trajets hors-colonie sont significativement différentes entre les individus et chaque individu présente différent degré de préférence dans les habitats visités. Un des individus a visité les habitats côtiers dans 81% de ses trajets hors-colonie, alors qu'un deuxième a visité les habitats urbains dans 71% de ses trajets. Le troisième individu ne présente pas de préférence évidente pour un habitat comme les autres individus mais est le seul individu à avoir visité des marais salés (24% des trajets) au cours de l'étude. En utilisant des estimateurs à noyau de la densité, la variation des aires des sites principaux d'alimentation calculés (50% d'utilisation) entre les individus démontrent les différents niveaux d'habitude des individus à fréquenter certains sites et types d'habitats. Malgré la taille d'échantillonnage réduite, cette étude suggère la présence de variations de l'écologie alimentaire attribuables à l'individu. Alors que les études basées sur le régime alimentaire ont présenté le Goéland marin comme une espèce généraliste au niveau de la population, les données télémétriques révèlent une forte spécialisation du comportement et de l'habitat au niveau de l'individu.

INTRODUCTION

Foraging ecology of large Laridae has been studied for decades. However, early studies were primarily focused on dietary reconstructions (Goethe 1958, Harris 1965) and behavioural observations from breeding or feeding grounds (Spaans 1971, Hunt & Hunt 1973, Davis 1975). These methods do not provide information about individual spatial use and movements; thus, much less is known about individual-level foraging habits of gulls (Caron-Beaudoin *et al.* 2013, Rock *et al.* 2016). This is particularly true for the North Atlantic's largest Larid, the Great Black-backed Gull *Larus marinus*. Understanding Great Black-backed Gull diet and foraging ecology is important particularly in the context of predation by gulls on other seabird species (Mawhinney & Diamond 1999a, Stenhouse & Montevecchi 1999, Veitch *et al*. 2016).

Bolnick *et al.* (2003) define a specialist as an individual having a narrower niche than its population that is not a consequence of sex, age, or a morphological group-based variation. While dietary studies have presented Great Black-backed Gulls as generalists at the population level (Good 1998), telemetry data may reveal strong behavioural and habitat specialization at the individual level. Feeding specialization is a known characteristic of some gull species (McCleery & Sibly 1986, Spear 1993, Bustnes *et al.* 2001), and could result in high individual variation of foraging behaviour within a population (Masello *et al.* 2013, Patenaude-Monette *et al.* 2014, Isaksson *et al.* 2016, Rock *et al.* 2016, Juvaste *et al.* 2017). Observations made from dietary studies also show variation and individual preference within and among Great Black-backed Gull colonies (Good 1998, Ronconi *et al.* 2014).

The recent development of GPS tracking technologies has allowed researchers to obtain new information on individual-level foraging behaviour. Precise data on foraging trip distance, duration, and habitat use are now easily retrievable. Some *Larus* species have already been host to these devices (Shamoun-Baranes *et al*. 2011, Caron-Beaudoin *et al.* 2013, Bécares *et al.* 2015, Rock *et al*. 2016). We provide the first known tracking data for Great Black-backed Gulls. The goal of this study was to investigate individual specialization among nesting Great Black-backed Gulls.

STUDY AREA AND METHODS

GPS tracking devices (Harrier-M, 16 g, 58 × 27 × 28 mm; Ecotone, Poland) were deployed on three incubating adult Great Black-backed Gulls on Devil's Island (44°34′52″N, 63°27′32″W), Nova Scotia, on 13 May 2016. Birds were tagged under Canadian Bird Banding Permit #10851, and the project received animal care committee certification (#16RR01) through the Wildlife Eastern Animal Care Committee, Environment and Climate Change

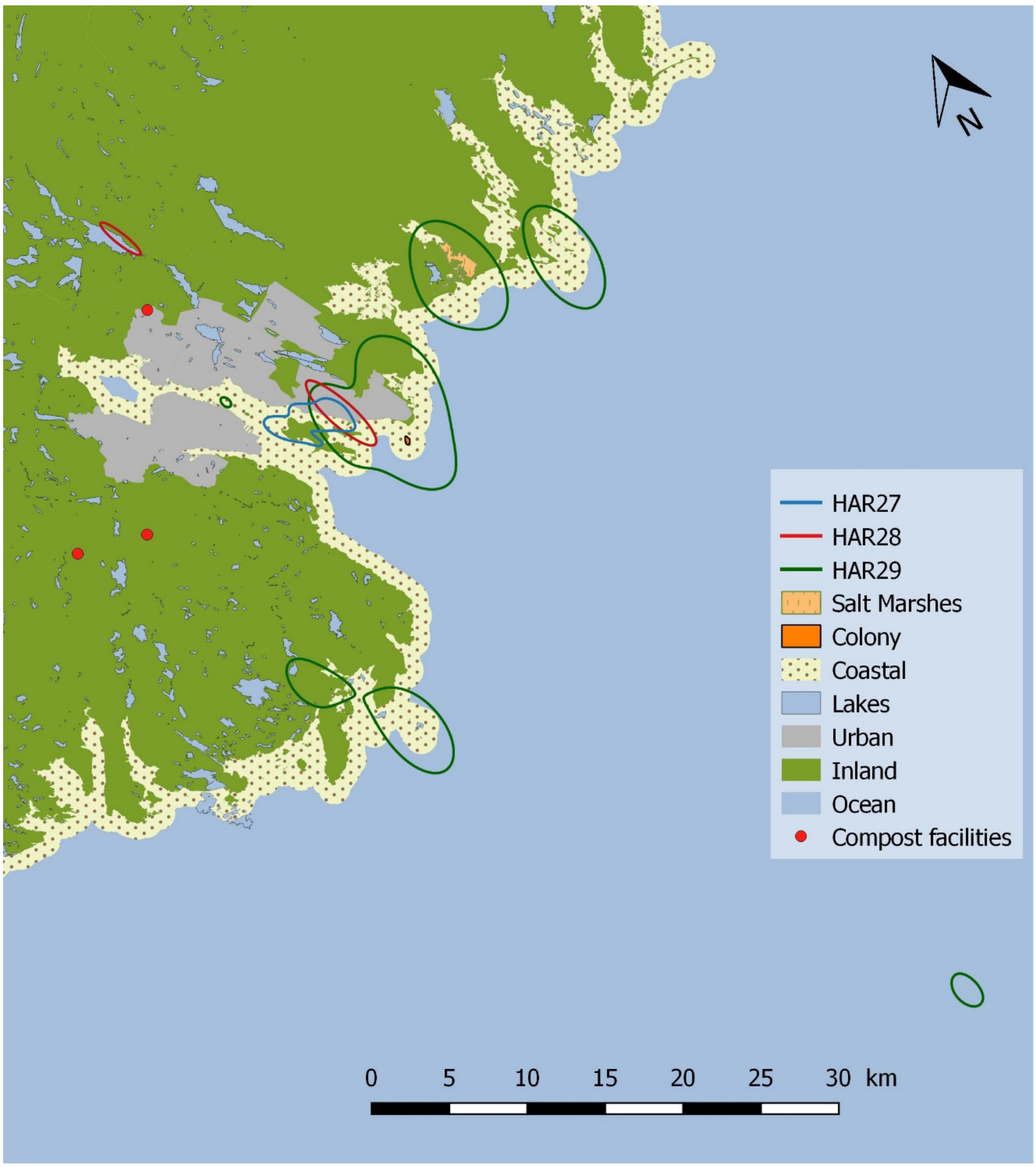

Fig. 1. Core foraging and roosting areas identified by kernel density utilization distribution (50% contours) for three individual Great Black-backed Gulls (HAR27, HAR28, and HAR29) monitored during 11–77 d of the breeding season.

Canada. Devil's Island hosts a colony of 176 pairs of Great Black-backed Gulls and 716 pairs of Herring Gulls *Larus argentatus* (Canadian Wildlife Service, unpubl. data). The colony is located approximately 2 km from the nearest urban areas, 1.5 km from the mainland, 18 km from each of two compost facilities, and 22 km from the nearest landfill (Fig. 1).

Solar-powered tags were programmed to record locations every 15 min and transmit data to a base station located approximately 100 m from the nest sites. The base station malfunctioned after 11 d; thus, only the first 11 d of tracking data are available for one individual (HAR28). Deployment of the base station during the following year fortunately allowed us to collect data for the whole breeding season (13 May–29 July 2016) from the other two individuals. Tags were attached with a Teflon ribbon leg-loop harness, as used by Mallory & Gilbert (2008); a similar crossover wing harness used on gulls showed no effects on breeding productivity or overwinter return rates (Thaxter *et al.* 2016). Sex was estimated using a discriminant function (Mawhinney & Diamond 1999b), which has a >90% accuracy for populations in Atlantic Canada (Robertson *et al.* 2016). Birds were captured with drop traps over nests. The nest of the first captured gull (tag ID HAR27) was depredated during the tagging procedure. At subsequent captures, the drop trap was left over the nest until the tag attachment was complete and the bird was released; no further depredation was observed.

Immediately after the tagging, we collected regurgitated pellets from within ~2 m of nest bowls (Steenweg *et al.* 2011) of tagged birds and other nearby nests. Each pellet was considered a "meal" and was dissected in the laboratory to determine contents to the lowest taxonomic level possible. Proportion of prey types in the diet, at the population level, is reported as frequency of occurrence (%FO) by enumerating the number of pellets containing the prey item divided by the total number of pellets. Thus, cumulative total %FO may exceed 100 when pellets contain more than one prey type.

Data analysis

An intersect function (ArcGIS 10.3.10) was used to discriminate the points recorded at the colony, the different foraging trips, and associated habitat types. Polygons for corresponding habitat types (Fig. 1; salt marshes, marine, urban, and freshwater lakes) and Devil's Island (colony) were created using information from base layer maps (open.canada.ca) and open-source polygons (openstreetmap.org). Coastal habitat was defined as a buffer zone of 1 km offshore from the coastal line (Fig. 1). In accordance with Isaksson *et al.* (2016), a foraging trip was defined as any trip outside the colony for a duration of two or more hours, thus containing at least eight points. Trip length, duration, and maximum distance from nest were calculated for each trip using packages *doBy* (Højsgaard & Halekoh 2016) and *argosfilter* (Freitas 2012) in program R. Using points within the polygon of the island (colony), colony attendance was calculated using the time difference between first and last point at the colony between foraging trips. Mean attendance per day (from 00h00 to 23h59) was then calculated for each bird. The number of trips outside the colony per day was also calculated for each individual.

The tags also recorded gull speed during each location acquisition, from which behaviour could be inferred. For further analysis concerning habitat use during foraging or roosting periods, we omitted points during transits, i.e., those having a speed >4 km/h, which we considered to be flying/travelling (Shamoun-Baranes *et al.* 2011). Considering the ecology of gulls and lack of prior information, discrimination between foraging and roosting could not be performed, and thus results were considered a mix of both behaviours. Proportion of trips visiting each habitat type was calculated for each individual (i.e., number of trips to the habitat divided by total number of trips). Analysis of variance was performed to compare trip parameters between individuals; parameters included trip length, maximum distance from nest, trip duration, number of trips outside the colony per day, and duration of colony attendance per day. In case of significant differences, Tukey tests were performed to compare among individuals. Finally, kernel density using all recorded points outside the colony was calculated for each bird separately using the Geospatial Modelling Environment module with ArcGIS. From these data, the 50% contour was calculated, which represents the core foraging areas used by a given bird (Magalhães *et al.* 2008, Soanes *et al.* 2013).

RESULTS

Diet

On 13 May 2016, 31 pellets were collected around nests, including nests of tracked individuals. Frequency of occurrence (%FO) for each prey type was 58% for crab, 21% for fish (mostly smaller species based on vertebrae size), 19% for mussel, 10% for mammal (containing fur and/or bones), and 10% for other birds (containing

TABLE 1
Comparison of foraging trip parameters among individual Great Black-backed Gulls (HAR27, HAR28, HAR29) [a]

	HAR27			HAR28			HAR29			*P*
	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	
Foraging trip length (km)	30.0	29.7	7.1–132.0	32.4	21.3	7.8–57.7	61.5	56.7	0.1–221.0	<0.001
Max distance from nest (km)	12.4	12.2	5.0–60.1	16.8	11	5.0–28.6	25.8	20.4	0.1–73.0	<0.001
Foraging trip duration (h)	7.5	7.6	2.0–39.3	3.8	1.1	2.4–5.7	6.8	4.8	1.8–27.8	NS
Number of trips per day	1.1	1.2	0–2	2.1	1.0	1–4	1.2	0.7	0–2	NS
Attendance per day (h)	14.9	2.8	7.7–18.9	17.8	2.7	11.0–20.6	15.5	3.7	4.6–23.7	NS
Number of foraging trips	57			7			76			

[a] *P* values indicate the statistical significance of analysis of variance test among individuals; NS = not significant, SD = standard deviation.

feathers only). One pellet (3%) contained plastics. As much as 23% of the pellets contained two prey types (e.g., fish and mussel, crab, and mammal).

Foraging trips

Three birds were tracked for a total of 165 bird-tracking days (77 d for each of HAR27 and HAR29, 11 d for HAR28) resulting in a total of 10 602 GPS locations. Discriminant function of morphometric measurements determined all birds to be putative males, with HAR27 being the smallest (1 680 g) relative to HAR28 (2 000 g) and HAR29 (1 970 g). On the basis of weight, tags weighed <1% of body mass of the gulls.

Excluding locations associated with colony attendance, 22.9% of locations were "inland" from the shoreline, 42.0% were over the ocean but within 1 km of shore, and the remainder were out to a maximum of 66.6 km from shore.

Mean foraging trip length and maximum distance differed significantly among individuals, but trip duration and number of trips per day did not (Table 1). Tukey tests indicated that HAR27 and HAR29 were different from each other for both parameters, and HAR28 was similar to both of the other individuals. HAR27 showed the lowest average trip length and maximum distance from nest, nearly half of what was observed for HAR29. Colony attendance did not differ significantly among individuals (Table 1).

Kernel density estimators identified 10 core foraging/roosting sites for the three tracked birds (Fig. 1). The areas overlapped with coastal areas (three birds), urban areas (three birds), salt marshes (one bird), marine (one bird), and freshwater lakes (two birds). HAR27 only had one core site, HAR28 had two, and HAR29 had seven, suggesting a varying degree of consistency in locations visited. Ellipses overlap among individuals in an urban area near the colony (~7 km).

Habitat use

Proportion of trips per individual, overlaid with habitat types, showed clear differences in habitat use among individuals (Fig. 2). While all three individuals visited coastal areas regularly, particularly HAR27 (80.7% of trips) and HAR29 (68.4%), urban areas showed high visitation by two individuals (HAR28 71.4% and HAR27 73.6%), and lakes were frequented mainly by one individual (HAR28 57.1%). Urban areas visited by the three birds included wharfs and one industrial site where birds appeared to be roosting on the tanks at an oil refinery and, possibly, foraging in adjacent fields. Marine and salt marsh habitats were visited mainly by one individual, HAR29 during 51.3% and 24% of trips, respectively. These results indicate preferences for habitat types among individuals.

DISCUSSION

Information on colony attendance is not abundant in the literature for Great Black-backed Gulls. Mean colony attendance per day during incubation recorded at one colony was 18.9 h (ranging 14.3–21.4 h for three birds; Cavanagh, unpubl. data in Good 1998). Studies from other gull species report colony attendance for approximately 50% of daytime hours (Belant & Seamans 1993, Bécares *et al.* 2015, Juvaste *et al.* 2017). Our study showed similar values for colony attendance, although HAR27 was known to have lost its clutch during handling. This indicates that this individual either attempted to breed again or displayed territorial behaviour throughout the breeding season. Differences in attendance may also occur upon hatching (Butler & Janes-Butler 1983). Breeding status was not monitored; thus, foraging trip parameters reported in this study should also be treated with caution, as they may not reflect the behaviour of nesting birds.

Foraging trip characteristics showed differences in comparison with other studies of large gulls. Cavanagh (unpubl. data, in Good 1998) reported a mean trip duration of 1.7 h (ranging 1.0–2.2 h for three birds) for Great Black-backed Gulls. In this study, the average trip duration was higher, possibly because food sources were further away or took longer to capture. Comparisons with other species showed both similarities and dissimilarities in trip duration. Mean trip duration was similar to values found for Lesser Black-backed Gull *Larus fuscus* (ranging 4.8–7.9 h; Shamoun-Baranes *et al.* 2011, Camphuysen *et al.* 2015, Isaksson *et al.* 2016), although Herring and Ring-billed gulls *Larus delawarensis* showed lower average trip duration, ranging 0.67–2.5 h (Hunt 1972, Bukacinska *et al.* 1996, Patenaude-Monette *et al.* 2014). Number of trips per day was similar to values for other species. Maximum distance from nest was lower than reported values for Lesser Black-backed Gull, ranging 22.3–35.4 km (Camphuysen *et al.* 2015, Isaksson *et al.* 2016, Juvaste *et al.* 2017), but similar to Herring Gull (10-86 km; Rock *et al.* 2016) and Ring-billed Gull (12.5 km; Patenaude-Monette *et al.* 2014). However, both of the latter two studies took place near urban centres, whereas the Lesser Black-backed Gull studies did not. Our results indicate that Great Black-backed Gull trips were slightly longer in duration but shorter in distance than those of other similarly sized gulls. Further understanding of factors influencing individual trips would require more individuals sampled across additional study sites and habitat types.

Regardless of the high variation in habitat use, all three individuals mainly used onshore habitats (Figs. 1, 2). The pellets collected from this colony support this finding, with most identified prey being coastal in nature (crabs and mussel, 77% combined) compared with fish (21%), which may have been scavenged from coastlines or captured offshore. Investigating Great Black-backed Gull diet,

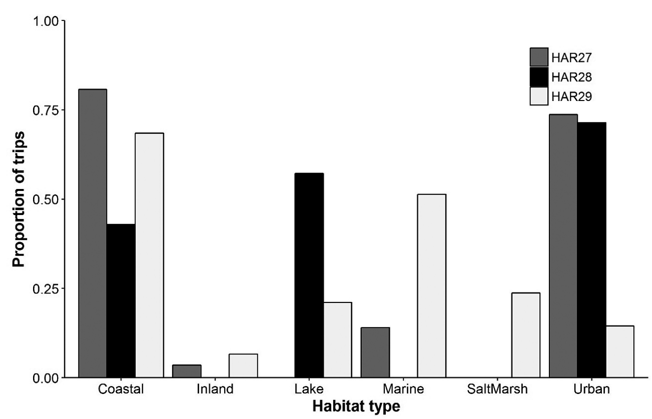

Fig. 2. Proportion of trips to different habitat types (coastal, urban, marine, lake, inland and salt marsh), for each individual Great Black-backed Gull (HAR27, HAR28, and HAR29). Total percentage per individual may exceed 100% when gulls visit multiple habitat types on a single trip.

Farmer & Leonard (2011) and Ronconi *et al.* (2014) found a decreased reliance on fish in recent years compared with historical data. Whereas fish is considered the most nutritious prey for gulls (Pierotti & Annett 1987, Good 1998), decreases in industrial fishing activities and reduction of fish stocks is believed to have induced a behavioural shift toward other prey items (Regehr & Montevecchi 1997, Massaro *et al.* 2000). Proximity to urban areas might also influence habitat preference, as gull species are known to become accustomed to urban food sources (Davis 1975). However, the birds we tracked used the urban area to different extents, and none foraged at waste facilities. Our sample size is low, and it is possible that we chose individuals that select terrestrial environments over offshore. A larger sample size will be required to make generalizations about this population or species.

The strong differences found in core foraging/roosting area and habitat use also indicate specialization of individuals. This is consistent with recent studies of Great Black-backed Gull diet that showed wide variation in stable isotope values among individuals within a generalist population (Ronconi *et al.* 2014). Our data indicate different degrees of specialization within the population. In addition, the wide extent of habitat types found supports the longstanding view of Great Black-backed Gulls as generalists at the population level.

The issues of small sample size and unbalanced data in this study necessitate caution in drawing conclusions. Further investigations are needed to more precisely estimate and understand the population- and individual-level variability in foraging trip parameters and habitat selection. Individual variation in foraging behaviours of gulls may also be influenced by sex (Butler & Janes-Butler 1983) and morphology (Camphuysen *et al.* 2015), neither of which are addressed in this study. Regardless, this study indicates that GPS technology can shed light on unanswered questions about the foraging behaviour of large gulls. Future studies should consider the effect of the individual and should conduct further analysis of behaviour during other periods of the annual cycle.

ACKNOWLEDGMENTS

Funding was provided by Environment and Climate Change Canada's Atlantic Ecosystem Initiative grant to Bird Studies Canada. Fieldwork was executed with logistical support from the Canadian Wildlife Service; we thank Andrew Boyne and Carina Gjerdrum for their help in the field. Laurie Maynard was supported by a Manitoba Graduate Fellowship from the University of Manitoba during the analysis and manuscript drafting of this work. This manuscript was improved by comments from two anonymous reviewers.

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