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Fidelity and Persistence of Ring-billed (*Larus delawarensis*) and Herring (*Larus argentatus*) Gulls to Wintering Sites

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Abstract.—While the breeding ecology of gulls (Laridae) has been well studied, their movements and spatial organization during the non-breeding season is poorly understood. The seasonal movements, winter-site fidelity, and site persistence of Ring-billed (*Larus delawarensis*) and Herring (*L. argentatus*) gulls to wintering areas were studied from 2008-2012. Satellite transmitters were deployed on Ring-billed Gulls (n = 21) and Herring Gulls (n = 14). Ten Ring-billed and six Herring gulls were tracked over multiple winters and > 300 wing-tagged Ring-billed Gulls were followed to determine winter-site fidelity and persistence. Home range overlap for individuals between years ranged between 0-1.0 (95% minimum convex polygon) and 0.31-0.79 (kernel utilization distributions). Ring-billed and Herring gulls remained at local wintering sites during the non-breeding season from 20-167 days and 74-161 days, respectively. The probability of a tagged Ring-billed Gull returning to the same site in subsequent winters was high; conversely, there was a low probability of a Ring-billed Gull returning to a different site. Ring-billed and Herring gulls exhibited high winter-site fidelity, but exhibited variable site persistence during the winter season, leading to a high probability of encountering the same individuals in subsequent winters. *Received 5 June 2014, accepted 28 August 2015.*

Key words.—fidelity, Herring Gull, *Larus argentatus*, *Larus delawarensis*, Massachusetts, Ring-billed Gull, winter.

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Philopatry is the return of an individual to its birthplace for reproduction and is directly related to population structure and gene flow (James 1995). Philopatric behavior can lead to a reduction in gene flow among groups of individuals that are breeding in geographically distinct locations (Stiebens *et al.* 2013). Although philopatry is specifically related to reproduction and has quantifiable genetic and evolutionary consequences, some ornithological literature expands the definition of philopatry to include all types of site faithful behavior including site fidelity to wintering areas, migratory stopover sights, and molting areas (Robertson and Cooke 1999; Mehl *et al.* 2004). However, these other types of fidelity should not be considered philopatry and should only be used to describe site specific attributes (i.e., winter-site fidelity, breeding-site fidelity) (Pearce 2007). Site faithful behavior has been documented in a diversity of avian species, and being site faithful during the breeding or non-breeding season can have a variety of ecological and evolutionary influences on bird populations.

Seasonal movements and site fidelity can influence an individual's ability to find a suitable breeding colony or mate, or take advantage of seasonally and spatially predictable food resources (Foote *et al.* 2010). A variety of research has studied the site faithful behavior of gulls during the breeding season (Southern and Southern 1985; Kinkel 1989; Smith *et al.* 1992). In contrast, little is known about the site fidelity of gulls during the non-breeding season. Spaans (2000) studied winter-site fidelity of Black-headed Gulls (*Larus ridibundus*) in The Netherlands and documented average return rates to the study site of 59%. However, other studies during the non-breeding season have relied on band returns from dead and recovered gulls to document movements (Southern 1974; Gabrey 1996). While the use of band returns is helpful to show the non-breeding season distribution, these limited data do not provide insight into site fidelity, inter-year movements, or persistence at a wintering area. Because conditions during the non-breeding season (i.e., low temperatures, limited food) may limit populations, returning to the same non-breeding area each year may provide an evolutionary advantage through increased familiarity with local food resources and roosting areas, or predator avoidance (Somershoe *et al.* 2009). Winter-site fidelity has been documented in other birds, including Eurasian Teal (*Anas crecca*) and Pink-footed Geese (*Anser brachyrhynchus*) (Fox *et al.* 1994; Guillemain *et al.* 2009).

Ring-billed (*Larus delawarensis*) and Herring (*L. argentatus*) gulls are year-round residents in Massachusetts, but inland populations increase dramatically during the fall and winter. Roosting Ring-billed and Herring gulls choose large inland water bodies in close proximity to their foraging areas (Clark 2014), which can lead to conflict when these roosts are also used for recreation or as water supplies, or are in close proximity to airports (Dewey and Lowney 1997; Nugent and Dillingham 2009; Converse *et al.* 2012). Inland Ring-billed and Herring gulls in Massachusetts often roost on Wachusett and Quabbin Reservoirs, which serve as the unfiltered water supply for over 2 million consumers in the greater Boston area (Clark 2014). Since the early 1990s, a harassment program has been used to exclude Ring-billed and Herring gulls from critical areas of each reservoir (Metropolitan District Commission 1992). Recent efforts have also focused on reducing the amount of anthropogenic food (e.g., landfills, handouts) around each reservoir (Clark *et al.* 2015).

Site fidelity in wintering Ring-billed and Herring gulls can be a critical consideration when developing or implementing harassment and food reduction programs. Our goal was to assess and quantify the winter-site fidelity of Ring-billed and Herring gulls within central Massachusetts. We wanted to determine the likelihood that Ring-billed and Herring gulls roosting on Wachusett and Quabbin Reservoirs, or foraging on nearby anthropogenic food, were the same individuals over successive years. In addition, we were interested in determining how long individual Ring-billed and Herring gulls persisted in the study areas during the non-breeding season, as well as determining if they routinely moved among study areas. Finally, we wanted to assess the extent and duration of Ring-billed and Herring gull movements throughout the non-breeding season to determine if multiple locations were used.

Methods

Study Area

This study was conducted in Massachusetts, USA, from October to April 2008-2012. We captured Ring-billed and Herring gulls at 37 trapping locations in urban or suburban areas around the cities of Worcester (42° 15' N, 71° 48' W) and Springfield (42° 6' N, 72° 35' W) (Fig. 1). A small number (< 20) of Ring-billed and Herring gulls were also captured at four locations in the greater Boston area. Trapping sites were chosen opportunistically based on the presence of gulls and were composed of a variety of locations, including landfills, parking lots, waste water treatment plants, and fresh and saltwater beaches.

Satellite Tracking

We used a Coda net launcher (Coda Enterprises), placed on the ground under the side of a pick-up truck, to capture gulls (Clark *et al.* 2014). A large pile of bait (typically bread, crackers, and/or French fries) was placed 3.0-4.5 m in front of the launcher, and the launcher was detonated from inside the truck's cab (Clark *et al.* 2014). Captured Ring-billed Gulls were fitted with solar powered 9.5-g (Microwave Telemetry) or 9.5-g (Northstar Science and Technology) Argos platform terminal transmitters (PTTs). Herring Gulls were fitted with solar powered 22-g or 30-g GPS transmitters (Microwave Telemetry) or 11.5-g PTTs (Northstar Science and Technology). Transmitters represented < 3% of body mass of the birds and were attached as backpacks with loops around the neck and body. The harness consisted of 6-mm wide tubular Teflon ribbon (Bally Ribbon Mills), braided nylon fishing line as thread, cyanoacrylate adhesive, and a 2.5-cm x 2.5-cm leather breast piece. Attachment was adapted from the procedure described by Snyder *et al.* (1989), but without the feather shield.

GPS-equipped transmitters were programmed to transmit six times per day (mid-morning, noon, mid-afternoon, late afternoon, evening, and night); times shifted slightly seasonally to account for longer days. Argos PTTs were programmed to turn on and transmit for 8 hr each day, then turn off for 18 hr (Argos 2013).

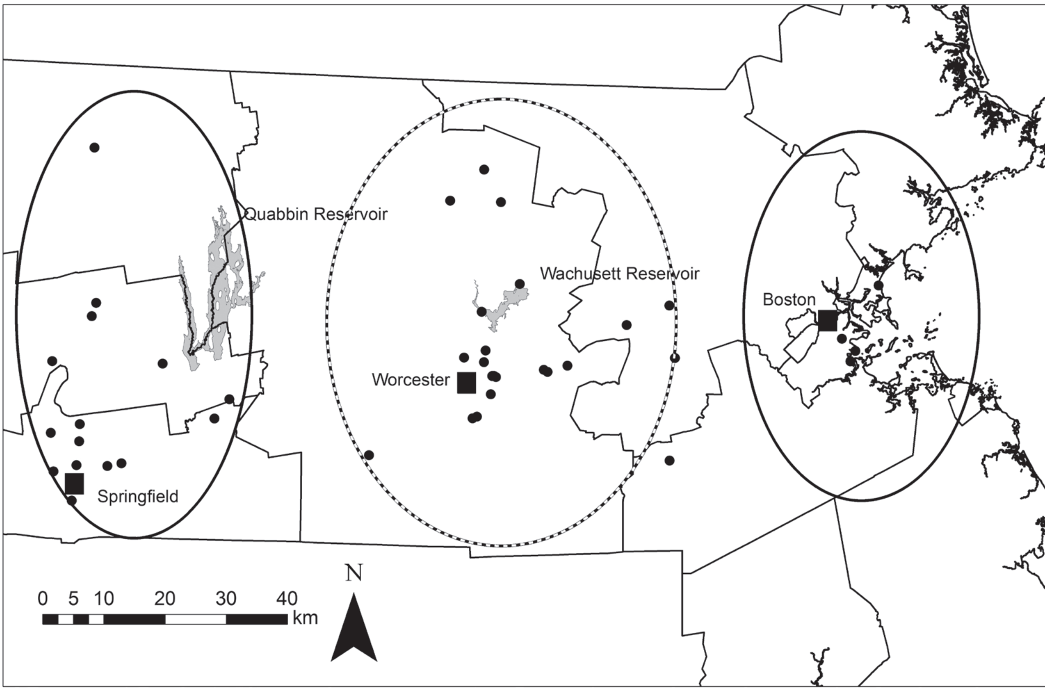

Figure 1. Gull capture locations (●) and general study area in relation to Quabbin and Wachusett Reservoirs and Springfield, Worcester, and Boston (■), Massachusetts.

This 26-hr duty cycle ensured that some transmissions occurred during all possible 24-hr time periods.

PTTs used the Argos system to transmit locations from tagged Ring-billed and Herring gulls via satellite. Each successful transmission was assigned a Location Class (LC) based on the quality of the reception (Argos 2013). Argos classified locations into one of seven classes (Z, B, A, 0, 1, 2, 3 in ascending order of accuracy). While Argos provided an associated accuracy assessment for LCs 0-3, we assessed transmitter accuracy (mean distance between test location and true position) independently in the field before deployment by activating and placing transmitters on a flat roof for ≥ 2 weeks. All locations from these tests were recorded and compared to the actual location. GPS transmitter accuracy was ± 18 m for the 22-g models and ± 30 m for the 30-g models. For PTTs, we used LCs A, 0, 1, 2, and 3. Transmitter accuracy for the 9.5-g Microwave models was ± 5,491 m (A), ± 7,556 m (0), ± 1,890 m (1), ± 1,217 m (2), and ± 354 m (3). Accuracy for the 9.5-g Northstar was ± 2,396 (A), ± 5,625 (0), ± 1,572 m (1), ± 587 m (2), and ± 336 m (3). For 11.5-g transmitters, accuracy was ± 6,015 (A), ± 6,741 (0), ± 1,959 m (1), ± 858 m (2), and ± 218 m (3).

Patagial Tagging

Captured Ring-billed and Herring gulls not fitted with satellite transmitters were marked with patagial tags. Tags were made out of 284-g/m^2 vinyl coated polyester fabric (Seattle Fabrics and Bondcote) treated for ultra-violet stabilization and were color coded based on species and capture location. Sighting probability can be influenced by tag color (e.g., darker colors are less visible to observers), tag retention, or survival (e.g., differential mortality with different color tags) (Seamans *et al.* 2010). We used vibrant or fluorescent colors to increase sighting probability and assumed tag loss was similar among colors. Seamans *et al.* (2010) reported higher resighting rates with orange and yellow tags; we used fluorescent orange, orange, fluorescent yellow, and yellow tags on all Ring-billed Gulls. Although less vibrant colors (e.g., green or blue) were used on Herring Gulls, they were clearly visible against light colored feathers. Wing-tags were 17 x 6 cm for Ring-billed Gulls and 18.5 x 7.5 cm for Herring Gulls and were dumbbell shaped (Southern 1971). Tags were folded in half over the leading edge of the wing, and we used a leather punch to make a small hole through the tag and patagium ~2 cm behind the wing chord. The tag was attached using a 3-mm aluminum washer over a 3-mm x 19-mm aluminum pop rivet, which was pushed through the hole from the underside of the wing. Another 3-mm aluminum washer was placed on top of the exposed pop rivet, and the rivet was compressed (Stiehl 1983). Both wings received wing-tags. The top and bottom sides of each wing-tag were marked with a unique alpha-numeric code using black all-weather cattle tag markers.

Data Analysis

Satellite data. All satellite locations were filtered using ArcGIS 10.0 to only include individuals that were tracked for more than one non-breeding season (i.e., individuals that were tracked for at least 12 months post-capture). Because we were interested in both year-round movement patterns and the spatial organization of Ring-billed and Herring gulls while in Massachusetts, we filtered our data to include all locations and Massachusetts only locations. All Massachusetts locations were plotted in Quantum GIS, and annual 95% minimum convex polygons were drawn using the HomeRange plugin (Mohr 1947; Quantum GIS Development Team 2012). We calculated the proportion of overlap between home range polygons for successive years. An overlap of 0 would indicate no overlap between successive years, while an overlap of 1.0 would indicate 100% overlap between years. In addition, we calculated between year estimates of overlapping habitat use using the kernaloverlap feature of the R package adehabitat (Calenge 2006; R Development Core Team 2012). This package implements the index of overlap between utilization distributions of two animals (or one animal over 2 years) as described by Fieberg and Kochanny (2005). The choice "VI" was used in the calculations to compute the volume of the intersection between the two utilization distributions. The VI index ranges between zero (no overlap) and 1 (ranges with the same utilization distribution) (Fieberg and Kochanny 2005). To quantify site persistence (i.e., how long an individual Ring-billed or Herring gull remained in Massachusetts), the arrival and departure date from Massachusetts was determined for each individual and the average length of stay in Massachusetts was calculated.

For the complete set of Ring-billed and Herring gull locations (i.e., year-round), we assigned locations to one of four movement periods: breeding, post-breeding, wintering, and pre-breeding. Changes in latitude and longitude and time of year were used to identify each period. A period was defined as a group of locations where there was less than a 2° change in longitude or latitude for at least 5 consecutive days. For each Ring-billed and Herring gull, more than one period could be identified (i.e., wintering 1, wintering 2, etc.). Short-term movements (i.e., migratory flights) were not assigned to a specific period. The approximate dates for each movement period were defined for each Ring-billed and Herring gull, the average duration (days) of each period was calculated, and the State or Province for each period was recorded.

Wing-tag resightings. Opportunistic surveys were made throughout central and eastern Massachusetts from 2008-2012 to locate tagged Ring-billed and Herring gulls. We surveyed known or suspected (i.e., locations reported by the public) gull sites at least once per week from September-April each year. In addition, we trapped Ring-billed and Herring gulls throughout central Massachusetts 1-2 days per week during the same period and recorded any tagged Ring-billed or Herring gulls seen during trapping events. In addition, efforts were made to advertise the study (e.g., newspaper articles, website) to the general public, local and regional birding groups, and other gull researchers to encourage people to report sightings. Because Ring-billed and Herring gulls frequently used human dominated habitats (e.g., beaches, parking lots, recreational lakes) and were tagged with brightly colored wing-tags, resightings of individuals within and outside of Massachusetts during the non-breeding season were common. However, we only had a sufficient number of resightings of Ring-billed Gulls to conduct the analyses; Herring Gulls were not included. For each sighting, we recorded the tag color, individual tag number, date, specific location, and general study area (Wachusett, Quabbin, Boston, or other). To determine site persistence of tagged Ring-billed Gulls, we determined the percentage of resightings of tagged individuals seen inside or outside the study area up to 20 weeks post-capture.

In the analysis, we only used sightings obtained from December-January each year to ensure that individuals had reached their wintering area. We used observations of wing-tagged Ring-billed Gulls seen at least twice during December-January to construct a complete history for each individual to calculate transition rates (Ψ) or movement among study areas (Hestbeck *et al.* 1991; Williams *et al.* 2008). The analysis was applied to three independent cohorts (e.g., capture areas) of Ring-billed Gulls for each year (2008-2012). We denoted four regions (movement areas) as A for Wachusett, B for Quabbin, C for Boston and D for any area outside Massachusetts (other). A zero indicated an occasion when an individual was not observed during a sampling period. For example, history A00AA denotes a gull captured and released in 2008 in the Wachusett study area, not seen in 2009 or 2010, and seen again in the Wachusett study area during either December or January in 2011 and 2012. We used the multi-state with recaptures in Program MARK (White and Burnham 1999) to model survival, resighting probabilities (i.e., probability that a Ring-billed Gull present in the study area during any given year is observed), and transition rates (i.e., probability that an individual alive in a certain time period survives to the next period and moves from one study area to another) for each cohort. Our global model contained 20 estimated parameters for 5 years, three rates (survival (S), resighting probability (p), and transition rate (Ψ)), and four wintering areas (g) (Wachusett, Quabbin, Boston and other). We looked at five nested models to evaluate differences related to time-constant vs. time-specific demographic rates, and similarity or differences in demographic parameters among the four wintering sites. To test for overdispersion of the global model, we calculated the variance inflation factor ($\hat{c}$) (Burnham and Anderson 2002). There was evidence of overdispersion ($\hat{c}$ = 4.60), so the quasi-likelihood method, $QAIC_c$, was used (Anderson *et al.* 1994). We used QAIC values, QAIC weights (w_i), and differences in QAIC (Δ_i) to determine the relative support for each model and considered the model with the lowest QAIC to be the most parsimonious model (Burnham and Anderson 2002). Winter site fidelity was determined from transition rates (fidelity = 1.0 – transition probability) using the selected model.

RESULTS

Satellite Data

We deployed 21 satellite transmitters on Ring-billed Gulls and 14 on Herring Gulls. Ten Ring-billed (four male, six unknown) and six Herring (two male, two female, two unknown) gulls provided locations for ≥ 12 months and were used in the analysis. Nine of the 10 Ring-billed Gulls returned to Massachusetts the winter following capture; one Ring-billed Gull traveled to New York, Connecticut, and New Jersey following capture and only returned briefly to Massachusetts 18 months after capture. Four of the six Herring Gulls returned to Massachusetts the year after capture; one Herring Gull left Massachusetts after capture and never returned and another never left Massachusetts.

Ring-billed Gulls arrived in Massachusetts between July and November each year and departed between November and March, although most were gone by December, and only one remained until March (Table 1). Ring-billed Gulls remained in Massachusetts from 20-167 days. Home range overlap of calculated minimum convex polygons was 0.0-1.0, and overlap between kernel utilization distributions ranged between 0.31-0.78 (Table 1). For example, Ring-billed Gull 98663 used very similar areas between successive winters (Fig. 2).

For Ring-billed Gulls, movements that marked the breeding period began in March or April and lasted an average of 110 days (Table 1). Breeding period locations were in Quebec, Ontario, New York, or Vermont. Following the breeding period, most Ring-billed Gulls spent an average of 81 days in their post-breeding location (June-December). These locations ranged from Quebec to Connecticut. Of the nine Ring-billed Gulls that made seasonal movements, seven used more than one wintering area. For example, Ring-billed Gull 87427 used four wintering stops during the two years it was tracked (Fig. 3). The average number of days spent at each wintering area was 58, 54, 24, and 43 for wintering areas 1, 2, 3, and 4, respectively. The pre-breeding period began in March or April and lasted an average of 11 days.

Herring Gulls arrived in Massachusetts between October and December each year and left between March and April (Table 1). Herring Gulls remained in Massachusetts between 74-161 days. Overlap between minimum convex polygons ranged between 0.42-1.00 for successive years, and overlap between kernel utilization distributions ranged between 0.38-0.79 (Table 1). For example, Herring Gull 33073 used very similar areas over four winters in Massachusetts (Fig. 4).

For Herring Gulls, concentrated movements defining the breeding period began in April or May and lasted an average of 168 days (Table 1). All breeding period locations were in the Canadian Maritime Provinces, including Newfoundland, New Brunswick, and Nova Scotia. Following the breeding period, Herring Gulls made one post-breeding stop that lasted an average of 15 days. Herring Gulls used only one wintering area and remained there an average of 119 days. The pre-breeding period lasted from 1-51 days. For example, Herring Gull 33073 used only one wintering area in Massachusetts over four consecutive winters (Fig. 5).

Wing-tag Resightings of Ring-billed Gulls

From 2008-2012, 666 Ring-billed Gulls were tagged and released in the Wachusett study area, and 1,476 resightings were recorded on 427 individuals (64%) during the non-breeding season (November-March). In Quabbin, 322 gulls were tagged during this period, and 500 resightings were recorded on 172 individuals (53%). In Boston, 17 gulls were tagged, and nine individuals were resighted 25 times (53%). For up to 20 weeks post-capture, an increasing percentage of tagged Wachusett gulls was seen outside the study area (Fig. 6). For Quabbin gulls, the trend was less apparent, but a slightly higher percentage of tagged gulls was seen outside the study area up to 20 weeks post-capture (Fig. 6).

We were able to construct complete histories for 240 Ring-billed Gulls from Wachusett, 79 from Quabbin, and four from Bos-

Table 1. Timing, duration, and locations of seasonal movements and home range overlap and persistence to areas in Massachusetts of satellite tagged Herring and Ring-billed Gulls, 2008-2012.

Gull	Movement Stage[a]	Approximate Dates	Duration (days)	Location(s)[b]	No. Days in MA	95% MCP Overlap for MA[c]	Kernel UD overlap for MA[d]
Adult Male	Breeding	Apr-Oct	199	NL			
Herring Gull	Post-Breeding	Nov-Dec	7-33	NH			
	Wintering 1	Dec-Apr	123	MA	123	0.82	0.38
	Pre-breeding	Early Apr	8-10	NH			
Adult Female	Breeding	May-Nov	135-191	NL			
Herring Gull	Post-Breeding	Nov-Dec	10-12	NB, ME, NH			
	Wintering 1	Dec-Mar	74	MA	74	0.96	0.39
	Pre-breeding	Mar-Apr	5-13	NH, ME, NB			
Adult Male	All	Year-round	586	MA	586	0.42	0.98
Herring Gull[e]							
Juvenile	Breeding	Apr-Dec	139-231	NB, NS			
Herring Gull	Post-Breeding	Dec-Jan	5-24	ME, NH			
	Wintering 1	Dec-Apr	87-139	MA, CT, RI	58	0.64-0.98	0.31-0.79
Sub-adult	Breeding	May-Dec	137-231	QU, NB, LA, NL	—	—	—
Herring Gull[f]	Wintering 1	Dec-Apr	119	CT, NY			
	Pre-breeding	Apr-Jun	13-51	NS			
Adult Female	Breeding	Apr-Sep	149-164	NL			
Herring Gull	Post-Breeding	Sep-Oct	5-44	NS			
	Wintering 1	Oct-Apr	151-182	MA, CT, RI	94	0.78-1.00	0.55-0.78
Adult Unknown	Period 1	Year-round	553	NY, NJ, CT			
Ring-billed Gull[g]	Period 2	May-Jun	20	MA	20	0.20	0.31

[a]Locations assigned to these periods based on time of year and constrained geographic movements.

[b]MA: Massachusetts, NY: New York, NJ: New Jersey, PA: Pennsylvania, QU: Quebec, MD: Maryland, VA: Virginia, GA: Georgia, FL: Florida, CT: Connecticut, VT: Vermont, ON: Ontario, SC: South Carolina, NC: North Carolina, ME: Maine, NH: New Hampshire, DE: Delaware, NB: New Brunswick, AL: Alabama, RI: Rhode Island, NS: Nova Scotia, NL: Newfoundland, LA: Labrador.

[c]MCP: 95% minimum convex polygon.

[d]UD: utilization distribution.

[e]Never left Massachusetts after capture and all subsequent movements were confined to a small geographic area.

[f]Never returned to Massachusetts but transmitter continued to function.

[g]Returned briefly to Massachusetts during the early summer 18 months after capture.

Table 1. (Continued) Timing, duration, and locations of seasonal movements and home range overlap and persistence to areas in Massachusetts of satellite tagged Herring and Ring-billed Gulls, 2008-2012.

Gull	Movement Stage[a]	Approximate Dates	Duration (days)	Location(s)[b]	No. Days in MA	95% MCP Overlap for MA[c]	Kernel UD overlap for MA[d]
Adult Unknown	Breeding	Apr-Jul	108	QU			
Ring-billed Gull	Post-Breeding	Jul-Aug	10	QU			
	Wintering 1	Aug-Nov/Dec	136	MA, CT, RI	84	0.84	0.48
	Wintering 2	Nov/Dec-Jan	13-41	NY, NJ, PA			
	Wintering 3	Jan-Feb	23	MD, VA, NC			
	Wintering 4	Feb-Mar	55	PA, NJ, NY, MA			
Adult Unknown	Breeding	Mar-Jul	108	QU			
Ring-billed Gull	Post-Breeding	Jul-Oct	100	ME			
	Wintering 1	Oct-Nov	26	MA	26	0.92	0.59
	Wintering 2	Nov-Dec	30-32	North AL, GA			
	Wintering 3	Dec-Feb	42-53	South AL, GA			
	Wintering 4	Feb-Mar	21-41	North AL, GA			
Adult Unknown	Breeding	Mar/Apr-Jun/Jul	91-94	ON			
Ring-billed Gull	Post-Breeding	Jul-Dec	51-162	MA, CT	94	0.92	0.78
	Wintering 1	Dec-Mar	83	NY, NJ, PA			
	Pre-breeding	Mar	14-16	MA, NY			
Adult Unknown	Breeding	Apr-Oct	169	NY			
Ring-billed Gull	Post-Breeding	Oct-Dec	55	MA, CT	35	0.91	0.40
	Wintering 1	Dec-Mar	91-100	FL			
	Pre-breeding 1	Mar	12-13	GA, SC			
	Pre-breeding 2	Apr	26	PA, DE, NJ			
Sub-adult	Breeding	Mar-Jul/Aug	67-110	QU			
Ring-billed Gull	Post-Breeding	Jul/Aug-Oct	66	ME, NB			
	Wintering 1	Oct-Dec	24	MA	24	0.11	0.37

[a]Locations assigned to these periods based on time of year and constrained geographic movements.

[b]MA: Massachusetts, NY: New York, NJ: New Jersey, PA: Pennsylvania, QU: Quebec, MD: Maryland, VA: Virginia, GA: Georgia, FL: Florida, CT: Connecticut, VT: Vermont, ON: Ontario, SC: South Carolina, NC: North Carolina, ME: Maine, NH: New Hampshire, DE: Delaware, NB: New Brunswick, AL: Alabama, RI: Rhode Island, NS: Nova Scotia, NL: Newfoundland, LA: Labrador.

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Table 1. (Continued) Timing, duration, and locations of seasonal movements and home range overlap and persistence to areas in Massachusetts of satellite tagged Herring and Ring-billed Gulls, 2008-2012.

Gull	Movement Stage[a]	Approximate Dates	Duration (days)	Location(s)[b]	No. Days in MA	95% MCP Overlap for MA[c]	Kernel UD overlap for MA[d]
	Wintering 2	Dec-Feb/Mar	63-75	VA, NC			
	Wintering 3	Feb/Mar-Apr	13-33	PA, NY, CT			
Adult Male	Breeding	Apr-Jul	94	VT, NY			
Ring-billed Gull	Post-Breeding	Jul-Dec	157	MA, NH	138	1.00	0.40
	Wintering 1	Dec-Feb	56	NY			
	Wintering 2	Feb-Apr	50	NJ, DE, MD			
	Pre-breeding	Apr	5	NY			
Adult Male	Breeding	Mar-Jul	110-114	QU, ON, NY			
Ring-billed Gull	Post-Breeding	Jul-Nov	125	NH, ME			
	Wintering 1	Nov-Dec/Jan	40-75	MA, CT	21	0.00-0.40	0.13-0.53
	Wintering 2	Jan-Feb/Mar	12-39	SC, NC, VA			
	Wintering 3	Jan-Feb/Mar	44-67	FL			
	Pre-breeding	Mar	6-17	MD, PA, NY			
Adult Male	Breeding	Apr-Jun	64-77	ON			
Ring-billed Gull	Post-Breeding	Jun-Oct	104	NY, VT			
	Wintering 1	Oct-Dec	54	MA, CT	33	0.83	0.77
	Wintering 2	Dec-Feb	44-81	FL			
	Wintering 3	Feb-Apr	43	VA, MD, NJ			
	Pre-breeding 1	Mar	9	GA, NY			
	Pre-breeding 2	Mar-Apr	28	MD, NJ			
Adult Male	Breeding	Mar-Jul	127-128	QU			
Ring-billed Gull	Post-Breeding	Jul-Oct	67-80	QU			
	Wintering 1	Oct-Dec/Jan	79-108	MA	94	0.85	0.54-0.71
	Wintering 2	Dec/Jan-Mar	7-48	NY, NJ, PA			
	Pre-breeding	Mar	9	MA, NY			

[a]Locations assigned to these periods based on time of year and constrained geographic movements.
[b]MA: Massachusetts, NY: New York, NJ: New Jersey, PA: Pennsylvania, QU: Quebec, MD: Maryland, VA: Virginia, GA: Georgia, FL: Florida, CT: Connecticut, VT: Vermont, ON: Ontario, SC: South Carolina, NC: North Carolina, ME: Maine, NH: New Hampshire, DE: Delaware, NB: New Brunswick, AL: Alabama, RI: Rhode Island, NS: Nova Scotia, NL: Newfoundland, LA: Labrador.
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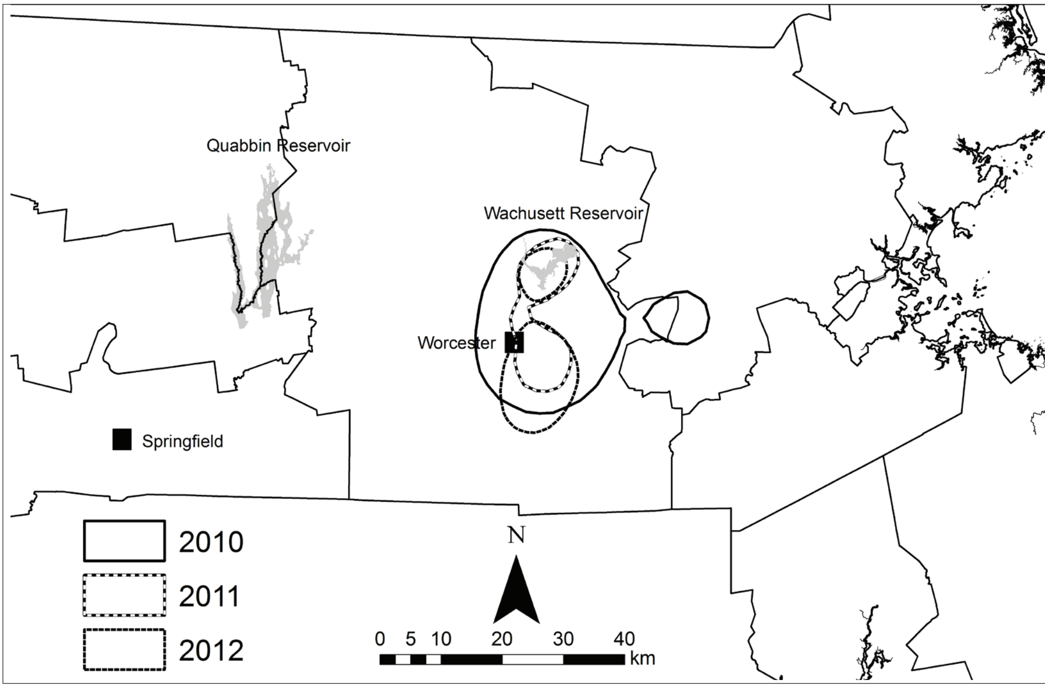

Figure 2. Estimated winter home range for Ring-billed Gull (band # 98663) during 2010-2012. Polygons represent 50th percentile kernel density estimates.

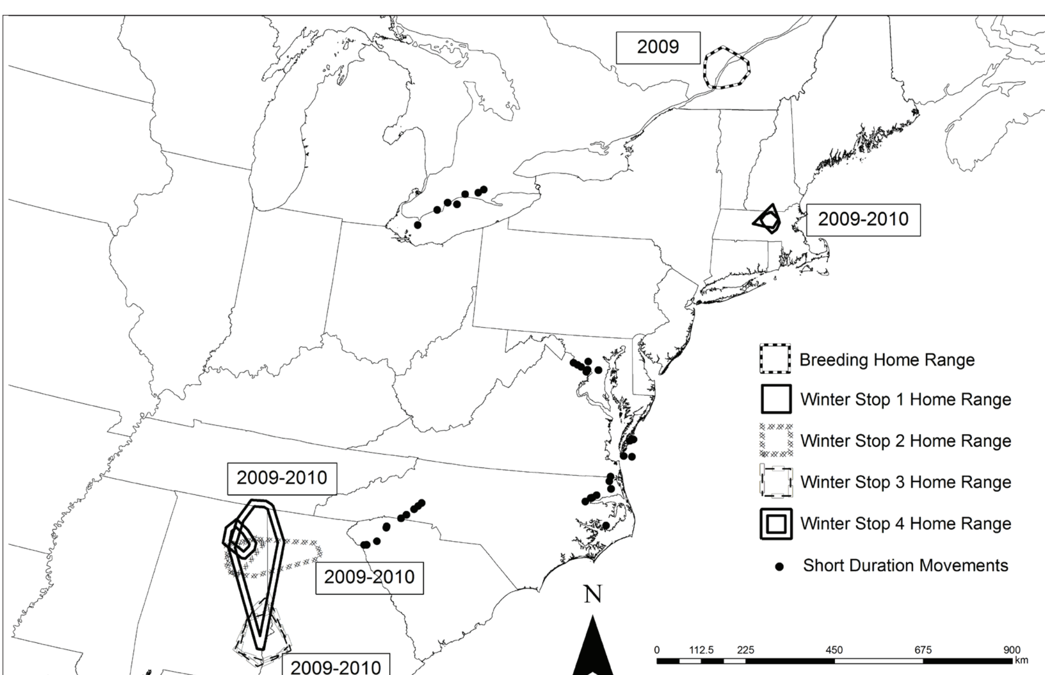

Figure 3. Seasonal movements expressed as 95% minimum convex polygons (for concentrated movements) and individual points (for short duration movements) for satellite tagged Ring-billed Gull (band # 87427) captured in Massachusetts on 29 October 2008. Each polygon represents the home range for a particular year.

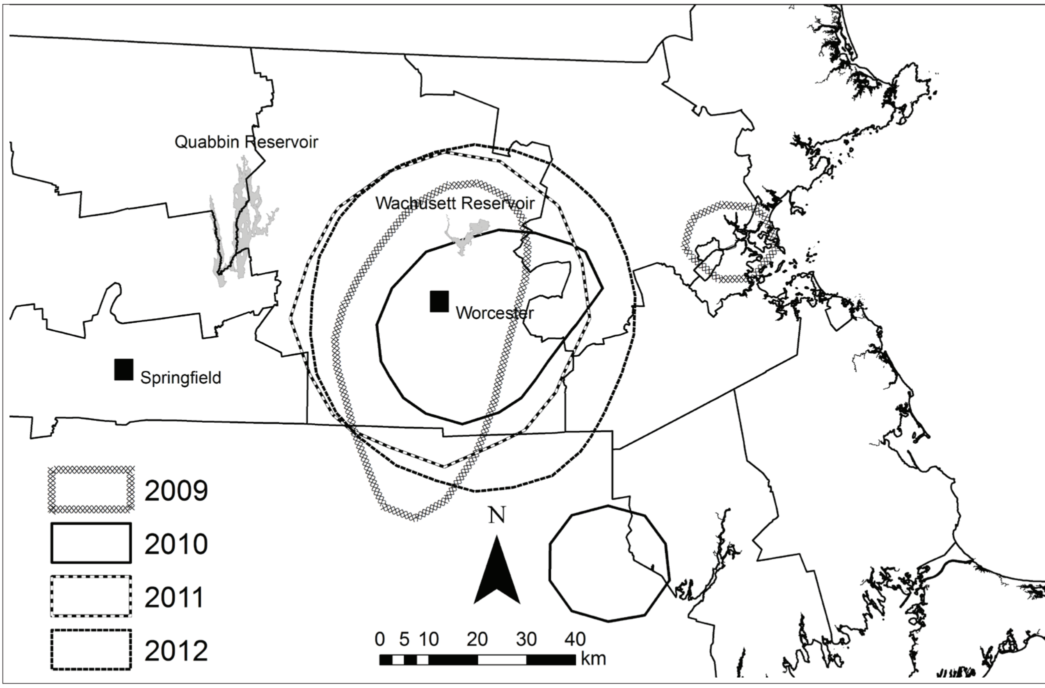

Figure 4. Estimated winter home range for Herring Gull (band # 33073) during 2008-2012. Polygons represent 50th percentile kernel density estimates.

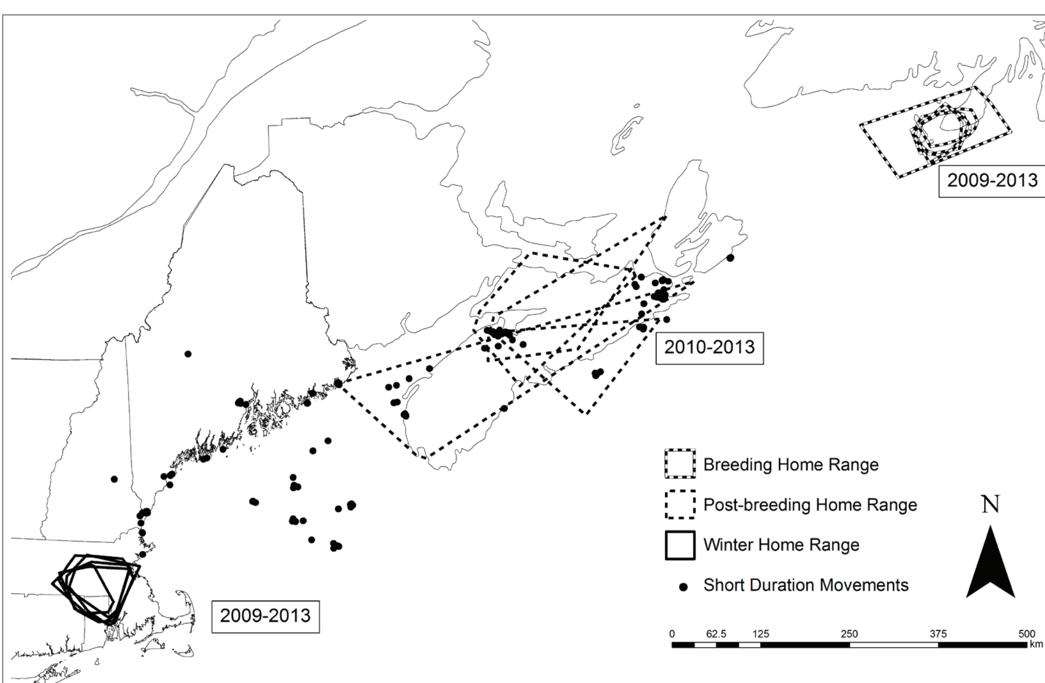

Figure 5. Seasonal movements expressed as 95% minimum convex polygons (for concentrated movements) and individual points (for short duration movements) for satellite tagged Herring Gull (band # 33073) captured in Massachusetts on 5 November 2008. Each polygon represents the home range for a particular year.

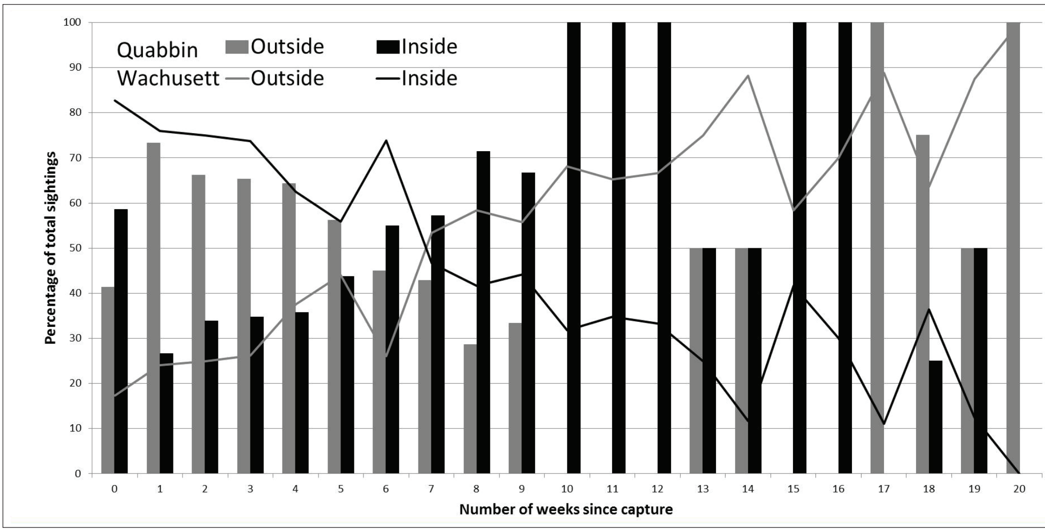

Figure 6. Percentage of wing-tagged Ring-billed Gulls captured in the Wachusett and Quabbin study areas, Massachusetts, seen inside and outside the study area 20 weeks post-capture.

ton. The model identified 96, 15, and three unique sighting histories for gulls captured and released at Wachusett, Quabbin, and Boston, respectively. We evaluated six potential models (including a constant model: {$S(_g) p(_g)\ \Psi(_g)$}; survival, sighting probability, and transition probability constant over time but different among study areas) of yearly apparent survival, resighting, and transition probabilities of Ring-billed Gulls captured and tagged in Wachusett, Quabbin, or Boston. The best model was the general model, and it showed strong support ($\Delta_i = 0$; $w_i = 0.999$) that survival, resighting, and transition probabilities were different among locations but were constant over time (Table 2). High transition probabilities of individual gulls returning to the same site each year were found for all locations (Table 3). Low estimates of movement among study areas were found, although a low estimated rate of movement from Quabbin to Wachusett was detected (Table 4). Overall, only a few (i.e., less than six) individuals originally captured in one of the study areas were seen in a different study area in subsequent years.

DISCUSSION

Our data suggest that during winter Ring-billed and Herring gulls exhibit high site fidelity to specific locations and little movement between spatially distinct areas. Because this is the first study to document winter site fidelity in these species, it is difficult to make meaningful comparisons; however, other studies of winter site fidelity in birds have used a variety of indices as evidence for fidelity. Studies using mark-recapture tech-

Table 2. Models estimating apparent survival (S), transition probabilities (Ψ), and resighting probabilities (p) of Ring-billed Gull groups (g) captured in central Massachusetts, 2008-2012. The quasi-likelihood method ($QAIC_c$), QAI differences (Δ), and AIC model weight (w_i) were calculated for each model. These values were based on the inflation factor of the global model ($\hat{c}$ = 4.60). The lowest $QAIC_c$ value was 271.98. The K parameter included the intercept and $\hat{c}$. The constant model (survival, transition probabilities, and resighting probabilities are constant over time, but are different between study areas) was the only model supported.

Model	Log-likelihood	K	$\Delta QAIC_c$	Weight(w_i)
{$S(_g)p(_g)\Psi(_g)$}	**1078.33**	**18**	**0.00**	**0.99**
{$S(_g)p(_.)\Psi(_g)$}	1121.25	20	13.69	0.001
{$S(_.)p(_.)\Psi(_g)$}	1132.24	20	16.08	0.00

Table 3. Resightings (December-January) of individual gulls within a location between years expressed as transition probabilities (Ψ) (± SE). *n* is the number of individuals identified in each location using wing-tags and/or leg bands.

Area	*n*	Ψ
Wachusett	96	0.864 (0.02)
Quabbin	15	0.972 (67.90)
Boston	3	0.750 (0.22)

niques have concluded that encountering, or capturing, individuals in subsequent winters is evidence for fidelity (Fox *et al.* 1994; Guillemain *et al.* 2009; Somershoe *et al.* 2009; McKinley and Mattox 2010). Studies using transition probabilities have reported fidelity rates of 0.34-0.97 (Williams *et al.* 2008; Foote *et al.* 2010). Our calculated transition probabilities (0.75-0.97) and large home range overlap indices among years (0.31-0.90) suggest that Ring-billed and Herring gulls are extremely site faithful to wintering areas within Massachusetts and throughout their range.

While there is little information on the winter-site fidelity of gulls, breeding-site fidelity in gulls has been identified or implied in a number of studies (Southern 1971; Threlfall 1978; Southern and Southern 1985; Kinkel 1989; Smith *et al.* 1992; Gabrey 1996). Smith *et al.* (1992) reported 69% of wing-tagged Silver Gulls (*L. novaehollandiae*) in New South Wales, Australia, returned to the breeding colony a year after tagging. Kinkel (1989) reported Ring-billed Gull site fidelity to breeding colonies of 62-100% in the year following banding at a colony in Michigan. Stenhouse and Robertson (2005) documented site fidelity of 81-92% for Sabine's Gulls (*Xema sabini*) breeding on Southampton Island in the Canadian Arctic. Gabrey (1996) reported that Ring-billed Gulls were less likely to return to their natal colony than Herring Gulls and suggested that Ring-billed Gulls may have strong fidelity to the lake where they hatched, but not necessarily the colony.

Robertson and Cooke (1999) proposed that individuals return to the same sites each year to take advantage of prior knowledge of the area. This knowledge could include the location of patchy (but potentially predictable) food resources, refugia from predators, locations of conspecifics and suitable roosting sites, or predator movements and habits. Individuals that use this local knowledge may more efficiently avoid predators or exploit food resources, thereby increasing their overwinter survival (Robertson and Cooke 1999). Further, good foraging conditions during the winter have been shown to increase female reproductive success in the subsequent breeding season in geese (Ankney and MacInnes 1978) and other waterfowl (Raveling and Heitmeyer 1989). Ring-billed and Herring gulls returning to the same sites in Massachusetts each winter can take advantage of known roosting locations and predictable food sources. We have documented individual tagged Ring-billed and Herring gulls roosting on Wachusett Reservoir over successive years and also identified individuals in the same parking lots in consecutive years foraging on food provided by people (i.e., handouts of bread and other human-provided food) (D. E. Clark, pers. obs.).

If Ring-billed and Herring gulls were moving through Massachusetts randomly or opportunistically, then efforts to reduce food resources within a defined geographic area would have minimal impact on the number of individuals present, since additional Ring-billed or Herring gulls could arrive at any time and remain for an indefinite period before potentially moving on. Further, harassment programs often rely on conditioning gulls to move away from critical

Table 4. Resightings (December-January) of individual gulls between locations expressed as transition probabilities (Ψ) (± SE). *n* is the number of individuals identified in each location using wing-tags and/or leg bands.

Areai	Area_j	n_i	n_j	n_{ij}	Ψ_{ij}
Wachusett	Quabbin	96	15	2	0.013 (0.09)
Quabbin	Wachusett	15	96	3	0.259 (18.09)
Wachusett	Boston	96	3	6	0.023 (0.01)

areas through repeated harassment efforts (D. E. Clark, pers. obs.). Randomly arriving birds would need to be constantly "trained," decreasing the efficiency and effectiveness of a program. Because Ring-billed and Herring gulls exhibit strong winter site fidelity, efforts to reduce local food sources could potentially impact local wintering Ring-billed and Herring gull populations because the same individuals are returning each year. Site faithful Ring-billed and Herring gulls returning to these anthropogenic food sources would encounter unfavorable conditions and potentially disperse to new areas or adjust their winter movements in subsequent years. It is unlikely that Ring-billed or Herring gulls that were site faithful to other wintering areas where no food reduction was occurring (e.g., other states outside Massachusetts) would leave their winter site and move to Massachusetts.

While satellite tagged Ring-billed and Herring gulls from our study showed high site fidelity, site persistence was variable. Some Ring-billed Gulls only remained in Massachusetts for < 30 days, while others remained for > 160 days. However, in all cases, Ring-billed Gulls did not remain in Massachusetts for the duration of the non-breeding/winter season, and most left Massachusetts by January. In contrast, Herring Gulls exhibited greater site persistence; all remained in Massachusetts ≥ 70 days. Further, Herring Gulls did not use multiple winter locations but instead spent a relatively short time in their post-breeding locations before traveling to their wintering area, where they remained until the following spring.

Ring-billed Gulls leaving Massachusetts during the winter continued moving south; some individuals stopped in New York or New Jersey for the remainder of the winter, while others made several other stops as far south as Florida. Stenhouse *et al.* (2012) tracked Sabine's Gulls through their migration and reported individuals arrived at their autumn staging sites between mid-August and mid-September and stayed for an average of 45 days. These Sabine's Gulls arrived at their wintering sites between October and November and remained there for ~152 days. It is possible that Massachusetts serves as a staging area for migrating Ring-billed Gulls; however, given the range of when Ring-billed Gulls are in Massachusetts (July-January), how long they stay at each wintering area, and their movements before and after stopping in Massachusetts, a more plausible explanation is that Ring-billed Gulls use multiple wintering sites (onward migration), similar to what Mandernack *et al.* (2012) described for wintering Bald Eagles (*Haliaeetus leucocephalus*). In most cases, staging areas are discrete locations used for relatively short periods of time by migrating birds on their way to a specific destination (i.e., breeding or wintering grounds). Tagged Ring-billed Gulls leaving their breeding grounds traveled directly to their post-breeding location, where they remained for a relatively long period of time. For some individuals, Massachusetts was the first stop post-breeding, while others stopped somewhere prior to arriving in Massachusetts. All tagged Ring-billed Gulls left Massachusetts sometime during the winter and continued to move south, making at least one more stop before beginning to move north in the spring. It is likely that competition for food, availability of freshwater roosts (i.e., how much ice cover is present), or changes in food abundance all influence Ring-billed and Herring gull movements during the winter.

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LITERATURE CITED

Anderson, D. R., K. P. Burnham and G. C. White. 1994. AIC model selection in overdispersed capture-recapture data. Ecology 75: 1780-1793.

Ankney, C. D. and C. D. MacInnes. 1978. Nutrient reserves and reproductive performance of female Lesser Snow Geese. Auk 95: 459-471.

Argos. 2013. Argos user's manual. Collecte Localisation Satellites /Argos, Toulouse, France. http://www.argos-system.org, accessed 10 April 2013.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, New York.

Calenge, C. 2006. The package "adehabitat" for the R software: a tool for the analysis of space and habitat use by animals. Ecological Modeling 197: 516-519.

Clark, D. E. 2014. Roosting, site fidelity, and food sources of urban gulls in Massachusetts: implications for protecting public water supplies. Ph.D. Dissertation, University of Massachusetts, Amherst.

Clark, D. E., K. K. G. Koenen, K. G. MacKenzie, J. W. Pereira and S. DeStefano. 2014. Evaluation of a net launcher for capturing urban gulls. Wildlife Society Bulletin 38: 605-610.

Clark, D. E., J. J. Whitney, K. G. MacKenzie, K. K. G. Koenen and S. DeStefano. 2015. Assessing gull abundance and food availability in urban parking lots. Human-Wildlife Interactions 9: 180-190.

Converse, R. R., J. L. Kinzelman, E. A. Sams, E. Hudgens, A. P. Dufour, H. Ryu, J. W. Santo-Domingo, C. A. Kelty, O. C. Shanks, S. D. Siefring and others. 2012. Dramatic improvements in beach water quality following gull removal. Environmental Science and Technology 46: 10206-10213.

Dewey, J. and M. Lowney. 1997. Attempted relocation of a Ring-billed Gull roost at Washington National Airport. Proceedings of the Eastern Wildlife Damage Management Conference 8: 152-157.

Fieberg, J. and C. O. Kochanny. 2005. Quantifying home-range overlap: the importance of the utilization distribution. Journal of Wildlife Management 69: 1346-1359.

Foote, A. D., T. Similä, G. A. Víkingsson and P. T. Stevick. 2010. Movement, site fidelity and connectivity in a top marine predator, the killer whale. Evolutionary Ecology 24: 803-814.

Fox, A. D., C. Mitchell, A. Stewart, J. D. Fletcher, J. V. N. Turner, H. Boyd, P. Shimmings, D. G. Salmon, W. G. Haines and C. Tomlinson. 1994. Winter movements and site-fidelity of Pink-footed geese (*Anser brachyrhynchus*) ringed in Britain, with particular emphasis on those marked in Lancashire. Bird Study 41: 221-234.

Gabrey, S. W. 1996. Migration and dispersal in Great Lakes Ring-billed and Herring Gulls. Journal Field Ornithology 67: 327-339.

Guillemain, M., J. Fuster, M. Lepley, J.-P. Mouronval and G. Massez. 2009. Winter site fidelity is higher than expected for Eurasian teal (*Anas crecca*) in the Camargue, France. Bird Study 56: 272-275.

Hestbeck, J. G., J. D. Nichols and R. A. Malecki. 1991. Estimates of movement and site fidelity using mark-resight data of wintering Canada geese. Ecology 72: 523-533.

James, R. A. 1995. Natal philopatry, site tenacity, and age of first breeding of the Black-necked Stilt. Journal of Field Ornithology 66: 107-111.

Kinkel, L. K. 1989. Lasting effects of wing tags on Ring-billed Gulls. Auk 106: 619-624.

Mandernack, B. A., M. Solensky, M. Martell and R. T. Schmitz. 2012. Satellite tracking of bald eagles in the upper Midwest. Journal Raptor Research 46: 258-273.

McKinley, J. O. and B. Mattox. 2010. Winter site fidelity of migratory raptors in southwestern Idaho. Journal Raptor Research 44: 240-243.

Mehl, K. R., R. T. Alisauskas, K. A. Hobson and D. K. Kellett. 2004. To winter east or west? Heterogeneity in winter philopatry in a central-Arctic population of King Eiders. Condor 106: 241-251.

Metropolitan District Commission. 1992. Water quality report: 1992 Wachusett Reservoir and watershed. Unpublished report, Division of Watershed Management, West Boylston, Massachusetts.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Field Naturalist 37: 223-249.

Nugent, B. and M. J. Dillingham. 2009. Gull management on Lake Auburn. New England Water Works Association 123: 319-325.

Pearce, J. M. 2007. Philopatry: a return to origins. Auk 124: 1085-1086.

Quantum GIS Development Team. 2012. Quantum GIS geographic information system. Open Source Geospatial Foundation, Beaverton, Oregon. http://qgis.osgeo.org, accessed 9 September 2012.

R Development Core Team. 2012. R: a language and environment for statistical computing v. 2.15.1. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/, accessed 15 March 2013.

Raveling, D. G. and M. E. Heitmeyer. 1989. Relationships of population size and recruitment of pintails to habitat conditions and harvest. Journal of Wildlife Management 53: 1088-1103.

Robertson, G. J. and F. Cooke. 1999. Winter philopatry in migratory waterfowl. Auk 116: 20-34.

Seamans, T. W., S. Beckerman, J. Hartmann, J. A. Rader and B. F. Blackwell. 2010. Reporting difference for colored patagial tags on ring-billed gulls. Journal of Wildlife Management 74: 1926-1930.

Smith, G. C., N. Carlile and S. Tully. 1992. Breeding and movements of wing-tagged silver gulls (*Larus novaehollandiae*) at the largest colony in New South Wales. Wildlife Research 19: 161-167.

Snyder, N. F. R., S. R. Beissinger and M. R. Fuller. 1989. Solar radio-transmitters on Snail Kites in Florida. Journal of Field Ornithology 60: 171-177.

Somershoe, S. G., C. R. D. Brown and R. T. Poole. 2009. Winter site fidelity and over-winter site persistence of passerines in Florida. Wilson Journal of Ornithology 121: 119-125.

Southern, W. E. 1971. Evaluation of a plastic wing-marker for gull studies. Bird-Banding 42: 88-91.

Southern, W. E. 1974. Seasonal distribution of Great Lakes region Ring-billed Gulls. Jack-Pine Warbler 52: 154-179.

Southern, L. K. and W. E. Southern. 1985. Some effects of wing tags on breeding Ring-billed Gulls. Auk 102: 38-42.

Spaans, A. L. 2000. High winter site fidelity of black-headed gulls (*Larus ridibundus*) in the Hague. Limosa 3: 87-96.

Stenhouse, I. J. and G. J. Robertson. 2005. Philopatry, site tenacity, mate fidelity, and adult survival in Sabine's Gulls. Condor 107: 416-423.

Stenhouse, I. J., C. Egevang and R. A. Phillips. 2012. Trans-equatorial migration, staging sites and wintering areas of Sabine's gulls *Larus sabini* in the Atlantic Ocean. International Journal of Avian Science 154: 42-51.

Stiebens, V. A., S. E. Merino, C. Roder, F. J. J. Chain, P. L. M. Lee and C. Eizaguirre. 2013. Living on the edge: how philopatry maintains adaptive potential. Proceedings of the Royal Society B 280: 20130305.

Stiehl, R. B. 1983. A new attachment method for patagial tags. Journal of Field Ornithology 54: 326-328.

Threlfall, W. 1978. Dispersal of Herring Gulls from the Witless Bay sea bird sanctuary, Newfoundland. Bird-Banding 49: 116-124.

White, G. C. and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 (Supplement): 120-138.

Williams, C. K., M. D. Samuel, V. V. Baranyuk, E. G. Cooch and D. Kraege. 2008. Winter fidelity and apparent survival of lesser snow goose populations in the Pacific flyway. Journal of Wildlife Management 72: 159-167.