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Illinois Waterfowl Surveys and Investigations W-43-R-64

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ANNUAL REPORT – FY2017
Illinois Waterfowl Surveys and Investigations
Federal Aid in Wildlife Restoration
W-43-R-64

EXECUTIVE SUMMARY

Objectives

1) Inventory abundance and distribution of waterfowl, shorebirds, and other waterbirds (a minimum of 10 species and guilds) during autumn migration at a minimum of 30 sites along and nearby the Illinois and central Mississippi rivers,
2) Estimate waterfowl and other waterbird population sizes (a minimum of 10 species and guilds) during autumn migration using an aerial quadrat survey in the central Illinois River Valley for comparison with aerial inventories (Objective 1),
3) Investigate movement and population ecology of lesser scaup, canvasback, and other diving ducks by trapping and leg-banding a minimum of 1,000 individuals during spring migration along the Illinois and Mississippi rivers,
4) Investigate the ecology of American green-winged teal and gadwall by radio-marking a minimum of 40 individuals of each species during spring migration in and nearby the central Illinois River Valley,
5) Investigate movements and home range size of a minimum of 10 Canada geese during winter in and near the Greater Chicago Metropolitan Area (GCMA) of Illinois,
6) Determine habitat quality of a minimum of 50 wetland and deepwater polygons during spring, summer, and early autumn for migrating dabbling ducks, breeding wetland birds, and migrating shorebirds in Illinois, and
7) Distribute results and findings to site managers and biologists of the Illinois Department of Natural Resources (IDNR) and other state agencies, the Mississippi Flyway Technical Section, the Upper Mississippi River and Great Lakes Region (UMRGLR) Joint Venture, the U.S. Fish and Wildlife Service, other scientists and collaborators as requested, and the general public through oral presentations, popular articles, technical reports, and peer-reviewed publications; make recommendations for future wetland management practices and research needs based on results and related research; contribute to regional conservation planning efforts during the project period as appropriate and requested.

Methods

We scheduled 17 waterfowl flights of the Illinois and Mississippi rivers from late August 2016 to early January 2017 during which we inventoried 18–23 areas in each river valley. In addition, we flew six spring flights for waterfowl along the Illinois River. One observer conducted all inventories from a single-engine, fixed-wing aircraft flying at an altitude of <450 ft and 150–160 mph (Havera 1999). We computed waterfowl use-day (Stafford et al. 2007) and peak abundance estimates for the Illinois River valley (IRV) and central Mississippi River valley (CMRV) and made comparisons between the current waterfowl abundance and the most recent 5-yr average. Concurrently from mid-October through early January, we surveyed 55 1-mi^2 quadrats within the La Grange and Peoria pools of the IRV to generate total population size for comparison with aerial inventories. We evaluated detection probabilities and count bias by comparing ground counts of fixed survey areas with aerial observer counts and evaluated a downward facing fuselage-mounted camera for future use in counting waterbirds.

We flew 12 complete (50 1-mi^2 quadrats) quadrat surveys of the Illinois River valley from Hennepin, IL to Meredosia, IL. We flew quadrat surveys during weeks when traditional aerial waterfowl inventories were conducted (Objective 1). We collected photographs from an aircraft-fuselage mounted camera during quadrat surveys to estimate detection probability and estimate waterbird abundance. Additionally, we used ground observers to verify waterbird abundance, determine species composition, and monitor waterbird behavior and disturbance during quadrat flights.

We completed four weekly, aerial, shorebird inventories of the central Illinois River during August 2016. We counted shorebirds at 60 locations from near DePue to Naples, IL.

We captured, using swim-in traps and rocket nets, and leg banded ducks during spring 2017 in Mason, Fulton, and Tazewell counties along the Illinois River. We radiomarked individuals with 6–7 g glue and suture, backpack, radio transmitters. Specifically, we tagged American green-winged teal (AGWT, scientific names presented in Table 1) and gadwall (GADW) in February and March 2017. We used VHF radio telemetry and truck-mounted null-peak antennae systems to monitor AGWT and GADW both diurnally and nocturnally to determine movement distances, habitat use, home range size, survival, and stopover duration in central Illinois. Additionally, we lethally collected foraging AGWT during February and March, 2017 to determine food use and selection in spring. We evaluated the abundance of waterfowl forage where AGWT were collected from Rice Lake State Fish and Wildlife Area near Banner, IL to Two Rivers National Wildlife Refuge at the confluence of the Illinois and Mississippi rivers.

We evaluated transitional movements of 24 Canada geese in the Greater Chicago Metropolitan area using cellular neck collars. Geese were fitted with neck collars between November 2015 and February 2016 during previous work, MS graduate student, University of Illinois (UIUC). We hired a PhD student at UIUC in January 2017 and have continued evaluating and monitoring Canada goose movements as they relate to runway arrival and departures from Midway International Airport.

We estimated wetland quantity and quality throughout Illinois during important time periods for several migratory bird guilds (spring – dabbling ducks, summer – marsh birds, autumn - shorebirds). We conducted aerial and ground counts for dabbling ducks and other waterbirds during spring, call-back surveys for marsh birds during late spring and early summer, and aerial and ground surveys for shorebirds during autumn; mapped wetland area and determined wetland quality during each time period; and conducted vegetation surveys during autumn (Conway 2011). We obtained habitat quality metrics within 100 meters surrounding the survey areas each time call-response surveys were conducted. We digitized visited wetlands in ArcMap with corresponding inundation and vegetation cover data taken in the field.

Major Accomplishments and Findings

We monitored the chronology and distribution of shorebirds aerially in the IRV during August 2016. Shorebird abundance peaked on August 11th just prior to extensive flooding of many bottomland lakes in the IRV. Most shorebirds using the IRV were no longer present by the

August 25th inventory. Chautauqua National Wildlife Refuge was a major concentration area for shorebirds during August 2016. We intend to further evaluate shorebird migration chronology and distribution as more data becomes available in FY2018.

We completed four scheduled flights of the IRV and CMRV in late-August and September to document the distribution of early-migrating blue-winged and American green-winged teal (scientific names presented in Table 1). We completed all (n = 13) scheduled flights of the Illinois and Mississippi rivers from the second week of October to the first week of January. Peak duck abundance of ducks in the IRV and CMRV was greater in 2016 than 2015. Duck abundance peaked in the IRV on 14 November at 333,095 birds and ranked 54th out of 68 years of monitoring. Peak abundance of ducks in the CMRV occurred on December 12th (859,775) and ranked 10th out of 68 years. Total duck use-days from the IRV ranked 51st and 20th along the Mississippi River since the inception of surveys in 1948.

We aerially evaluated the spring migration chronology of waterbirds in the IRV and completed six flights from mid-February to mid-April, 2017. Due to the early arrival of mallards, total duck numbers peaked on the 28 February flight with over 300,000 ducks. Lesser scaup numbers peaked at nearly 70,000 birds on March 9th, and Upper Peoria Lake received the greatest proportional use by scaup.

We posted aerial survey data weekly on the Forbes Biological Station web page (www.bellrose.org) for public outreach to the waterfowl hunting and bird watching communities. Additionally, we reported general observations of waterfowl and habitat conditions following each flight in a blog that was posted weekly on the Forbes Biological Station web page (www.bellrose.org) and on social media (http://www.facebook.com/forbesbiologicalstation) and reached 189,252 Facebook users in 2016 with an average weekly viewership of 13,518 followers each week. Additionally, our blog was posted weekly at http://www.heartlandoutdoors.com/yetter, and http://www.straycasts.net, and it was printed in weekly newspaper columns in the Mason County Democrat and Fulton County Democrat. Aerial survey data was also used by the Mallard Migration Observation Network to generate the Mallard Migration Status map posted online by the Missouri Department of Conservation (http://huntfish.mdc.mo.gov/hunting-trapping/species/waterfowl/waterfowl-reports-prospects/mallard-migration).

We determined the detection probability of waterfowl was ~100% and the proportion of waterfowl detected was 93% (SE = 5%) during traditional and quadrat surveys and varied from 61%–96% across guilds. Our data show that estimated waterfowl abundance derived from aerial photographs was not reliable. Error rates between aerial-observer and photograph-generated waterfowl abundance in the IRV was 206% (SE = 40%). On average, 10% (SE = 1%) of ducks were disturbed by aerial surveys and 2% (SE = 1%) of ducks abandoned the survey site completely. When we combined all locations in the IRV, error between the two survey types for population size within the entire study area ranged from -512% for lesser scaup to 56% for northern shoveler. For several species, aerial quadrat surveys produced higher abundance estimates than traditional inventory surveys. We found quadrat surveys were more parsimonious during early time periods, with total ducks and waterbirds displaying errors of 4% and 5%, respectively. However, between-survey error increased during later time periods for both ducks

(45%) and total waterbirds (36%) due to redistributions of birds as ice cover dominated wetlands.

We triangulated 1,656 locations (761 diurnal and 895 nocturnal) of AGWT and GADW during spring 2017. Movement distances between day and night roosts ranged from 2,325–3,445 m. We documented only one GADW mortality during spring 2017, all AGWT survived spring stopover in the IRV. Apparent stopover duration during spring 2017 was 18.6 days and 20.9 days for AGWT and GADW, respectively. The combined estimate of stopover duration for both species was 19.5 days. Our estimates of home range size (95% Minimum Convex Polygons) for AGWT and GADW averaged 1,880 ha (SE = 249) and 3,455 ha (SE = 601), respectively.

We lethally collected and processed gastrointestinal tracts of 42 foraging AGWT (29 male, 13 female) in the IRV during February 22 – April 4, 2017. Generally, plant material was observed more often than invertebrate items. The four most common food items were *Cyperus* achenes, *Ammannia* seeds, *Polygonum* seeds, and aquatic worms (Class Oligochaeta). Food density was 328 kg/ha across collection locations during spring migration 2017. Waterfowl forage density was greatest at Mel's Slough in the North Pool of Chautauqua National Wildlife Refuge (1,044 kg/ha) and Stump Lake (582 kg/ha) in the confluence region of the Illinois and Mississippi rivers.

We monitored cellular-collared Canada geese in the Greater Chicago Metropolitan Area, specifically their use of space near Midway International Airport (MWD). Of 3,008 transitional movements around MDW, 92% intersected ≥ 1 focal air operation areas. Runway 13/31 was impacted most frequently at 13.3% of transitional movements. A MS Thesis and manuscript on the wintering ecology Canada geese in the GCMA were produced and are attached as an Appendix.

During 2017, field work and wetland monitoring were completed for this project. Average polygon inundation rates during spring monitoring was 68.2%, 79.0% summer, and 53.0% autumn. Mudflats comprised a small proportion of all habitat types during autumn (<3.1%). We monitored 243 wetland plots during mid-February – mid-March, 2017 by INHS (128 plots) and SIU (115 plots) crews. During spring 2017, 9,737 ducks were counted during aerial surveys, and waterbirds were detected in 74% of surveyed plots. From mid-April through mid-June, 59 wetland plots were surveyed by INHS and 63 by SIU. We detected 128 sora (*Porzana Carolina*), 9 least bittern (*Ixobrychus exilis*), 7 Virginia rail (*Rallus limicola*), 6 American coot (*Fulica Americana*), and 5 pied-billed grebes (*Podilymbus podiceps)* in survey plots. We will provide additional analyses and summaries with multi-year comparisons across surveyed plots and wetland polygons during FY2018.

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NARRATIVE

STUDY 130: AERIAL INVENTORIES OF WATERFOWL IN ILLINOS

Objectives:

1) Identify and enumerate shorebirds at a minimum of 15 locations along the Illinois River of Illinois during autumn migration using light aircraft.
2) Identify and enumerate waterfowl and American coots at a minimum of 30 locations along the Illinois and central Mississippi rivers of Illinois during autumn migration using light aircraft.
3) Compute annual use-days and peak abundances for observed species and compare with long-term averages.
4) Provide general inference regarding the distribution of waterfowl in space and time relative to habitat conditions.
5) Summarize and distribute these data to agency personnel, research collaborators, the scientific community, and the general public through popular articles, oral presentations, technical reports, peer-reviewed publications, and other means.

Introduction

The Illinois and Mississippi river valleys are major migration and wintering areas for nearly 30 species of waterfowl in the Mississippi Flyway. Additionally, these regions provide significant recreational opportunities (e.g., hunting and bird watching). Data from aerial inventories are used to direct waterfowl management, habitat acquisition, ecological research, and for public outreach. There are many important private, state, and federal waterfowl areas and refuges within these river floodplains, such as the Mark Twain National Wildlife Refuge (NWR), the Illinois River National Wildlife and Fish Refuges, and Keokuk Pool. The Illinois Natural History Survey (INHS), with support from the Illinois Department of Natural Resources (IDNR) and the Federal Aid in Wildlife Restoration Fund through the U.S. Fish and Wildlife Service (USFWS), has conducted aerial inventories of waterfowl along the Illinois and Mississippi rivers since 1948 (flown each year but 2001). This undertaking represents the longest known inventory of waterfowl, preceding even the USFWS breeding waterfowl counts and mid-winter inventories established in 1955. Therefore, 68 years of data exist on autumn-migrating waterfowl for these critical ecoregions, collected by only 4 observers.

Aerial inventory data are frequently requested and used by federal and state agencies for regulatory decisions, evaluation of management or enhancement projects, and conservation prioritization. Specifically, the IDNR relies on these inventories to guide the establishment of hunting season dates, zones, and other regulations and to prioritize wetland habitat acquisitions.

Previously, this database has been used by the Mississippi Flyway Technical Section and Council to monitor abundance and distribution of migrating waterfowl, especially canvasbacks, mallards, and northern pintails. Requests for inventory information are received annually from state, federal, and private-sector employees to be used for projects such as Environmental Management Programs, scientific publications, theses and dissertations, formal presentations, and newspaper and magazine articles. Further, the long-term nature of this dataset makes it particularly unique and valuable; therefore, it was essential that the autumn inventory database continue to be summarized and maintained for future analyses. We monitored waterfowl in Illinois to maintain this long-term dataset, evaluated spatial and temporal variation in abundance and distribution of waterfowl, and presented these data concisely to aid waterfowl and wetland management decisions in this region.

Methods

The INHS began aerial inventories of waterfowl during autumn migration in the Illinois and Mississippi river floodplains in 1948. Initially, these flights were conducted weekly from 1–21 September to mid-December, and the winter inventory in early January was added in 1955. More recently, four flights were made in September and weekly flights from the second week of October through the first week of January to better overlap with important migration periods of waterbirds in our study region. We used fixed-wing aircraft to conduct aerial inventories of waterfowl and other waterbirds present at selected sites along the Illinois (Hennepin to Grafton, IL) and central Mississippi river valleys (Grafton to near New Boston, IL) during autumn and early winter (Fig. 1; Havera 1999). One observer conducted all inventories from a single-engine, fixed-wing aircraft flying at an altitude of <450 ft and 150–160 mph (Havera 1999, Stafford et al. 2007).

During each flight in autumn, we inventoried 18–23 areas in each river valley that typically host the majority of waterfowl in the region (Horath and Havera 2002). We recorded the number and species composition of waterfowl at each site, and survey methods mirrored previous years to maintain consistency with past inventories (Table 1; Havera 1999). In addition, we inventoried 60 locations for waterfowl in the Illinois River valley (IRV) during spring 2017. We computed waterfowl use-day (Stafford et al. 2007) and peak abundance estimates for the IRV and central Mississippi River valley (CMRV) during autumn and made comparisons between the current waterfowl abundance and the most recent 5-year average. And at 60 locations along the central Illinois River, we conducted aerial shorebird surveys during four weekly flights in August 2016. We estimated shorebird abundances at survey locations and identified them as small (≤

pectoral sandpiper sized birds) and large (> pectoral sandpipers) size classes. We also noted river water levels and resulting foraging habitat quality for waterfowl during September flights (Fig. 2).

Results and Discussion

Autumn Wetland Habitat Conditions

We ranked wetland habitat conditions for migratory waterfowl and noted river stage readings during the growing season. Summer 2016 was characterized by frequent rains with August being exceptionally wet across much of Illinois. Most of central Illinois saw rainfall at least 5 inches above normal in August that caused extensive flooding along the Illinois River valley (IRV; Fig. 2; U.S. Army Corps of Engineers, unpublished data). Consequently, waterfowl food availability ranked below average for both the upper and lower reaches of the IRV. Notable exceptions included Hennepin & Hopper Lakes, Banner Marsh State Fish and Wildlife Area, The Emiquon Preserve, Cuba Island, and Big Lake (Brown County) which had above average moist-soil and/or aquatic plant communities.

Wetland habitat conditions along the central Mississippi River valley (CMRV) were considered above average during autumn 2016 despite some late-summer rains that decimated moist-soil vegetation at the Port Louisa and Batchtown refuges of the Upper Mississippi River National Wildlife and Fish Refuge. Beds of submersed aquatic vegetation (SAV) at Pool 19, a key migratory stopover habitat for diving ducks (Aythyini), of the Mississippi River were considered above average. However, similar to summer 2015, we noted the diminished American lotus (*Nelumbo lutea*) bed north of Montrose, IA along the western shore of Pool 19. This stand of floating-leaved vegetation (typically >800 acres) was virtually non-existent during autumn inventories, but beds of SAV were considered above average at Montrose. Many of the refuges along the lower CMRV had above average waterfowl forage with exceptional moist-soil vegetation at key refuges: Keithsburg, Shanks, Delair, Towhead, Cannon, Cuivre, Dardenne, and Swan Lake.

Autumn Shorebird Inventories

We completed four shorebird flights of the IRV from near DePue to near Naples, IL ranging in dates from 3–25 August, 2016 (Appendix 1). Shorebird abundance peaked on 11 August at 83,525 birds. Water levels in the IRV were on the rise following the 11 August flight, and by 18 August many of the mudflats used by shorebirds along the Illinois River were inundated (Fig. 2). By 25 August, only 3,495 shorebirds were observed in the IRV. Shorebirds abundance was most pronounced at Chautauqua National Wildlife Refuge across all 4 inventories which reflected its status an Important Bird Area and Western Hemisphere Shorebird Reserve Network site. We will provide additional shorebird abundance analyses and comparisons in future reports.

Autumn Waterfowl Inventories

We provided weekly summaries of waterbird abundance to the IDNR, USFWS, and other parties of interest (Appendix 2). We completed 17 of 17 (100%) scheduled weekly aerial inventories of both the IRV and CMRV during autumn migration beginning 31 August 2016 and ending 5 January 2017. Normal temperatures and fluctuating river levels characterized autumn 2016. Wetlands along both rivers started freezing during the first week of December and significant ice was documented by the 12 December inventory. Wetland habitats along both rivers were ice covered until early January 2017. As a consequence of below average food availability, peak abundance estimates of ducks ranked 54th in the IRV (333,095 total ducks) out of the 68 years we have been monitoring waterfowl along these rivers (Fig. 3). To the contrary, abundant food likely increased stopover in the CMRV when peak numbers of ducks (859,775 total ducks) ranked 10th overall since 1948. One would have to go all the way back to 3 November 1980 to find a greater peak number of ducks in the CMRV.

Peak abundance of total ducks was greater in the IRV and CMRV in 2016 than 2015 (Table 2). In the IRV, peak abundance of total ducks for 2016 occurred on 14 November (Fig. 4; 333,095); this estimate was 10% above the 2015 peak (302,780) but 37% below the most recent 5-year average of 529,264 (2011–2015; hereafter, 5-year average). Peak counts of waterfowl in the IRV over the last 5 years have varied chronologically from 14 November (2016), 2 November (2015), 5 November (2014), 8 November (2013), to 12 December (2012).

Duck abundance peaked (12 December) nearly one month later in the CMRV relative to the IRV as bird numbers steadily rose from early November to mid-December (Figs. 5). Total ducks peaked in the CMRV (859,775) at levels 32% above 2015 (649,895) and 54% above the 5-year average (558,493) (Table 2). Peak abundance of total ducks has varied from 25 November to 12 December over the last 5 years: 2016 (12 December), 2015 (3 December), 2014 (25 November), 2013 (29 November), and 2012 (12 December). The peak abundance of total ducks for the two river systems combined (1,148,990) was 35% above the peak in 2015 (850,605) and 21% above the 5-year average (952,449).

Use-day estimates for total ducks were lower in the IRV but higher in the CMRV in 2016 than 2015 (16,218,430 [-4%] and 25,701,810 [3%], respectively; Table 3; Fig. 6). In the IRV, estimated use days for dabbling ducks were slightly lower (-3%) in 2016 than 2015. And, dabbling duck use days were up 7% in the CMRV (20,937,025) in comparison to 2015 (19,618,448). Excepting mallards, northern pintail, and blue-winged teal, estimated use days for other dabbling duck species were lower in 2016 than 2015 in the IRV. In contrast, mallards and blue-winged teal had lower use days in the CMRV in 2016 than 2015; however, other dabbler species had greater numbers of use days in 2016 than 2015. Since the inception of the waterfowl inventory in 1948, total duck use days in the IRV ranked 51st in 2016. Conversely, total duck use days in the CMRV ranked 20th out of 68 years.

Total diving duck use-day estimates in the IRV were 8% lower in 2016 than 2015 (2,468,153 and 2,671,003, respectively; Table 3). Use-day estimates for lesser scaup and ruddy ducks were down 25% each in the IRV from 2015; however, ring-necked ducks and buffleheads were up 39% and 71% autumn 2015, respectively. In the CMRV, scaup, ruddy duck, and bufflehead use-days were down 54%, 51% , and 20% from 2015, respectively; however, canvasback use days were similar to the previous autumn. Overall, autumn diving duck use days in the CMRV (4,717,535) were down 10% from 2015, but were similar (-1%) from the 2011–2015 average.

Spring Waterfowl Inventories

We flew 6 waterfowl flights of the IRV from 14 February–14 April 2017 (Appendix 3). Peak numbers of ducks occurred on 28 February when total ducks were estimated at 301,945 birds. Mallards also peaked this same week with 102,415 birds. Lesser scaup steadily increased in abundance until they peaked on 9 March with 68,440 ducks. Upper Peoria Lake consistently help the greatest proportion of lesser scaup each week. Canvasbacks peaked over 2 weeks earlier (21 February) than lesser scaup; however, peak numbers of canvasbacks were low at 5,010 birds. The diving duck migration chronology reflected trends in leg banding and capture data reported in Study 132 below. The ratio of banded scaup to canvasbacks was 15:1. This ratio of banded scaup to canvasbacks was very similar to the 13:1 ratio of lesser scaup to canvasbacks observed across waterfowl inventories during spring 2017. We will provide spring use-day estimates of waterfowl in the IRV with comparisons between years in future analyses.

Outreach

We distributed waterbird abundance data weekly as autumn aerial inventories were completed and summarized. INHS biologist Aaron Yetter also recorded his general observations of waterfowl distributions and wetland habitat conditions following flights (n = 14) in a blog that was posted weekly at www.bellrose.org, www.facebook.com/forbesbiologicalstation, http://www.heartlandoutdoors.com/yetter, and http://www.straycasts.net and printed in a weekly newspaper column in the Mason County Democrat and Fulton County Democrat. Our Facebook page received 189,252 views over the 14 weeks; for an average readership of 13,518 Facebook followers each week.

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Table 1. Avian species encountered during autumn 2016 and spring 2017 aerial inventories of the Illinois and central Mississippi rivers.

Common Name/Species Group	Scientific Name[a]	Abbreviation
Dabbling ducks		
Mallard	*Anas platyrhynchos*	MALL
American black duck	*Anas rubripes*	ABDU
Northern pintail	*Anas acuta*	NOPI
Blue-winged teal	*Spatula discors*	BWTE
American green-winged teal	*Anas crecca*	AGWT
American wigeon	*Mareca americana*	AMWI
Gadwall	*Mareca strepera*	GADW
Northern shoveler	*Spatula clypeata*	NSHO
Diving ducks		
Lesser scaup	*Aythya affinis*	LESC
Ring-necked duck	*Aythya collaris*	RNDU
Canvasback	*Aythya valisineria*	CANV
Redhead	*Aythya americana*	REDH
Ruddy duck	*Oxyura jamaicensis*	RUDU
Common goldeneye	*Bucephala clangula*	COGO
Bufflehead	*Bucephala albeola*	BUFF
Mergansers		
Common merganser	*Mergus merganser*	COME
Red-breasted merganser	*Mergus serrator*	RBME
Hooded merganser	*Lophodytes cucullatus*	HOME
Geese		
Greater white-fronted goose	*Anser albifrons*	GWFG
Canada goose	*Branta canadensis*	CAGO
Snow goose	*Chen caerulescens*	LSGO
American coot	*Fulica americana*	AMCO
American white pelican	*Pelecanus erythrorhynchos*	AWPE

[a] According to the American Ornithologists' Union Check-list, 2017.

Table 2. Peak abundance estimates of various species of waterfowl during autumns 2015 and 2016, the average for 2011–2015 and the percent change (Δ) between 2016 and periods of interest.

Species and Regions	2015	2016	2011–2015 Average	% Δ from 2015	% Δ from 2011–2015
Mallard					
Illinois River	130,350	186,855	253,103	43	-26
Central Mississippi River	390,195	482,325	333,229	24	45
Illinois & Mississippi Rivers	510,740	669,180	587,985	31	14
American black duck					
Illinois River	700	560	1,313	-20	-57
Central Mississippi River	600	750	577	25	30
Illinois & Mississippi Rivers	1,300	1,310	1,630	1	-20
Northern pintail					
Illinois River	59,880	51,920	76,201	-13	-32
Central Mississippi River	105,100	102,660	84,631	-2	21
Illinois & Mississippi Rivers	144,080	144,050	144,994	0	-1
Blue-winged teal					
Illinois River	49,405	28,355	33,185	-43	-15
Central Mississippi River	18,855	7,930	7,665	-58	3
Illinois & Mississippi Rivers	68,260	36,285	40,597	-47	-11
American green-winged teal					
Illinois River	78,720	45,290	89,226	-42	-49
Central Mississippi River	73,535	103,300	59,537	40	74
Illinois & Mississippi Rivers	138,325	148,590	128,644	7	16
American wigeon					
Illinois River	4,205	2,410	6,948	-43	-65
Central Mississippi River	650	3,200	2,303	392	39
Illinois & Mississippi Rivers	4,855	3,665	8,337	-25	-56
Gadwall					
Illinois River	30,210	43,720	74,313	45	-41
Central Mississippi River	36,000	57,550	49,368	60	17
Illinois & Mississippi Rivers	62,185	97,660	114,511	57	-15
Northern shoveler					
Illinois River	32,210	22,020	33,427	-32	-34
Central Mississippi River	23,570	30,270	16,310	28	86
Illinois & Mississippi Rivers	55,780	52,290	44,958	-6	16
Dabbling ducks					
Illinois River	254,695	271,205	452,703	6	-40
Central Mississippi River	517,930	632,725	437,696	22	45
Illinois & Mississippi Rivers	666,160	871,530	778,013	31	12

Table 2. Continued.

Species and Regions	2015	2016	2011–2015 Average	% Δ from 2015	% Δ from 2011–2015
Lesser scaup					
Illinois River	5,700	9,215	12,318	62	-25
Central Mississippi River	35,710	24,400	43,029	-32	-43
Illinois & Mississippi Rivers	41,410	30,320	54,685	-27	-45
Ring-necked duck					
Illinois River	15,610	25,295	36,720	62	-31
Central Mississippi River	33,125	67,470	28,586	104	136
Illinois & Mississippi Rivers	46,810	81,675	56,639	74	44
Canvasback					
Illinois River	4,370	15,765	5,044	261	213
Central Mississippi River	120,000	159,675	149,033	33	7
Illinois & Mississippi Rivers	124,310	175,440	151,074	41	16
Redhead					
Illinois River	1,370	625	659	-54	-5
Central Mississippi River	875	425	1,084	-51	-61
Illinois & Mississippi Rivers	1,370	645	1,232	-53	-48
Ruddy duck					
Illinois River	44,360	30,360	35,147	-32	-14
Central Mississippi River	28,295	21,150	22,798	-25	-7
Illinois & Mississippi Rivers	66,660	46,000	53,888	-31	-15
Common goldeneye					
Illinois River	210	12,140	2,195	5681	453
Central Mississippi River	5,600	20,900	12,921	273	62
Illinois & Mississippi Rivers	5,810	33,040	14,314	469	131
Bufflehead					
Illinois River	560	2,000	899	257	122
Central Mississippi River	6,300	4,750	5,605	-25	-15
Illinois & Mississippi Rivers	6,860	6,750	6,292	-2	7
Diving ducks					
Illinois River	66,635	61,825	83,063	-7	-26
Central Mississippi River	219,695	226,625	200,170	3	13
Illinois & Mississippi Rivers	269,270	276,525	232,819	3	19
Total mergansers					
Illinois River	980	510	2,470	-48	-79
Central Mississippi River	200	425	9,309	113	-95
Illinois & Mississippi Rivers	1,180	935	11,119	-21	-92

Table 2. Continued.

Species and Regions	2015	2016	2011–2015 Average	% Δ from 2015	% Δ from 2011–2015
Total ducks					
Illinois River	302,780	333,095	529,264	10	-37
Central Mississippi River	649,895	859,775	558,493	32	54
Illinois & Mississippi Rivers	850,605	1,148,990	952,449	35	21
Greater white-fronted goose					
Illinois River	10,115	2,160	5,987	-79	-64
Central Mississippi River	3,200	4,980	3,668	56	36
Illinois & Mississippi Rivers	13,315	6,165	9,550	-54	-35
Canada goose					
Illinois River	7,430	4,400	12,324	-41	-64
Central Mississippi River	13,890	7,010	8,998	-50	-22
Illinois & Mississippi Rivers	19,050	10,835	19,228	-43	-44
Lesser snow goose					
Illinois River	8,405	3,070	6,002	-63	-49
Central Mississippi River	7,200	5,500	6,883	-24	-20
Illinois & Mississippi Rivers	15,605	8,570	11,668	-45	-27
American coot					
Illinois River	208,870	192,385	169,568	-8	13
Central Mississippi River	69,000	47,675	47,177	-31	1
Illinois & Mississippi Rivers	270,685	228,715	207,077	-16	10

Table 3. Use-day estimates of waterfowl during autumns 2015 and 2016, the average for 2011–2015 and the percent change (Δ) between 2016 and periods of interest.

Species and Regions	2015	2016	2011–2015 Average	% Δ from 2015	% Δ from 2011–2015
Mallard					
Illinois River	5,289,830	5,321,450	7,877,248	1	-32
Central Mississippi River	9,331,268	8,006,938	8,074,928	-14	-1
Illinois & Mississippi Rivers	14,621,098	13,328,388	15,952,176	-9	-16
American black duck					
Illinois River	26,240	10,203	36,408	-61	-72
Central Mississippi River	9,183	3,900	6,133	-58	-36
Illinois & Mississippi Rivers	35,423	14,103	42,541	-60	-67
Northern pintail					
Illinois River	2,143,095	2,716,808	2,687,717	27	1
Central Mississippi River	4,294,508	5,752,890	2,957,207	34	95
Illinois & Mississippi Rivers	6,437,603	8,469,698	5,644,924	32	50
Blue-winged teal					
Illinois River	760,438	757,388	726,023	0	4
Central Mississippi River	315,360	225,928	166,637	-28	36
Illinois & Mississippi Rivers	1,075,798	983,315	892,659	-9	10
American green-winged teal					
Illinois River	3,369,768	2,169,103	3,580,193	-36	-39
Central Mississippi River	3,282,230	3,577,030	2,260,565	9	58
Illinois & Mississippi Rivers	6,651,998	5,746,133	5,840,757	-14	-2
American wigeon					
Illinois River	103,873	77,413	186,772	-25	-59
Central Mississippi River	16,388	70,285	42,694	329	65
Illinois & Mississippi Rivers	120,260	147,698	229,466	23	-36
Gadwall					
Illinois River	1,181,795	1,586,880	2,108,863	34	-25
Central Mississippi River	1,518,155	2,317,330	1,373,287	53	69
Illinois & Mississippi Rivers	2,699,950	3,904,210	3,482,149	45	12
Northern shoveler					
Illinois River	1,295,323	1,099,345	1,238,294	-15	-11
Central Mississippi River	851,358	1,018,725	512,311	20	99
Illinois & Mississippi Rivers	2,146,680	2,118,070	1,750,605	-1	21
Dabbling ducks					
Illinois River	14,170,360	13,738,588	18,441,516	-3	-26
Central Mississippi River	19,618,448	20,973,025	16,196,343	7	29
Illinois & Mississippi Rivers	33,788,808	34,711,613	34,637,859	3	0

Table 3. Continued.

Species and Regions	2015	2016	2011–2015 Average	% Δ from 2015	% Δ from 2011–2015
Lesser scaup					
Illinois River	186,280	140,483	152,994	-25	-8
Central Mississippi River	1,027,090	470,953	864,681	-54	-46
Illinois & Mississippi Rivers	1,213,370	611,435	1,017,675	-50	-40
Ring-necked duck					
Illinois River	559,143	778,330	767,455	39	1
Central Mississippi River	1,126,125	1,667,665	774,707	48	115
Illinois & Mississippi Rivers	1,685,268	2,445,995	1,542,162	45	59
Canvasback					
Illinois River	165,005	168,123	105,606	2	59
Central Mississippi River	1,775,305	1,775,738	2,112,246	0	-16
Illinois & Mississippi Rivers	1,940,310	1,943,860	2,217,852	0	-12
Redhead					
Illinois River	33,610	10,443	11,457	-69	-9
Central Mississippi River	22,515	4,155	15,487	-82	-73
Illinois & Mississippi Rivers	56,125	14,598	26,943	-74	-46
Ruddy duck					
Illinois River	1,706,003	1,280,175	883,460	-25	45
Central Mississippi River	1,123,453	547,088	670,858	-51	-18
Illinois & Mississippi Rivers	2,829,455	1,827,263	1,554,318	-35	18
Common goldeneye					
Illinois River	4,955	63,170	24,477	1,175	158
Central Mississippi River	109,340	195,080	210,079	78	-7
Illinois & Mississippi Rivers	114,295	258,250	234,555	126	10
Bufflehead					
Illinois River	16,008	27,430	16,511	71	66
Central Mississippi River	71,105	56,858	87,533	-20	-35
Illinois & Mississippi Rivers	87,113	84,288	104,043	-3	-19
Diving ducks					
Illinois River	2,671,003	2,468,153	1,961,958	-8	26
Central Mississippi River	5,254,933	4,717,535	4,747,931	-10	-1
Illinois & Mississippi Rivers	7,925,935	7,185,688	6,709,889	-9	7
Total mergansers					
Illinois River	16,673	11,690	24,344	-30	-52
Central Mississippi River	2,338	11,250	50,134	381	-78
Illinois & Mississippi Rivers	19,010	22,940	74,477	21	-69

Table 3. Continued.

Species and Regions	2015	2016	2011–2015 Average	% Δ from 2015	% Δ from 2011–2015
Total ducks					
Illinois River	16,858,035	16,218,430	20,427,818	-4	-21
Central Mississippi River	24,875,718	25,701,810	20,994,407	3	22
Illinois & Mississippi Rivers	41,733,753	41,920,240	41,422,225	0	1
Greater white-fronted goose					
Illinois River	99,155	55,805	49,879	-44	12
Central Mississippi River	56,978	128,903	37,066	126	248
Illinois & Mississippi Rivers	156,133	184,708	86,945	18	112
Canada goose					
Illinois River	381,783	306,503	328,812	-20	-7
Central Mississippi River	734,235	347,458	415,909	-53	-16
Illinois & Mississippi Rivers	1,116,018	653,960	744,720	-41	-12
Lesser snow goose					
Illinois River	103,075	25,555	41,856	-75	-39
Central Mississippi River	67,478	84,435	61,415	25	37
Illinois & Mississippi Rivers	170,553	109,990	103,271	-36	7
American coot					
Illinois River	8,039,368	6,968,070	5,994,782	-13	16
Central Mississippi River	2,547,065	2,126,478	1,457,467	-17	46
Illinois & Mississippi Rivers	10,586,433	9,094,548	7,452,249	-14	22

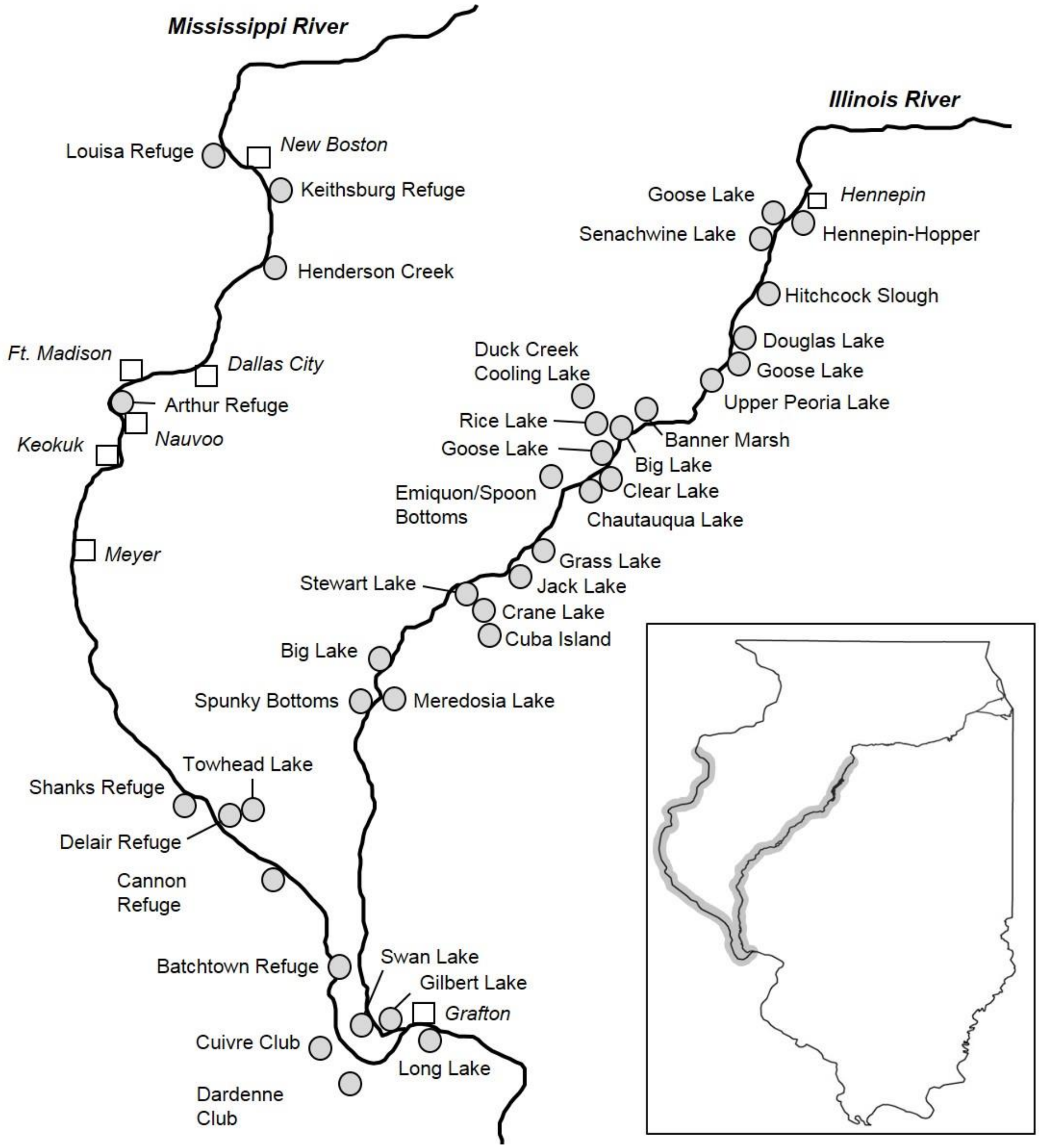

Figure 1. Locations in the Illinois and central Mississippi river valleys aerially inventoried for waterfowl by the Illinois Natural History Survey, autumn 2016.

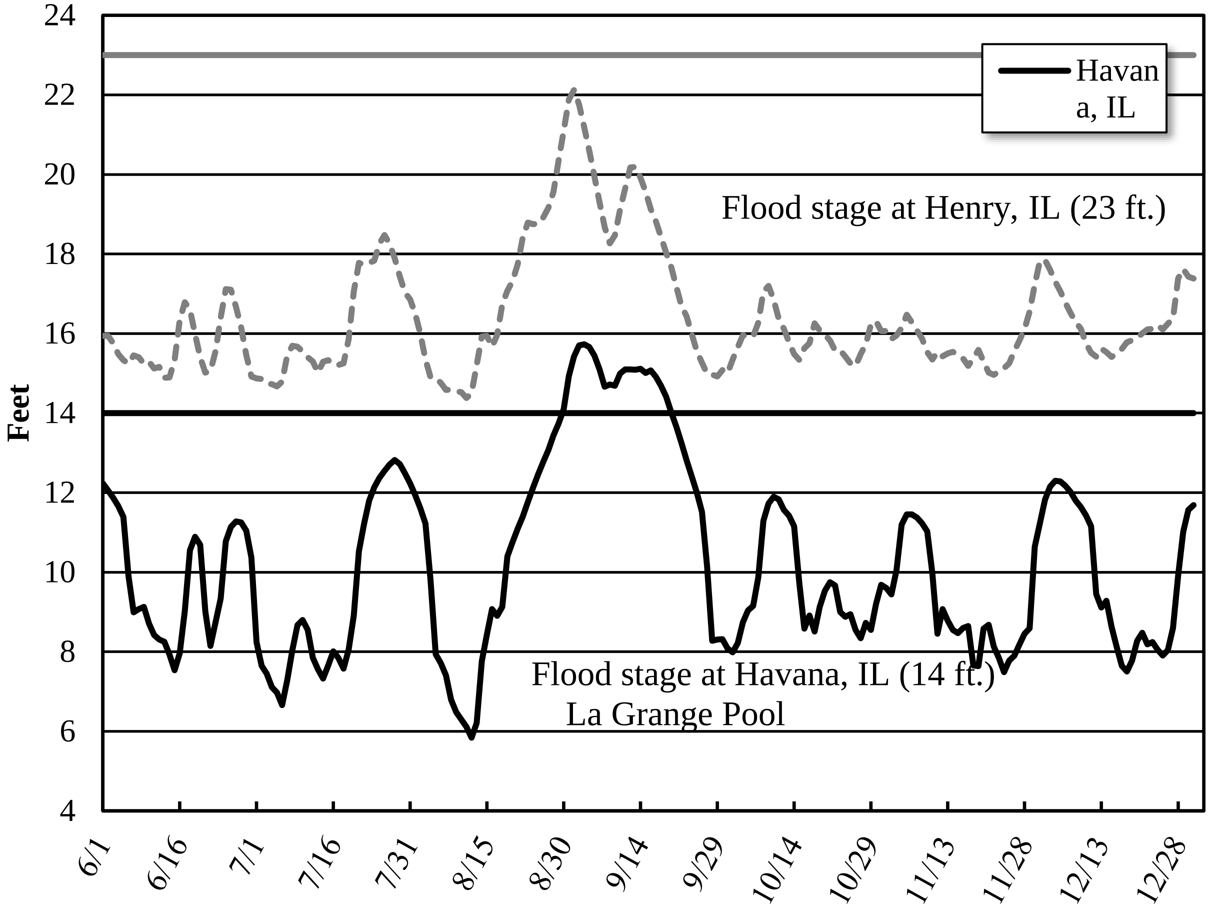

Figure 2. Water levels of the Illinois River during the 2016 growing season and autumn waterfowl migration. (http://rivergages.mvr.usace.army.mil/WaterControl/new/layout.cfm)

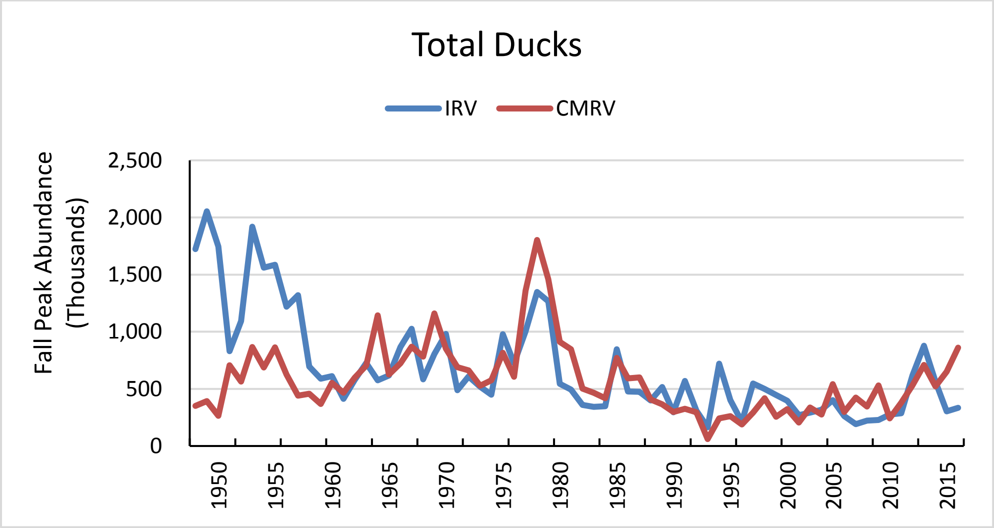

Figure 3. Peak abundance of total ducks observed during autumns 1948–2016 in the Illinois River valley and central Mississippi River valley.

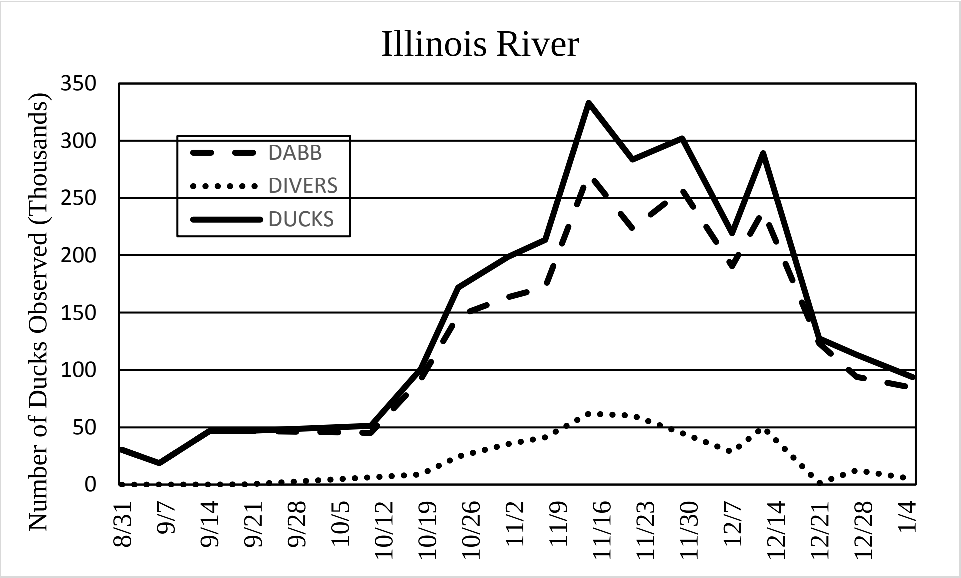

Figure 4. Estimated abundance of dabbling ducks, diving ducks, and total ducks observed during autumn 2016 in the Illinois River valley.

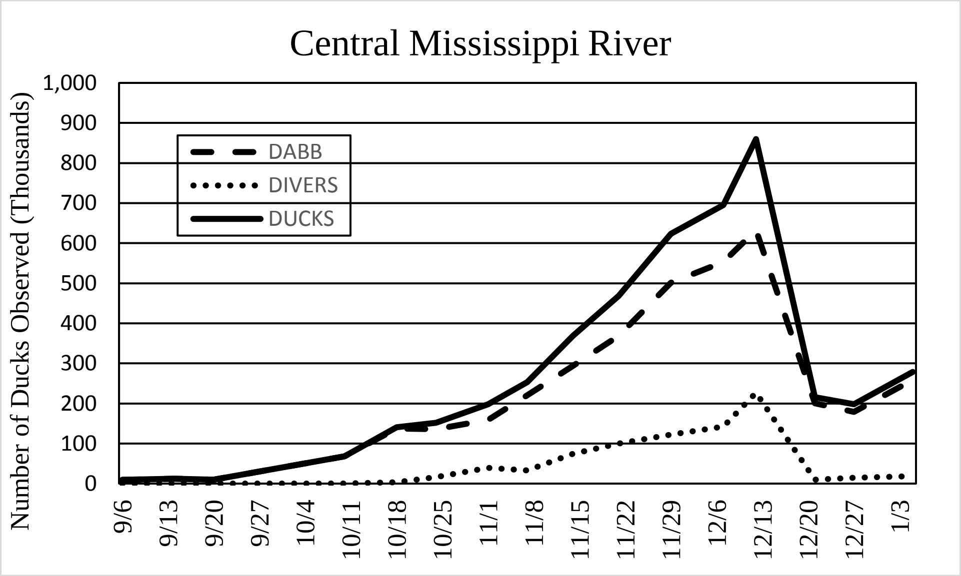

Figure 5. Estimated abundance of dabbling ducks, diving ducks, and total ducks observed during autumn 2016 in the central Mississippi River valley.

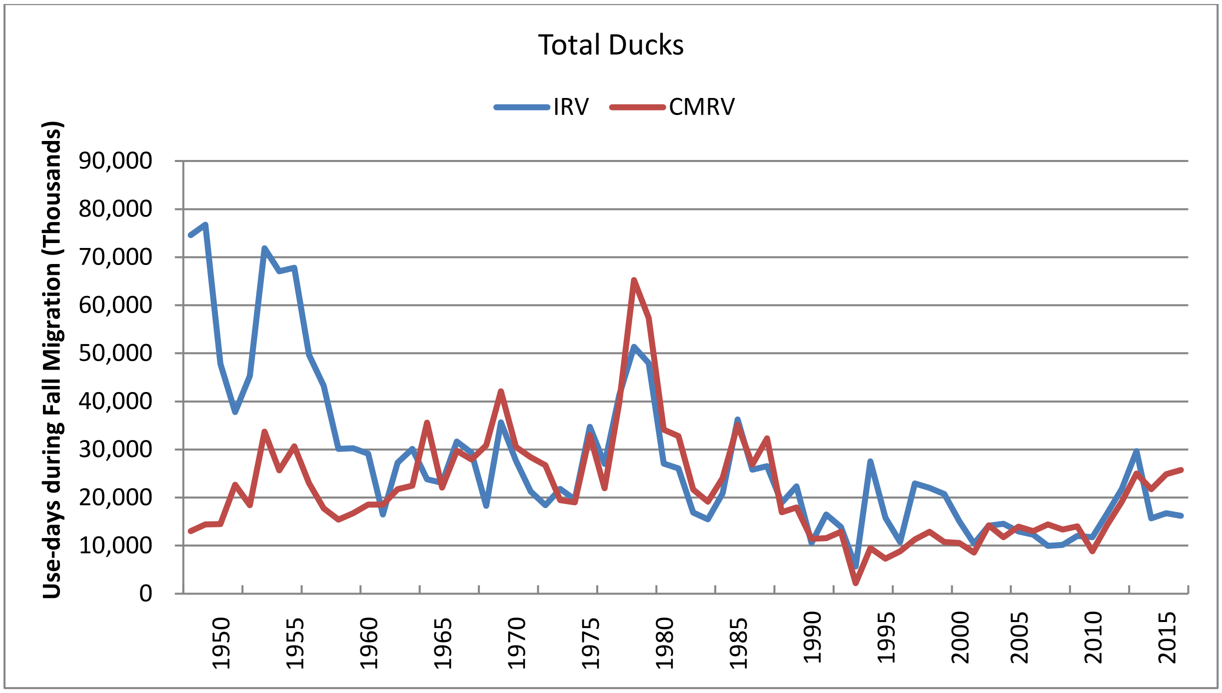

Figure 6. Total duck use-day estimates observed during autumns 1948–2016 in the Illinois River valley and central Mississippi River valley.

STUDY 131: EVALUATION OF AN AERIAL QUADRAT WATERFOWL SURVEY ALONG THE ILLINOIS RIVER

Objectives:

1) Use an aerial quadrat survey design to identify and enumerate waterfowl and American coot at a minimum of 50 sites during a minimum of 12 weeks in and nearby the IRV during autumn migration,
2) Evaluate feasibility and cost of an aerial quadrat waterfowl survey along the Illinois River compared to traditional aerial inventories (Study 130).
3) Estimate bias in traditional aerial waterfowl inventories.
4) Determine sample size necessary to yield target level of precision (<20%) and factors affecting precision.
5) Summarize and distribute these data to agency personnel, research collaborators, the scientific community, and the general public through popular articles, oral presentations, technical reports, peer-reviewed publications, and other means.

Introduction

Aerial counts of waterfowl have been conducted along the Illinois River of Illinois since 1948. Methodologies have remained the same since initiation of the survey, making the survey a reliable index of waterfowl abundances over time (Havera 1999). A myriad of stakeholders use aerial survey data of waterfowl for recreation, research, conservation planning, and administrative purposes (see Study 130). However, there is increasing need to estimate actual population size by using a randomized survey design and incorporating methods which allow determination of detection probability (Pearse et al. 2008*a,b*). In fact, conservation planners seek population estimates of waterfowl in order to prioritize wetland habitat conservation and management activities across the state and the region (Soulliere et al. 2007, Schultheis and Eichholz 2013).

An evaluation of long-term aerial surveys conducted by the INHS and IDNR are needed to determine bias in relation to actual population sizes. Two projects have recently been completed to evaluate aerial survey designs for rivers with an associated floodplain. Hennig et al. (2013) used a quadrat survey design consisting of 2.6 km2 (1-mi^2) sections (i.e., sample units) to enumerate waterfowl along the Wabash River in southeastern Illinois and recommended this approach for riverine areas. Shirkey (2012) recommended transect surveys with distance methods for estimating population sizes of diving ducks, but Hagy et al. (2013) used transect surveys perpendicular to the river course on Pool 19 of the Mississippi River and concluded that distance methods produced highly variable and unrealistic population sizes. Unlike transect surveys, quadrat surveys allow observers to use natural reference points on the landscape (e.g., mile sections) and are logistically compatible with currently available low-winged aircraft. Moreover, transect surveys in river systems require frequent turns and may be less economical and taxing on personnel than a quadrat design.

Given consistent methodology for more than 60 years and uniqueness of the long-term data set (see Study 130), a concurrent evaluation of a new survey design with existing traditional aerial inventory methods is needed. Evaluating and refining a new survey design concurrent with an existing inventory design will allow comparisons between counts and estimates. Understanding this relationship will provide a linkage between estimates produced by new aerial surveys and counts produced using traditional methods.

Methods

Abundance

We defined our study area as the 100-year floodplain of the Illinois River as determined by the Illinois State Water Survey from Hennepin to Meredosia, IL. Using ArcMap 10.2, we generated a grid of 1-mi^2 quadrats (n = 432) and layered the boundary shapefile on a second shapefile outlining the typical concentration areas of waterbirds within core survey locations inventoried under Study 130. We excluded Upper Peoria Lake, Goose Lake (Fulton County), and Spunky Bottoms from core areas because of their lack of ducks during waterfowl hunting season. During early flights, we determined that we could survey approximately 50 quadrats per day within our study area. We designated two sample strata for quadrat surveys, a high-density stratum and a low-density stratum. The high-density strata contained quadrats which were within the 100-year floodplain of the Illinois River and overlapped an area where waterfowl concentrations during autumn were typically high at one of our traditional inventory locations (n = 73; Pearse et al. [2008*a*]). We randomly selected at least one quadrat overlapping each traditional aerial survey location each week until 25 were selected. Larger sites which typically hosted large concentrations of waterfowl, such as Chautauqua National Wildlife Refuge and Emiquon Preserve, had more than one quadrat from the high-density stratum each week. Additionally, we randomly selected 25 quadrats that did not overlap high-density locations but were within the 100-year floodplain of the Illinois River (n = 359; low density stratum). Following waterfowl enumeration and identification within each of the 50 quadrats, we re-surveyed five randomly-selected quadrats from within the high-density stratum to determine if time-of day influenced counts.

We flew aerial quadrat surveys from a single-engine, fixed-wing aircraft flying approximately 241 kph (150 mph) and 91 m (300 ft) above ground level. We flew quadrat surveys the day following traditional waterfowl aerial inventories (Study 130) unless prevented by weather, but for comparison both inventory and quadrat surveys were always flown within the same week. A pilot plus two observers flew a diagonal from the NE to SW corner and around the outside of each 1-mi^2 quadrat. The front seat observer estimated waterbird abundances by species while the rear seat observer recorded habitat information from within the 1-m^2 quadrat (e.g., inundated, woody vegetation, open water, herbaceous vegetation, ice coverage).

We compared abundance estimates between the traditional survey methods (Study 123) and the aerial quadrat design. Differences between aerial survey methods were calculated using the equation:

$$\%\,Difference = \frac{I - G}{I} * 100$$

where I = the estimate from the aerial inventory and G = the estimate from the aerial quadrat survey. Results are presented in relation to the traditional aerial inventory. Counts from locations where individuals did not occur in both survey types were excluded. Means and standard errors were calculated by species and location.

Detection Probability and Count Bias

We attempted to determine waterbird abundance estimates during aerial quadrat surveys from photographs collected from a camera mounted to the fuselage of the aircraft. While flying a diagonal across the quadrat, photographs were taken from a camera mounted to the bottom of the fuselage. Once activated by the observer at the edge of the quadrat, the camera captured a series of photographs that covered the entire diagonal of the quadrat. Photos were taken at a rate that each photograph lined up to the edge of the next photograph, creating a sequence that covered the entire diagonal of the quadrat. Photographs were georeferenced with GPS coordinates and altitude. We collected digital images only from the high density stratum to increase the chances of capturing waterbirds on images. If this method produces reasonable abundance estimates, it may be used to determine detection probability in the future.

We successfully collected photos on 28 surveys during autumns 2014–2016 on a total of 781 quadrats. Due to the impracticalities of maintaining a constant speed, elevation, and heading while flying the quadrat, not every photograph was analyzed. We determined duck abundance in every other photograph to eliminate the possibility of double counting birds in overlapping photographs. The georeferenced aerial photographs were added to a geographic information system containing the boundaries of all quadrats. Photographs that did not reside inside the corresponding quadrat were removed from analysis. Each photograph was visually searched for waterbirds and each individual was counted and identified to species. Birds that could not be identified to species were identified to the lowest possible taxonomic group (e.g., dabbler, diver, duck, goose, swan). Both the geographic area and the numbers of waterbirds in each photograph were summed for all photographs in a quadrat. The proportion of the total photograph area to the entire area of the quadrat (260 ha) was calculated for each quadrat. This value was used to extrapolate the total number of counted waterbirds to represent the entire quadrat. Extrapolated waterbird numbers were compared to the adjusted aerial estimate for each corresponding quadrat and an error rate was calculated. An overall error rate was calculated for all waterbird species along with individual error rates for each major guild (e.g., ducks, geese, swans).

We conducted ground surveys concurrent with traditional aerial inventories and quadrat surveys to determine detection probability and count bias. Immediately before an aerial survey, a ground observer enumerated all waterbirds within a discrete area by species from an elevated location where visibility was unobstructed by vegetation or infrastructure. Due to the large size of the quadrats (1 mi2) and inability of ground observers to view entire quadrats, most ground survey locations were comparably small (<25 ha) and well defined areas that could be counted effectively. When possible, we used natural landmarks as boundaries (e.g., shorelines, levees, vegetation) to define a survey location. When natural landmarks were not present, we used buoys (e.g., brightly painted duck decoys) to define plot boundaries. Before surveys, we provided both aerial and ground observers a map of the survey location. When possible, discrete ground locations were nested within quadrats or traditional census locations. We used optics (e.g., spotting scope, binoculars) to tally all waterbirds present in the survey location. All individuals were identified to species or smallest possible taxonomic group (e.g., dabbling duck, diving duck, goose, grebe, gull).

Disturbance

While conducting ground surveys, we documented disturbance to waterbirds presumably attributable to the aerial survey. Ground observers counted and recorded the number of each species within each count area that 1) exhibited a noticeable response to the airplane (e.g., flew but settled back in the survey area, dove under water, ran across the water but remained in the survey area) and 2) abandoned the plot completely and did not return during or immediately following aerial surveys. We also estimated the distance abandoning birds traveled when they abandoned the survey area. We determined disturbance rates for all waterfowl species and American coot.

Results and Discussion

Detection Probability and Count Bias

Our data show that photograph-estimated numbers for all waterfowl were greater than that of aerial estimates with an average percent error of 206% (SE = 40%). Total ducks had an average percent error of 211% (SE = 43%), geese had an average percent error of 324% (SE = 147%), and swans had an average percent error of 180% (SE = 72%). Our photograph-based estimates of American coot abundance were also greater than that of aerial estimates with an average percent error of 53% (SE = 12%).

We compared aerial estimates to ground counts to determine count bias (Table 4). The aerial observer detected 93% (SE = 5%) of all waterfowl resulting in a count bias correction factor of 1.07. On average, ducks were underestimated by 9% (average proportion detected = 91%, SE = 6%) resulting in a correction factor of 1.10. Dabbling ducks were underestimated by 4% (average proportion detected = 96%, SE = 7%) resulting in a correction factor of 1.04. Diving ducks were underestimated by 12% (average proportion detected = 88%, SE = 14%) resulting in a correction factor of 1.14. Geese were underestimated by 8% (average proportion detected = 92%, SE = 4%) resulting in a correction factor of 1.08. Swans were underestimated by 5% (average proportion detected = 95%, SE = 3%) resulting in a correction factor of 1.05. American coots were underestimated by 39% (average proportion detected = 61%, SE = 8%) resulting in a correction factor of 1.64.

Disturbance

We determined that 14% (SE = 2%) of waterfowl were disturbed by aerial surveys and 3% (SE = 1%) of waterfowl abandoned the survey site completely (Table 5). We estimated 10% (SE = 1%) of ducks were disturbed (dabbling ducks = 10% [SE = 1%], diving ducks = 6% [SE = 1%]) and 2% (SE = 1%) abandoned the survey site (dabbling ducks = 1% [SE = 1%], diving ducks = 3% [SE = 1%]). For geese, 21% (SE = 3%) were disturbed and 9% (SE = 2%) abandoned the survey site. For swans, 5% (SE = 2%) were disturbed, but none abandoned the survey site. For American coot, 4% (SE = 1%) were disturbed, but none abandoned the survey site.

We identified differences in disturbance rates of quadrat surveys and traditional inventory-style surveys (Table 5). For all waterfowl, aerial quadrat surveys had a disturbance rate of 8% (SE = 1%) and an abandonment rate of 2% (SE = 1%) while traditional area surveys had a disturbance rate of 16% (SE = 2%) and an abandonment rate of 4% (SE = 1%) for total ducks.

Overall Abundance

Differences between the quadrat and traditional inventory surveys, with the exception of lesser scaup and hooded mergansers, ranged from -183.7% for American black ducks to 56.4% for northern shoveler (Table 6). Aerial inventory counts often (45%) yielded lower estimates than the quadrat survey for the various species and guilds. Relative to the traditional inventory, quadrat surveys for Canada geese had the lowest error rate (-4.6%) with a SE of 14.8%. We found surveys were more parsimonious during early time period, with total ducks and waterbirds displaying errors of 4.2% and 5.1%, respectively; however, between-survey error increased during later time periods for both ducks (44.7%) and total waterbirds (35.7%). Most wetlands in the IRV encountered substantial ice by December 12, 2016 and results from the aerial inventory on December 21, 2016 indicated that many ducks departed the IRV with that cold weather event (Table 6, Fig. 7). Aerial quadrat surveys lacked precision with CV values for total ducks ranging from 96–272% during autumn 2016 (Fig. 7).

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Table 4. Average detection rates of waterbirds during aerial quadrat surveys in autumn 2014–2016 within the 100-yr floodplain of the central Illinois River.

Species/Guild	% Detected	Correction Factor
Waterfowl	93%	1.07
Ducks	91%	1.10
Dabbling Ducks	96%	1.04
Diving Ducks	88%	1.14
Geese	92%	1.08
Swans	95%	1.05
American Coot	61%	1.64

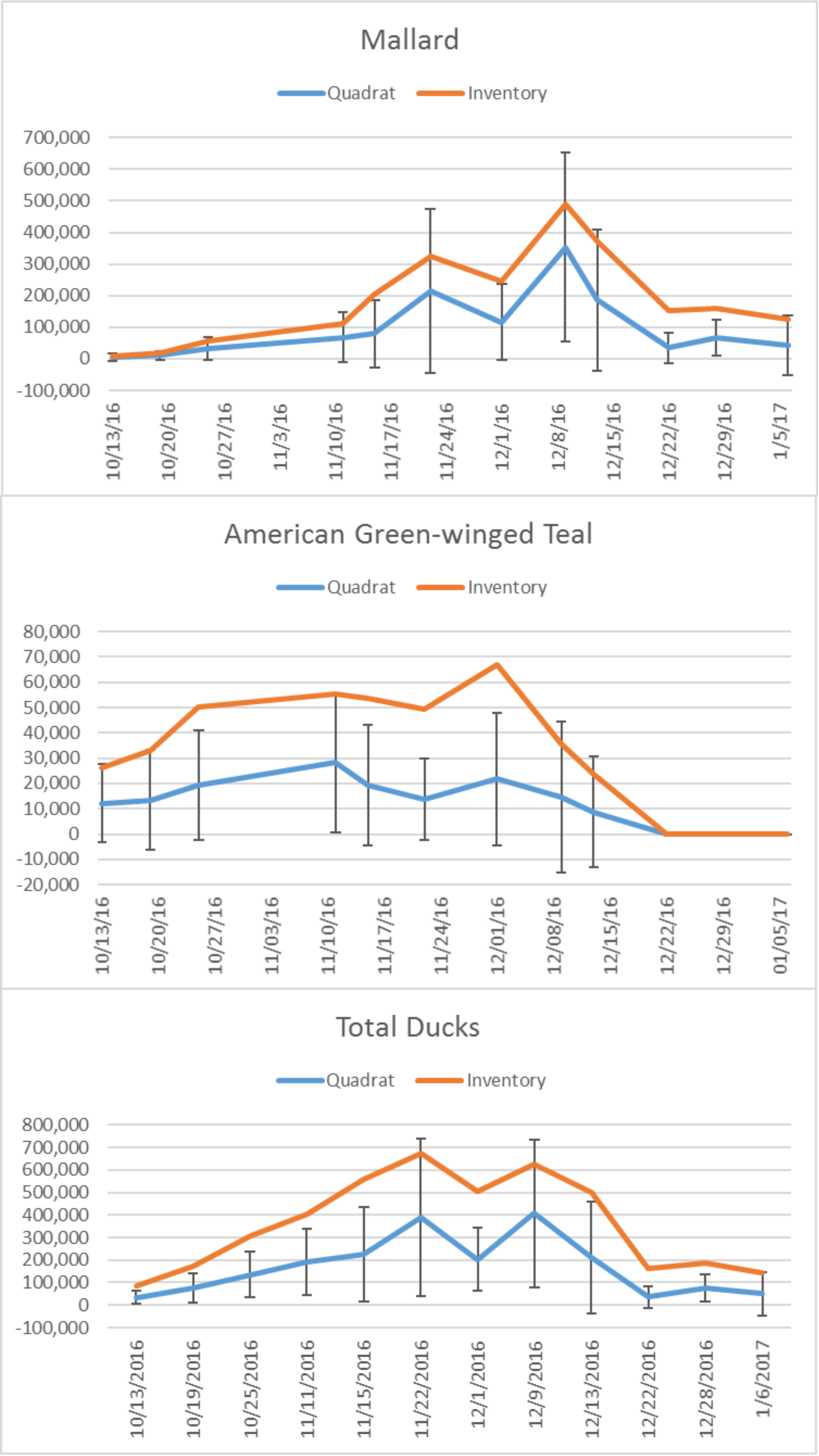
Table 5. Percentage of waterbird guilds exhibiting a response to (disturbed) or abandoning quadrats and selected survey area during aerial surveys along the Illinois River in autumn 2014–2016.

Species/Guild	Disturbed			Abandoned		
	Overall	Quadrat	Area	Overall	Quadrat	Area
Waterfowl	14%	8%	16%	3%	2%	4%
Ducks	10%	6%	13%	2%	1%	3%
Dabbling Ducks	10%	6%	12%	1%	1%	2%
Diving Ducks	6%	4%	8%	3%	1%	4%
Geese	21%	12%	25%	9%	7%	10%
Swans	5%	6%	4%	2%	6%	0%
American Coot	2%	0%	4%	0%	0%	0%

Table 6. Error between aerial inventory counts and aerial quadrat survey population estimates across all survey periods and locations within the Illinois River valley during autumn 2016 for select waterbird species/guilds with associated standard errors and sample sizes. Differences represented in relation to the aerial inventory (e.g., aerial inventory estimate is x% greater or less than the quadrat survey estimate). "Early" data included the first 8 survey periods, "late" data were survey periods 9-12, and "overall" includes all survey periods. SWAN = Total Swans, DABB = Total Dabbling Ducks, DIVER = Diving Ducks, DUCKS = Total Ducks, WTRB = Total Waterbirds.

	Early			Late			Overall		
Species/Guild	Mean	SE	N	Mean	SE	N	Mean	SE	N
MALL	-50.4%	21.3%	8	37.8%	15.1%	4	-21.0%	19.2%	12
ABDU	-281.4%	173.3%	7	-12.5%	49.9%	4	-183.7%	115.8%	11
NOPI	17.0%	19.0%	8	-297.7%	385.2%	3	-68.8%	101.2%	11
AGWT	33.2%	7.5%	8	41.4%		1	34.1%	6.7%	9
GADW	7.2%	25.0%	8	-53.1%	104.1%	4	-12.9%	36.4%	12
NSHO	50.2%	11.2%	8	72.9%	27.1%	3	56.4%	10.7%	11
LESC	-774.4%	828.1%	7	99.4%	0.6%	3	-512.2%	581.2%	10
RNDU	34.6%	12.9%	8	51.3%	48.7%	3	39.1%	14.8%	11
CANV	-13.5%	54.5%	7	100.0%	0.0%	3	20.5%	41.1%	10
RUDU	36.4%	21.6%	8	86.1%	13.9%	2	46.4%	18.4%	10
COGO	16.5%	70.2%	4	54.3%	18.5%	4	35.4%	34.4%	8
COME	11.0%	89.0%	2	45.4%	12.6%	4	33.9%	25.4%	6
HOME	-316.9%	232.2%	5	-263.8%	220.2%	2	-301.8%	167.6%	7
CAGO	0.3%	12.0%	8	-14.4%	41.0%	4	-4.6%	14.8%	12
GWFG	-258.3%	306.7%	7	23.9%	61.8%	4	-155.7%	195.4%	11
LSGO	100.0%	0.0%	3	-46.0%	146.0%	2	41.6%	58.4%	5
SWAN	-183.8%	149.0%	8	-76.1%	54.6%	4	-147.9%	99.6%	12
AMCO	-33.0%	40.5%	8	50.7%	32.3%	4	-5.1%	30.5%	12
DABB	-2.2%	18.6%	8	40.6%	12.9%	4	12.1%	14.1%	12
DIVER	30.7%	13.1%	8	55.8%	15.2%	4	39.1%	10.3%	12
DUCKS	4.2%	15.2%	8	44.7%	9.9%	4	17.7%	11.9%	12
WTBD	5.1%	16.5%	8	35.7%	10.3%	4	15.3%	12.0%	12

Figure 7. Weekly waterbird abundance estimates from the traditional aerial inventory and aerial quadrat surveys (with standard error bars) during autumn 2016 in the Illinois River valley.



STUDY 132: ECOLOGY OF DIVING DUCKS IN ILLINOIS RIVER

Objectives:

1) Trap and leg-band a minimum of 1,000 lesser scaup, canvasback, and other diving ducks along the Illinois River and Pool 19 of the Mississippi River,
2) Anecdotally document distribution of lesser scaup and canvasback among and within wetlands of both river systems,
3) Summarize and distribute these data to agency personnel, research collaborators, the scientific community, and the general public through popular articles, oral presentations, technical reports, peer-reviewed publications, and other means.

Introduction

Historically, diving ducks were abundant during spring and autumn migration on the Illinois River. For example, 710,275 lesser scaup (*Aythya affinis*; hereafter, scaup) were recorded on the upper Illinois River on 20 November 1949. However, autumn abundance of diving ducks in the IRV declined precipitously in the 1950s and has not recovered; peak abundance of scaup during autumns 1993–1996 averaged only 4,465 (Havera 1999). The central Mississippi River, specifically Pool 19, is also a critical area for migrating diving ducks, but peak abundances during autumn have declined in this region from about 480,000 during 1978–1982 to 51,300 during 1993–1996 (Havera 1999). Most recently, peak abundance of scaup was 42,115 on Pool 19 during autumn 2013 (A. Yetter, INHS, *unpublished data*).

Interestingly, diving ducks are more abundant in these systems during spring than autumn. For example, INHS personnel counted nearly 12,500 scaup at Emiquon Preserve in the IRV on 10 March 2007 and 350,000 scaup and 20,000 canvasbacks on Pool 19 of the Mississippi River on 24 March 2008. Thus, wetlands of both rivers systems appear to provide important stopover habitats during spring, a critically important time in the annual cycle of waterfowl. Because diving ducks partially rely on nutrients acquired during spring migration for breeding, the quality of Illinois' wetlands likely influence population dynamics of these species (Anteau and Afton 2004, 2011).

Lesser scaup and canvasback are two diving ducks species considered in greatest need of conservation under the Illinois Comprehensive Wildlife Conservation Plan and Strategy (ICWCPS 2005). Continental populations of both species have decreased significantly over the last 30–40 years. The canvasback population reached a low of 373,000 in 1978 and concern remains over the future status of this species. Similarly, the continental breeding population of lesser scaup was estimated near 8.0 million in 1972, but only 3.2 million in 2006. The “Spring Condition Hypothesis” may explain the scaup decline, which indicates that foraging habitats in the midcontinent have declined in quality (e.g., abundance of food; Anteau and Afton 2004, 2008*a*,*b*, 2011). If inadequate forage exists for lesser scaup at stopover locations during spring migration, these birds may not have the endogenous resources required to reproduce successfully.

Recent researchers have indicated a need for increased banding data during multiple seasons of the year to improve the reliability of current survival estimates, especially during non-breeding periods (Koons et al. 2006). Band returns establish linkages between migration stopover locations and other critical areas used during the annual cycle; however, scaup have been typically underrepresented in banding efforts and additional banding data is critically needed (Austin et al. 2000). As the Illinois River is a major autumn and spring migration stopover location for ducks traveling to the Great Lakes and the Prairie Pothole Region, additional banding data is needed to assess the relative importance of this region and compare with the Mississippi River using banding data from concurrent studies (e.g., A. Afton, Louisiana State University).

Methods

We captured and banded diving ducks at Chautauqua National Wildlife Refuge and The Emiquon Preserve along the Illinois River using baited swim-in traps during March 2017 (Anteau and Afton 2008*b,c*, Yetter et al. 2012, Hagy et al. 2015). We identified species and sex, obtained morphological measurements, and attached an incoloy leg band to all diving ducks captured.

Results

During spring 2017, we leg-banded 1,141 lesser scaup (*Aythya affinis*), 74 canvasback (*A. valisineria*), and 8 redhead (*A. americana*). Our ratio of banded scaup to canvasbacks was 15:1. Spring 2017 banding data were electronically submitted to the Bird Banding Laboratory at the Patuxent Wildlife Research Center. Since 2012, the Forbes Biological Station has leg-banded 9,689 lesser scaup along the Illinois River during spring; for an average of 1,615 leg-banded scaup per year.

<u>STUDY 133</u>: ECOLOGY OF SPRING-MIGRATING DABBLING DUCKS IN THE ILLINOIS RIVER VALLEY

Objectives:

1) Determine home range size, estimate survival, and describe daily movements of a minimum of 40 American green-winged teal and 40 gadwall during spring migration in central Illinois,
2) Determine diet composition and food selection of a minimum of 50 experimentally-collected American green-winged teal during spring in central Illinois,
3) Estimate energy density at foraging locations of a minimum of 50 American green-winged teal during spring in central Illinois,
4) Summarize and distribute these data to agency personnel, research collaborators, the scientific community, and the general public through popular articles, oral presentations, technical reports, peer-reviewed publications, and other means.

Introduction

Millions of waterbirds rely on Illinois wetlands during autumn and spring migration, despite these landscape-scale modifications (Havera 1999). In particular, the IRV is a focus area of the Upper Mississippi River and Great Lakes Region (UMRGLR) Joint Venture of the North American Waterfowl Management Plan (Soulliere et al. 2007). Peak abundance of ducks in the IRV currently averages 388,000 during autumn (range 210,000–545,000; based on 1995–2005 INHS aerial inventories). Additionally, the UMRGLR Joint Venture specifically relies on the IRV and other migratory focal areas in Illinois to protect, maintain, enhance or restore more than 800,000 ha of wetland habitats for waterfowl (Soulliere et al. 2007). Migratory waterfowl common to this region are ecologically important as predators and prey and economically important to Illinois communities by providing hunting and viewing opportunities (see Study 123). Thus, investigations of migrating and wintering waterfowl in Illinois are critical to guide conservation planning and harvest management that provide recreational and economic benefits to Illinois.

According to U.S. Fish and Wildlife Service parts collection survey data from 2010–2012, gadwall (*Anas strepera*, GADW) and American green-winged teal (*A. crecca*, AGWT) comprised approximately 15% of the duck harvest in Illinois and were commonly in the top five duck species harvested in the state; however, little information exists to describe spring migration ecology of these important species, which is related to autumn population size

(Hoekman et al. 2002). Detailed information on spring distribution, habitat associations, food selection, and stopover duration for these species are lacking or antiquated. An investigation documenting these factors would provide data critical to effectively allocating conservation efforts and help guide wetland habitat restoration and conservation planning at state and regional levels. Extensive declines of natural wetlands within habitats that these species typically frequent (e.g., aquatic bed, moist-soil, exposed mudflats) may necessitate restoration of these and other important habitats. Currently, energetic carrying capacity models used for prioritization of habitat restoration and protection objectives require accurate estimates of stopover duration, habitat use and selection, energetics of foods used by these species, and possibly other useful aspects of their migration ecology. Previous studies have indicated generally low food densities in most spring habitats used by diving and dabbling ducks, but some data indicates that birds respond positively to spring-flooding of seasonal wetlands; however, little information exists to help managers understand food use and availability in spring-flooded wetlands, especially in agricultural fields (Straub et al. 2012).

Additionally, recent research has indicated a need for increased banding data during multiple seasons of the year to improve the reliability of current survival estimates, especially during non-breeding periods (Koons et al. 2006). Band returns establish linkages between migration stopover locations and other critical areas used during the annual cycle; however, lesser scaup (*Aythya affinis*) have been typically underrepresented in banding efforts and additional banding data is critically needed (Austin et al. 2000). As the Illinois River is a major autumn and spring migration stopover location for ducks traveling to the Great Lakes and the Prairie Pothole Region, additional banding data is needed to assess the relative importance of this region and compare with the Mississippi River using banding data from concurrent studies.

Methods

Our study area encompassed the La Grange Pool, Illinois River extending from Pekin (River Mile 160), IL, to the La Grange Lock and Dam (River Mile 80) near Meredosia, IL. This segment of the Illinois River floodplain included portions of Putnam, Bureau, Marshall, Woodford, Peoria, Tazewell, Fulton, Mason, Schuyler, Brown, and Cass counties. Additionally, we monitored telemetered birds in tributary streams, wetlands, and strip-mined lands outside of the Illinois River floodplain in these counties as necessary. We also experimentally collected

AGWT in the confluence region of the Illinois and Mississippi rivers in Calhoun and Jersey counties, IL.

We used rocket nets and swim-in traps baited with corn to capture AGWT and GADW during spring migration (Sykes et al. 1990, Johnson et al. 1991, Anich et al. 2009). We attached a standard aluminum leg band and a glue-on, VHF transmitter (6-7 gram; <3% of body mass) equipped with a mortality switch to individual birds. We staggered capture and radio-marking of individuals throughout the spring migration period.

We used standard radio-telemetry techniques to track AGWT and GADW to determine diurnal (½ hr after sunrise to ½ hr before sunset) and nocturnal (½ hr after sunset to ½ hr before sunrise) habitat use. Birds were located by ground crews using triangulation techniques with vehicle-mounted null-array antenna systems and hand-held antennas (Davis et al. 2009). We determined locations of ducks using Program LOAS 4.0.3.8, which partially automated telemetry locations using a global positioning system and digital compass. Tracking crews practiced triangulations until azimuth standard deviation was <3°. We recorded habitat use of radio-marked individuals triangulated to wetland and upland habitat types as depicted on aerial images and National Wetlands Inventory base layer shapefiles in LOAS. We aerially searched for birds not found via ground tracking approximately weekly. When birds were located from the air, ground crews were dispatched to that area for location and triangulation. We rotated tracking schedules so that a minimum of half of our telemetered birds were triangulated during each diurnal and nocturnal tracking period. For example, a transmittered duck found during the diurnal period of Day 1 would subsequently be located during the nocturnal period of Day 2, and then this bird would again be triangulated diurnally on Day 3 and so on. We determined habitat use of GADW and AGWT by overlaying daily waypoints of triangulated birds on the 2010 Illinois Landcover database in ArcMAP 10.3. During each triangulation, we verified status (i.e., alive or dead). We calculated consecutive day roost to night roost (Day-Night) and night roost to day roost (Night-Day) movement distances from daily location data using the Pythagorean Theorem. We calculated home range size (95% Minimum Convex Polygons [MCP]) for birds that remained in the study area ≥ 3 days using the Minimum Bounding Geometry Tool in ArcToolBox ArcMAP 10.3.1. We used separate general linear models in SAS (Proc GLM) to compare home range sizes between age groups and sexes of marked ducks. For stopover estimation, we assumed an individual had emigrated from the study area if we failed to locate them via ground or aerial searches. We report apparent stopover duration for each species during spring 2017. We will estimate total stopover duration using encounter sampling through Program DISTANCE (Otis et al. 1993, Lehnen and Krementz 2005) during January 2018. We reported apparent survival of each species during spring 2017 and will estimate survival of spring migrating AGWT and GADW using the known fate model in Program MARK (White and Burnham 1999, White et al. 2006) in January 2018. We intend to use Akaike's Information Criterion to evaluate models containing effects of age, sex, and capture date on daily survival rates.

We used radio-telemetry locations to identify potentially important foraging habitats (e.g., temporary wetlands in agricultural fields, spring-flooded moist-soil wetlands) and experimentally collected foraging green-winged teal with a shotgun to determine food use. Prior to collection, birds were observed foraging for ≥5 minutes to increase the likelihood of ingesta upon dissection. Immediately after harvest, we removed the upper digestive tracts (i.e., proventriculus and esophagus) from birds, placed zip ties at the anterior of the esophagus and at the junction of the proventriculus and gizzard, preserved food items by injecting a 10% formalin solution stained with rose Bengal at several locations within the digestive tract, and refrigerated the entire digestive tracts in a bath of the aforementioned preservative until processing occurred at the Forbes Biological Station in Havana, IL (approximately 90–160 days). In the laboratory, the proventriculus and esophagus were thawed and all food items identified, enumerated, and weighed to the nearest 0.1 mg. We followed approved protocols and necessary approvals prior to collections (i.e., University of Illinois Institutional Animal Care and Use Committee Permit #15032, U.S. Fish and Wildlife Service Scientific Collection Permit #MB145466-4, Illinois Department of Natural Resources Scientific Collecting W17.6079 and Scientific Research permits SS16-030, U.S. Fish and Wildlife Service Central Illinois River Refuges Permit #33653E-16-001, U.S. Fish and Wildlife Service Salvage Permit #MB121922-0, and The Nature Conservancy Research Permit #2017-2).

We collected benthic core samples (hereafter, food samples) from within experimental collection locations to quantify density (kg/ha) of plant seeds, invertebrates, and other potential waterfowl foods. We collected 3 benthic cores (5 cm diameter × 10 cm depth) in each collection location. We combined core samples for each location in the field, preserved each amalgamation with 10% formalin solution stained with rose bengal, and refrigerated the mixture in polyethylene bags until processing (approximately 60–120 days). We rinsed (500-µm mesh sieve) samples through sieves to remove preservatives and soil, removed invertebrates and dried to constant mass separately by lowest taxonomical level practical, dried samples at room temperature for >24 hr, removed seeds by hand, and enumerated and weighed by species or genus using published protocols (Hagy et al. 2011, Hagy and Kaminski 2012). At each food sample location, we also recorded water depth and secchi depth for use in later analysis.

Results and Discussion

We radiomarked 74 American green-winged teal (AGWT) and 42 gadwall (GADW) during spring 2017. However, five AGWT died within two days due to capture myopathy which reduced our sample to 69 AGWT. A total of 1,656 locations (761 diurnal and 895 nocturnal) were triangulated during spring 2017. Mean movement distances of AGWT from day to night was and 2,325.1 m (SE = 443.5, *n* = 31) and from night to day locations was 3,766.3 m (SE = 134.9, *n* = 388), respectively. Similarly, day–night and night–day movement distances for GADW were 3,445.3 m (SE = 521.6, *n* = 36) and 5,172.1 m (SE = 245.3, *n* = 241), respectively. Apparent stopover duration during spring 2017 was 18.6 days (CI^{95} = 16.0–21.2 days) for AGWT and 20.9 days (CI^{95} = 16.1–25.7 days) for GADW. Estimated of stopover duration for both AGWT and GADW combined was 19.5 days (CI^{95} = 17.1–21.9 days). Only one GADW was known to have perished following radio transmitter attachment during spring 2017 in the Illinois River valley. Therefore, apparent survival of GADW was 97.6%. No mortality events were observed for AGWT during spring 2017. We estimated home range size (95% MCP) for AGWT was 1,880.0 ha (*n* = 65, SE = 249) and GADW home range size was 3,455.1 ha (*n* = 41; SE = 601.2). We determined 50 (45%) of our transmitters (33 AGWT and 17 GADW) fell off prior to departure from the IRV in 2017. Due to this result, we will change transmitter design during spring 2018.

We lethally collected and processed gastrointestinal tracts of 42 foraging AGWT (29 male, 13 female) in the IRV during 22 February–4 April 2017. We removed 2 male AGWT diet samples from analyses that contained insufficient food in the upper gastrointestinal tract for inference (<0.1g/bird and/or <5 items). Plant material was observed at a similar rate (97.5%) and at a greater percent aggregate mass (76.8%) than invertebrates (92.5% and 23.1%, respectively; Table 7). Notable food items occurring in AGWT included seeds of sedges (*Cyperus* spp.), smartweed (*Polygonum* spp.), sprangletop (*Leptochloa* spp.), and toothcup

(*Ammania* sp.), as well as blood worms (Family Chironomidae larvae) and aquatic worms (Class Oligochaeta).

We collected and processed core samples (*n* = 41) from 11 locations throughout the IRV. Across all locations, seeds, tubers, and invertebrates totaled 328.0 kg/ha (292.6 lbs/ac; Table 8), with seeds and tubers comprising 61.8% of available food during 2017. Whereas AGWT showed some selection tendencies for plant foods, we did not observe apparent selection of specific taxa in either plant or animal foods. Our second year of results support previous studies which reported AGWT frequently consuming seeds of sedges, smartweeds, grasses (e.g., sprangletop), and other foods that can be procured from exposed mudflats or shallow-water environments. While traditional food items were present in diets, a wide variety of plant and animal material was present suggesting omnivorous tendencies of AGWT in the IRV during spring migration. One issue we discovered during spring 2017 was the lack of *Ammannia spp*. seeds present in core samples relative to the large amount present in AGWT diets collected from the confluence region of the Illinois and Mississippi rivers. Our methods of field washing of core samples through a 500-µm sieve bucket to reduce the volume of core samples in the field was identified as the potential source of seed loss. In 2018, we will collect core samples at collection sites without any manipulations in the field using sieve buckets and wash samples through a 250 µm sieve in the lab to prevent loss and incomplete sampling of these extremely small seeds.

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Table 7. Proportion of spring-migrating American green-winged teal (*Anas crecca*) consuming individual food items (percent occurrence) and mean biomass per individual (aggregate percent) of common food items with mean food availability (kg/ha) and rankings of dominant items in the Illinois River valley during spring 2017. Note *Ammannia spp.* was not properly sampled due to small seed size and current food availability sampling methods.

Taxa	Percent Occurrence	Aggregate Percent	Diet Rank	Food Availability	Availability Rank
Cyperus spp.	95.2%	36.5%	1	9.2	7
Ammannia spp.	9.5%	11.7%	2	N/A	N/A
Polygonum spp.	47.6%	8.9%	3	47.5	2
Oligochaeta	23.8%	7.0%	4	15.9	6
Leptochloa spp.	35.7%	6.1%	5	7.7	10
Chironomidae	45.2%	5.1%	6	6.2	13
Ostracoda	54.8%	4.2%	7	0.2	53
Echinochloa spp.	33.3%	4.0%	8	35.3	3
Potamogeton spp.	7.1%	3.8%			
Physidae	11.9%	2.3%			
Zea mays	2.4%	2.0%			
Corixidae	21.4%	1.6%			
Amaranthus spp.	33.3%	0.9%			
Unk. Seed	23.8%	0.8%			
Morus alba	2.4%	0.8%			
Scirpus spp.	9.5%	0.6%			
Sagittaria spp	35.7%	0.5%			
Lemna spp.	38.1%	0.4%			
Chenopodium spp.	16.7%	0.4%			
Cladocera	14.3%	0.4%			
Ipomea spp.	2.4%	0.3%			
Leersia oryzoides	14.3%	0.3%			
Eleocharis spp.	11.9%	0.3%			
Panicum spp.	16.7%	0.3%			
Amphipoda	9.5%	0.2%			
Eragrostis hypnoides	14.3%	0.2%			

Table 8. Sampling locations of American green-winged teal (*Anas crecca*) during spring 2017 in the Illinois River valley, number of birds collected (*n*), densities (kg/ha) of seeds and tubers (Seeds), benthic invertebrates (Benthos), and combined (Overall) of taxa typically consumed by dabbling ducks.

Location	*n*	Seeds	Benthos	Overall
Anderson Lake	2	31.8	112.2	144.0
Chautauqua NWR - Mel’s Slough	2	1,016.3	27.4	1,043.7
Chautauqua NWR - North Pool	4	443.6	41.5	485.2
Chautauqua NWR - South Pool	1	53.3	279.2	332.6
Emiquon NWR - South Globe	1	256.1	6.8	263.0
Emiquon Preserve	4	242.1	58.0	300.2
Lacey Ditch	3	5.3	55.0	60.3
Rice Lake SFWA	3	271.9	34.7	306.7
Stump Lake	8	557.5	24.6	582.2
Two Rivers NWR - Calhoun Area	11	96.7	14.4	111.2
Two Rivers NWR - Swan Lake	2	136.5	170.1	306.6
Illinois River valley	41	317.2	58.2	328.0

<u>STUDY 134</u>: MOVEMENT ECOLOGY OF CANADA GEESE WINTERING IN THE GREATER CHICAGO METROPOLITAN AREA

Objectives:

1) Determine daily flight distance, winter home range size, and proportional habitat use of a minimum of 10 Canada geese in the GCMA during winter,
2) Determine factors affecting daily movements and habitat use of a minimum of 10 Canada geese in the GCMA during winter,
3) Identify movement patterns of a minimum of 10 Canada geese that pose risks for conflict with humans in target areas of the GCMA during winter,
4) Summarize and distribute these data to agency personnel, research collaborators, the scientific community, and the general public through popular articles, oral presentations, technical reports, peer-reviewed publications, and other means.

Introduction

Canada geese (*Branta canadensis*) are important ecologically and economically throughout Illinois and the midwestern United States. Canada goose population ecology is well studied in the U.S. and Canada, and this species is intensively managed to regulate sport harvest within and among goose subpopulations (Klimstra and Padding 2012). In the past several decades, the Mississippi Valley population of subarctic-breeding Canada geese, which breeds in the lowlands of Hudson Bay, Canada, has remained relatively stable in abundance but appears to have changed its wintering range and migration timing (Gates et al. 2001, AGJV 2013).

Anecdotal information suggests that subarctic-breeding geese winter farther north than historically and many previous assumptions regarding factors affecting their movements may be incorrect due to changing food and habitat availability on the landscape. Concurrently, temperate-breeding (i.e., “resident”) Canada goose populations have increased drastically across much of the Midwest (Nelson and Oetting 1998, Dolbeer et al. 2014). During winter, these populations’ ranges overlap creating large abundances of geese in some areas (Paine et al. 2003).

One such mixed congregation area is the Greater Chicago Metropolitan Area (GCMA) in northeastern Illinois which includes the city of Chicago and surrounding suburbs with a human population of greater than 9.4 million and a breeding goose population of >30,000 (Paine et al. 2003, U.S. Census Bureau 2013). In northern wintering regions, geese may congregate in mixed, high-density flocks near electric generation cooling lakes, open river channels, navigation waterways, and other isolated areas of open water (Havera 1999). During mild winters, the

GCMA may be the terminal wintering latitude for many migrating subarctic-breeding geese, and many temperate breeding geese may remain throughout winter creating mixed high-density aggregations. Geese are likely attracted to the GCMA because of reduced risk from natural predators and little to no hunting; open water throughout winter at aerated ponds, warm-water out-flows into waterways, and electrical generation cooling lakes; and presumably ample food sources due to extensive agriculture and waste grain within the region. The total GCMA goose population may reach significant numbers during winter offering opportunities for wildlife recreation (e.g., viewing, hunting), but may also create challenges and conflicts that range from inconvenient (e.g., noise, droppings) to extremely dangerous (e.g., aircraft strikes).

The risk of Canada geese to air operations at Midway International Airport (MDW) during winter is immense. Two populations of Canada geese commonly use the GCMA during winter, the temperate- (*B.c. maxima*) and subarctic-breeding (*B.c. interior*) populations from the Mississippi Flyway (USFWS 2017). Anecdotal observations suggest winter abundances of Canada geese in urban habitats near MDW likely number in the tens-of-thousands. Large abundances of geese in winter pose greater risk to air operations at MDW. Bird strikes with aircraft are well documented in terms of numbers, species, and economic loss (Dolbeer 2006, Dolbeer and Wright 2009, FAA 2016), but very limited information exists on factors leading to movements of geese in the vicinity of airports in order to more effectively manage the risk of bird-aircraft collisions. To reduce risks of bird strikes with aircraft, wildlife managers use habitat management, lethal removal to reduce population sizes, and harassment on and near airports. We will use advance GPS technology to track Canada geese in relation to air operations at MDW to better understand potential intersections of geese with flight paths to predict risk of aircraft strikes. The goal of the study was to identify specific areas, climatic conditions, time of day, and time of year that lead to increased risks of goose-aircraft collisions (Walter et al. 2012; Rutledge et al. 2015a). By understanding the movements of geese near airports, we can provide information on where and when geese might be in the patch of aircraft and better understand why geese cross commercial airspace.

We will investigate wintering Canada goose ecology in the GCMA, including characterizing daily movements, characteristics of desirable and undesirable habitats, and the influences of weather and other factors on habitat use. Results of this research will provide a better understanding of factors influencing how geese use the GCMA, source populations of geese using areas of interest, and how wildlife and habitat managers can manage geese to increase wildlife related recreation or dissuade geese from using areas to avoid dangerous conflicts.

Methods

Study Area

Canada geese were captured in the Greater Chicago Metropolitan Area (GCMA; 915 km^2) located in northeastern Illinois, USA (Fig. 8) during late autumn and winter. The GCMA includes portions of three counties (Cook, Du Page, and Will). The GCMA is heavily urbanized, but did have agricultural fields present within the GCMA boundaries (United States Department of Agriculture 2015). The GCMA averages 43 days annually below freezing, with 7 days below -18 °C. November has an average high of 9 °C and a low of 0 °C, December has an average high temperature is 2 °C with a low of -6 °C, January has an average is a high of 0 °C and a low of -9 °C, and February has an average high of 2 °C and low of -7 °C (NOAA 2015*a*). Chicago averages approximately 93 cm of snowfall annually (NOAA 2015*a*). The GCMA has an estimated temperate-breeding Canada goose population exceeding 30,000 individuals (Paine et al. 2003) and a human population of 9.4 million, including the city of Chicago and surrounding suburbs (United States Census Bureau 2013).

Field Methods

During 13 November 2014 through 28 February 2015 and 14 November 2015 through 29 February 2016, we captured and attached transmitters to 41 Canada geese within the GCMA. We focused capture efforts at sites nearby Midway International Airport (41º47'6.5"N, 87º45'6"W) such as large parks, cemeteries, and the Stickney Water Reclamation Plant because of their available habitat and increased risk of goose-aircraft collisions when Canada geese concentrated at these locations throughout the fall and winter months (Fig. 8). Standard waterfowl capture techniques (e.g., rocket nets and cannon nets) could not be used in most urban areas, so cast nets and small animal net guns (Wildlife Capture Services, Flagstaff, Arizona, USA) were used for most capture attempts. After a Canada goose was captured, we determined sex and age using cloacal inversion and feather characteristics and then obtained morphological measurements (i.e., mass, skull length, culmen length, tarsus length; Moser and Rolley 1990, Moser et al. 1991) as potential indicators of body condition. All length measurements were taken using a caliper (nearest 0.1 mm) and mass was obtained using a Rapala mini digital scale (nearest 0.01 km). An aluminum tarsal band and a GPS transmitter affixed to a white plastic waterfowl neck collar with black alphanumeric codes was then placed on each goose prior to release (Castelli and Trost 1996, Coluccy et al. 2002, Caswell et al. 2012).

Transmitters (n = 10 in 2014–2015 and n = 31 in 2015–2016) were deployed during four times periods each year (mid November, early December and mid December, and early January) to account for temporal variation and across seven different capture locations to account for spatial variation. Transmitters recovered from hunters (n = 3) were redeployed during the late February. Transmitters included solar-powered GPS units from Cellular Tracking Technologies in Somerset, Pennsylvania, USA, and operated on the Global System for Mobile communications network and were configured to acquire a GPS location once per hour.

Generation 2 models were used during 2014–2015 ($\bar{x}$ = 69.7 grams, SE = 0.2) and Generation 3 transmitters were used during 2015–2016 ($\bar{x}$ = 62.2 grams, SE = 0.2). Transmitters were < 2% of the body mass of Canada geese ($\bar{x}$ = 4,713 grams, SE =10.6) and all Canada geese were captured and handled using the approved methods detailed by the University of Illinois Institutional Animal Care and Use Committee (Protocol # 14155).

Data Analysis

We quantified intersections of transitional movements with focal air areas at MDW during winter from 1 November to 28 February 2016. We defined transitional movements as the straight line between two consecutive GPS locations in which a change in habitat occurred. Movements between sites of the same habitat type (i.e., one park to another) were not analyzed because we were interested in the effect of movements between habitat types that fulfill different life history needs. We examined all instances of transitional movements that occurred within the GCMA. Transitional movements of transmitters that failed within 10 days of deployment due to technical issues (n = 4 in 2015–2016) were excluded. Movements with a start or end location with fixes derived from < 1 satellite or had a horizontal dilution of precision of > 5 were removed in order to maintain locational accuracy (CTT 2015). We removed movements that included a location with a speed value of > 15 km/h to exclude in-flight locations. In order to provide a description of flight altitudes of Canada geese, we described altitude frequency as meters above ground level for in-flight locations.

We classified transitional movements based on habitat types associated with the locations associated with each movement. Habitat types associated with start and end locations of movements were used to classify transitions. We classified habitats as green space, water, rooftop, railyard, or miscellaneous using available aerial imagery and ancillary information (Google Earth Pro, Google Inc., Mountain View, CA, USA). Green spaces were typically large parks, cemeteries, and other large areas of turf that contained a mixture of trees and shrubs, large sports fields, and golf courses within their boundaries. Water habitats included waterbodies that remain ice free throughout the year and include shipping canals and rivers as well as waterbodies that freeze during cold periods and include park ponds, wetlands, and impoundments. These habitats are primarily used as roosting and loafing locations. Rooftops were the tops of large commercial buildings including retail stores, factories, and distribution centers. Rooftops are generally used as loafing or resting locations during winter (Dorak et al. 2017). Railyards include any area related to railroad operations including switching yards, loading yards, and depots. Railyard habitats may serve as foraging sites due to the existence of waste and spilt grain there (Dorak et al. 2017). Miscellaneous habitats included parking lots and open industrial areas.

We chose six focal air operations areas by which to quantify the intersection of movements. Three buffers were chosen based on FAA recommendations separation distance between habitats known to attract wildlife and airports (Cleary and Dolbeer 2005, FAA Advisory Circular 150/5200-33A; Fig. 9). We analyzed intersection of movements with a 1.61 km and 3.05 km radius buffers, the recommended separation distance between wildlife attractants and airports serving piston-powered and turbine-powered aircraft, respectively (Cleary and Dolbeer 2005). Additionally, we examined intersections with an 8.05 km buffer, the FAA recommended separation distance for habitats that cause wildlife movement across approach and departure paths (Cleary and Dolbeer 2005). We also analyzed intersections of goose movements with airport runways and lines on runway headings extending for 3.21 km (2 mi) from the ends of three runways 13/31 and runways 4/22 (hereafter runway extensions) as an approximation for aircraft approach paths for those runways; Fig. 9).

We used ANOVA to examine differences in habitat transitions and proportion of intersections by individuals and habitat types (AOV; Program R, R Foundation for Statistical Computing, Vienna, Austria). The binary outcome of movements, intersected or did not intersect, were modeled using mixed effect, logistic regression modeling (GLMER) in Program

R. We tested for correlation between predictor variables using a Pearson pairwise correlation analysis and excluded one variable in the pair if correlation existed. We used a suite of biologically plausible predictor variables based on existing literature (Table 9) and individual goose ID as a random effect to account for subject-specific effects. We reported model outcomes as predicted probabilities or the influence of a specific variable on the probability of a movement intersection by holding all other variables at their means (Muller and MacLehose 2014).

Results

During 16 November 2015 – 28 February 2016, 3,008 transitional movements were recorded from 24 transmittered Canada geese with 125.33 ± 15.62 movements per goose. The number of transitional movements reflected the number of transmittered birds in the GCMA during each month. The majority of transitional movements were recorded during January (44.75%, x = 1,346, n = 23), followed by February (38.26%, x = 1,151, n = 23), December (14.70%, x = 442, n = 15), and November (2.30%, x = 69, n = 5). Of 3,008 transitional movements recorded, 2,767 (92%) were identified as intersecting one or more focal air operation area of MDW (Table 10). Of focal area buffers, the 8.05 km buffer was most frequently intersected (91.26% of transitional movements, x = 2,745) followed by the 3.05 km buffer (27.29% of transitional movements, x = 821), and the 1.61 km buffer (7.48% of transitional movements, x = 225). Extensions of runways 13 and 31 were intersected more frequently (13.26% of transitional movements, x = 225) than extensions of runways 4 and 22 (2.52% of transitional movements, x = 76). We recorded 18 instances of movements intersecting actual runways at MDW (0.60% of transitional movements).

Greater than 75% of intersections stemmed from movements associated with greenspace habitats. Transitional movements from greenspace to water habitats had the most intersections with focal airspace operations areas (n = 23, x = 879 intersecting of 1061 movements), followed by railyard to greenspace habitats (n = 14, x = 540 intersecting of 540 movements), and green space to miscellaneous habits (n = 23, x = 401 intersecting of 415 movements; Table 10). The runway 13 and 31 extensions were intersected more (x = 399) than runway 4 and 22 extensions (x = 76; Table 10). For runway 13 and 31 extensions, greenspace and railyards contributed the highest percentage of the intersecting movements (46.9%, x = 187), followed by rooftop and greenspace (28.8%, x = 115; Table 10).

We did not fit models for intersections of runway 4 and 22 extensions and MDW perimeter because too few intersections occurred while too many movements intersected with the 8.05 buffer for model fitting. No correlation was detected between parameters thus all parameters were included in model fit (Pearson, $P < 0.15$). Several habitat types, particularly those to and from rooftop and railway habitats, had positive effect on intersections with focal airport operations areas while most other fixed effects had little or negative effect on intersections (Fig. 10). The probability of intersection of runway headings 13 and 31 was greatest for movements between greenspace and railway and greenspace and rooftop habitats across all months (Fig. 11). For a 1.61 km buffer around MDW, the greatest probability for intersection was from movements between greenspace and rooftop habitats, followed by railway and miscellaneous, greenspace and railway, and water and rooftop (Fig. 11). Movements between railway and miscellaneous followed by greenspace and rooftop, water and rooftop, and greenspace and railway habitats had the highest predicted probabilities for intersection of movements with a 3.05 km buffer around MDW (Fig. 12). Movements in November had the highest probability of intersecting runway 13/31 extensions (Fig. 13), the 1.61 km buffer, and the 3.05 km buffer of the four months examined.

Recorded altitude of transmitters in flight (>15 knots) revealed few flights occurring over 50 m above ground level (29%; Fig. 14). Mean altitude of birds in flight was 29.8 m above ground level (AGL, SE = 1.13; $n = 377$) while the highest recorded altitude was 149 m AGL.

Discussion

We documented a substantial number of potential intersections between Canada geese and flight paths around MDW highlighting the risk to human safety and need for management of Canada goose in areas outside of the airport boundaries. Managing wildlife outside of the airport should be a focus of managers responsible for mitigating bird strike as Canada geese pose risks outside airport boundaries (Dolbeer 2011, Rutledge et al. 2015). Our use of GPS-GSM transmitters in relation to focal areas highlight the risk overwintering Canada geese pose to air traffic as they move between near-airport habitats. This approach produced detailed information on factors influencing movements intersecting air operation and guide efforts to reduce the risk of bird strikes.

Previous studies have utilized transmitters to examine avian movements in relation to air operations with Canada geese (Rutledge et al. 2015) and vultures (Avery et al. 2011, Walter et al. 2012), but habitat use and movements likely differ greatly by species and region. The use of transmitter identified specific sites increasing the risk of Canada goose involve bird strikes with air traffic from MDW. These data provide APHIS-WS with a clearer understanding of where management efforts will be most effective at dispersing concentrations of Canada geese and reducing risks to air operations at MDW. In addition, this study highlights the utility of a small number of transmitters to identify and guide harassment and other management efforts at greenspaces, rooftops, and railyards near airports.

Studies examining the effectiveness of harassment on urban Canada geese have been mixed (Smith et al. 1999, Sherman and Barras 2004, Seamans and Goss 2016). The use of a wide gamut of harassment techniques have been determined to be ineffective at reducing urban Canada goose populations as a whole (Mott and Timbrook 1988, Holevinski et al. 2007). Several papers have suggested the large-scale management of Canada geese within an 8 km buffer of airports would be required for effective reduction of bird strike risk (Seamans et al. 2009, Rutledge et al. 2015). However, the abundance of suitable habitats for geese near MDW makes management at such a large scale difficult. Despite inconclusive evidence and logistical constraints, the risk Canada geese pose to air operations is great and harassment efforts to reduce goose abundances near airports justified (Seamans et al. 2009). Furthermore, few studies have examined the effects of harassment during winter months when the effect of disturbance on thermoregulation may have more dire energetic consequences (Dorak et al. 2017). We suggest harassment of Canada geese at sites known to intersect with air operations during winter has the greatest potential to reduce the risk of catastrophic bird strikes.

Identifying habitat types and sites will allow managers to use resources most effectively to reduce the risk of winter goose abundances to air operations at MDW through harassment. Canada goose movements between greenspace-rooftop habitats and greenspace-railyard habitats were the most likely to intersect focal areas at MDW. Dorak et al. (2017) recently documented the use of rooftops and railyards by wintering Canada geese. These novel habitats may provide thermal benefits and act as refuge from harassment efforts near airports (Dorak et al. 2017). Thus, harassment during cold periods may effectively reduce the risk of bird strikes and potentially incur an energetic deficit for Canada geese using rooftops.

We advocate for the use of GPS-equipped transmitters to examine risks of avifauna to human health and safety. Fine-scale movement data derived from transmitters has a myriad of applications for guiding wildlife managers. For instance, we found movements to and from the Belt Way Clearing Yard (i.e., railyard) and nearby rooftops approximately, only 1.5 km from MDW, to greenspaces account for > 75% of transitional movements that intersected runway 13/31 extensions. We believe geese are using this rail yard for foraging on waste and spilt grain while the use of rooftops is likely related to the lack of disturbance there. Thus, harassment on rooftops and efforts to reduce food and mitigate goose numbers in the rail yard have potential to greatly reduce the total number of movements that pose risks to aircraft using those runways for arrival and departure. Further research should be used to examine responses to harassment activities (Rutledge et al. 2015) and exam airspace distribution of avifauna in relation to air traffic distribution to better examine bird strike risks (Avery et al. 2011). Additional research is needed to better understand response of Canada geese to harassment in urban areas and understand thermoregulatory balance in these areas.

Future Direction

The project has deployed 41 transmitters and currently has > 15 transmitters functioning with birds located from Chicago to parts of Hudson Bay. We will receive an additional 24 transmitters to deploy this fall with money from IDNR and Wildlife Services. Accelerometer data has been collected, organized, and analyzed in preparation for future work using sensors to quantify differences in behaviors and movement between urban and rural wintering geese. The project will examine questions dealing with movements throughout the annual cycle, response of transmitter-marked geese to targeted disturbance, behavior specific habitat use, and other aspects of Canada goose ecology that may inform management decisions. We will begin examining effects of harassment on movement and behavior in collaboration with USDA- Wildlife Services this winter.

In addition to work described here, our previous M.S. student, Brett Dorak, completed his graduate work at the University of Illinois. Mr. Dorak’s thesis and recent publication are attached (Appendix Q) at the end of this document.

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Table 9. Variables used in mixed effect, logistic regression models of Canada goose (*Branta canadensis*) movements intersecting with focal air operations areas at Midway International Airport in Chicago, Illinois, USA during 16 November 2015 – 28 February 2016.

Variable	Levels	Shorthand
Fixed Effect		
Categorical		
Month of year	4	month
Habitat types	8	type
Continuous		
Daily low temperature (c°)		tmp.c.
Average daily wind speed (km)		wind.spd.
Snow depth (cm)		snow.cm.
Time of day		hr.day.strt
Random Effect		
Categorical		
Transitter ID	24	ID

Table 10. Percentage of intersecting movements of focal air operations areas at Midway International Airport, Chicago, IL, USA by transitional habitats for movements recorded 16 November 2015 – 28 February 2016.

			Intersecting			Movements
Habitat type	1.61 km	3.05 km	8.05 km	Runway 13/31	Runways 4/22	Total
Green/Misc (*n* = 24)	8.9%	11.1%	14.6%	6%	27.6%	415
Green/Rail (*n* = 22)	32%	30.1%	19.7%	46.9%	9.2%	540
Green/Roof (*n* = 21)	34.7%	22.3%	12.1%	28.8%	14.5%	336
Green/Water (*n* = 24)	7.1%	7.6%	32%	3.8%	23.7%	1061
Rail/Misc (*n* = 17)	8.9%	11.8%	4.4%	3.8%	3.9%	120
Rail/Water (*n* = 17)	2.2%	5.2%	4.9%	3.5%	6.6%	135
Roof/Water (*n* = 20)	4%	5.2%	3.1%	3.5%	7.9%	90
Water/Misc (*n* = 23)	2.2%	6.7%	9.3%	3.8%	6.6%	311
Total (*n* = 24)	225	821	2745	399	76	3008

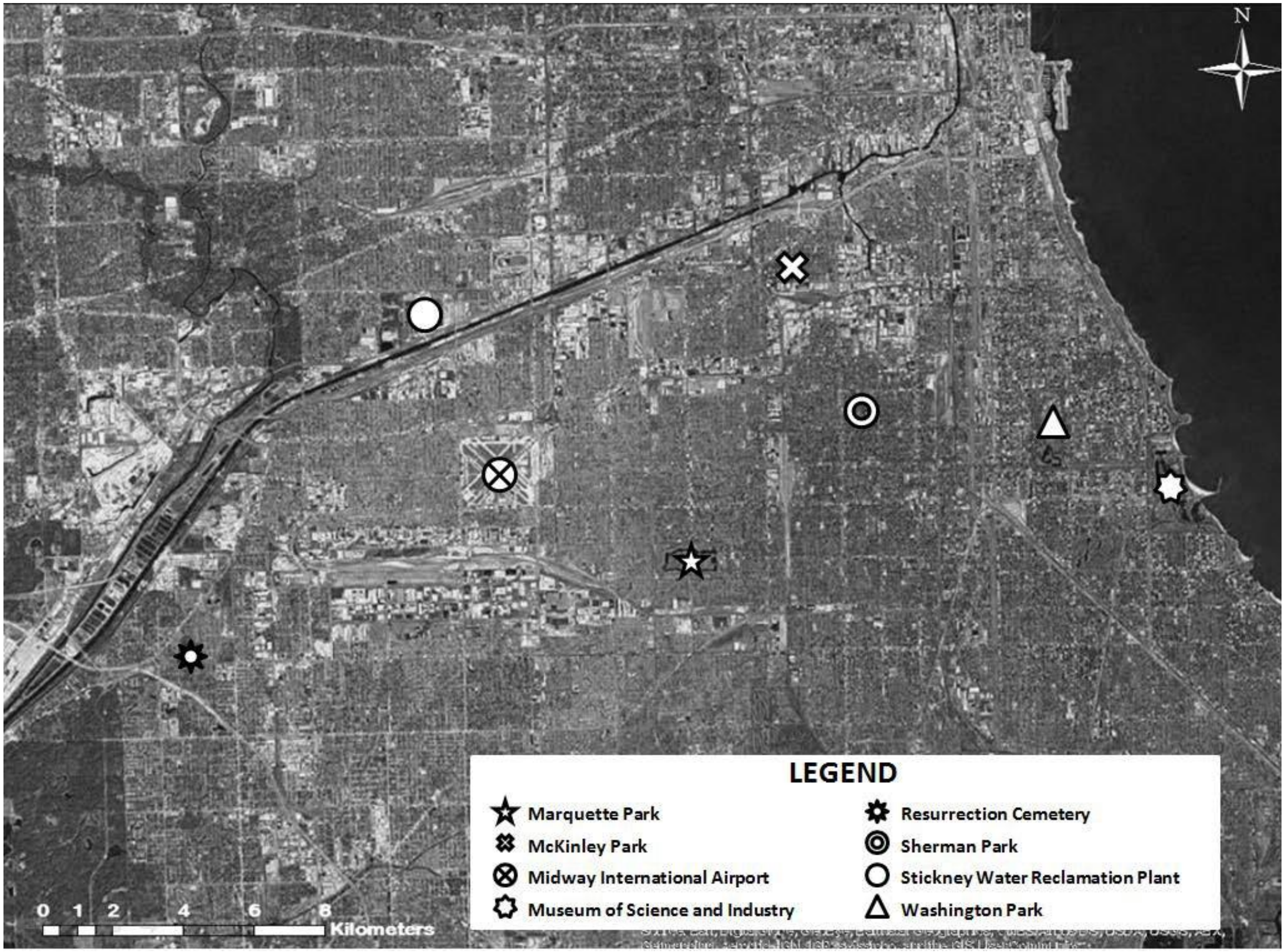

Figure 8. Main capture locations (*n* = 7) for Canada geese (*Branta canadensis*) in relation to Midway International Airport in the Greater Chicago Metropolitan Area, Illinois, USA

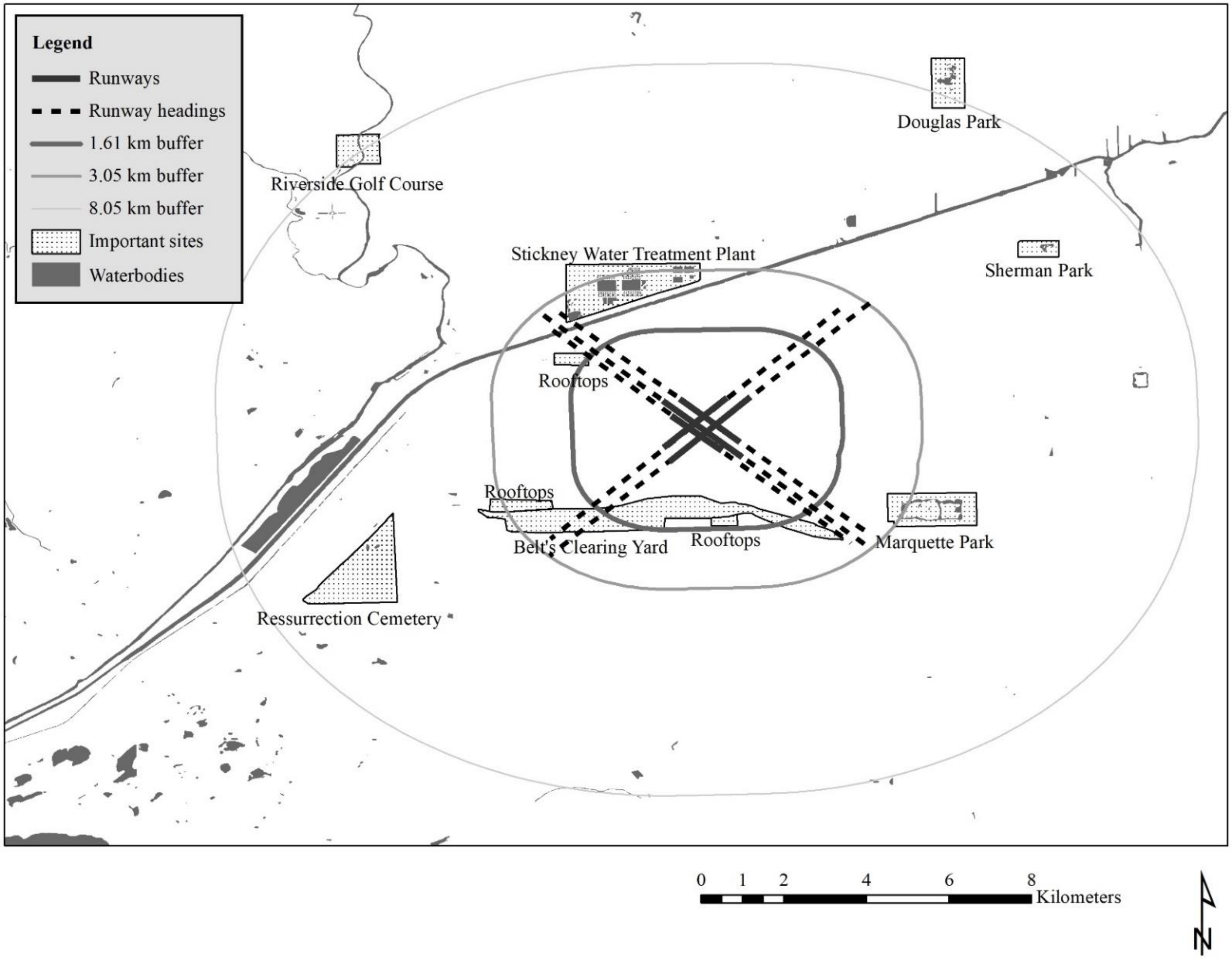

Figure 9. Map of focal air operations areas of Midway International Airport in Chicago, Illinois, USA in relation to sites of goose abundances during November 2015 – February 2016.

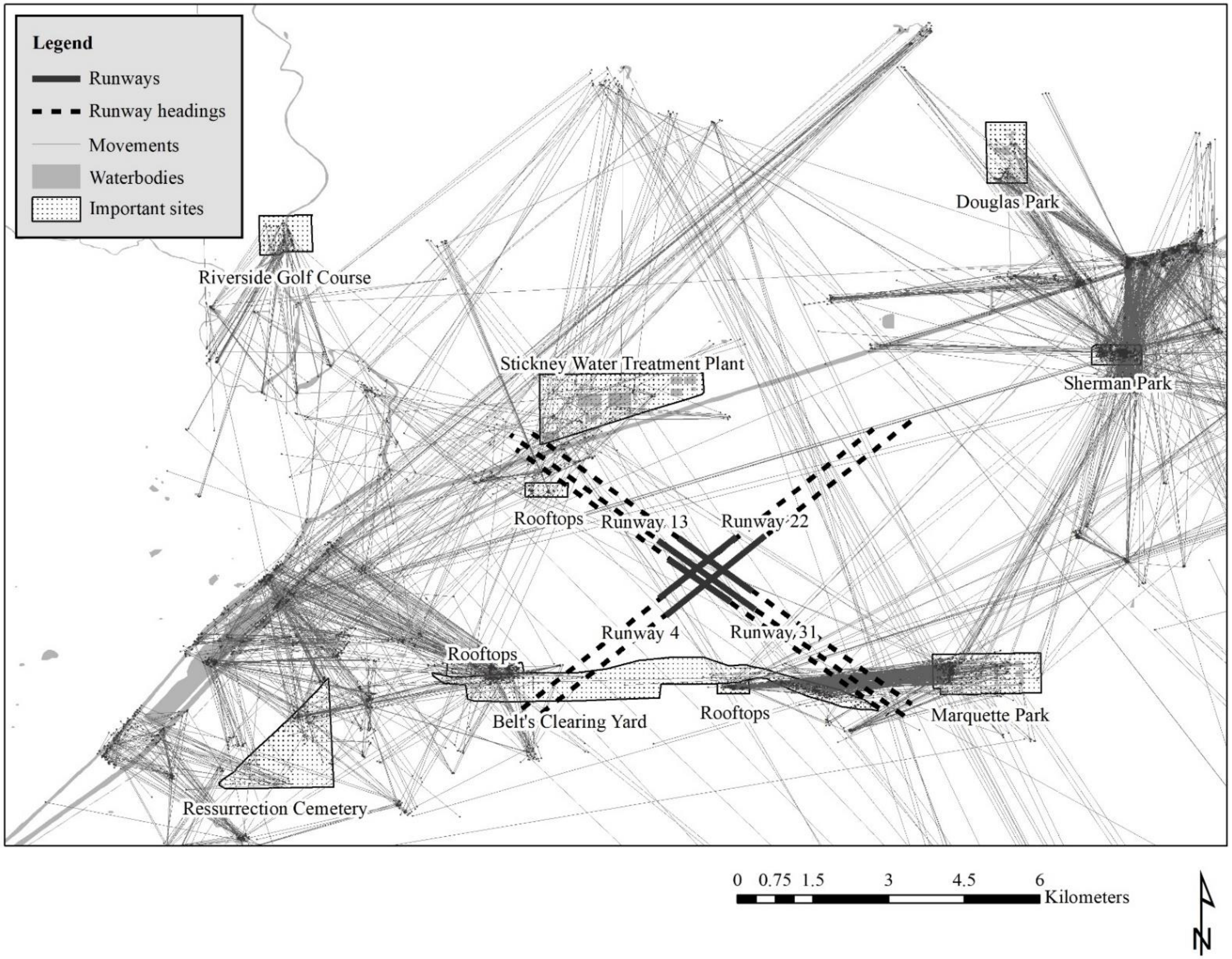

Figure 10. Map of transitional movements in relation to Midway International Airport and runway headings in Chicago, Illinois, USA during November 2015 – February 2016.

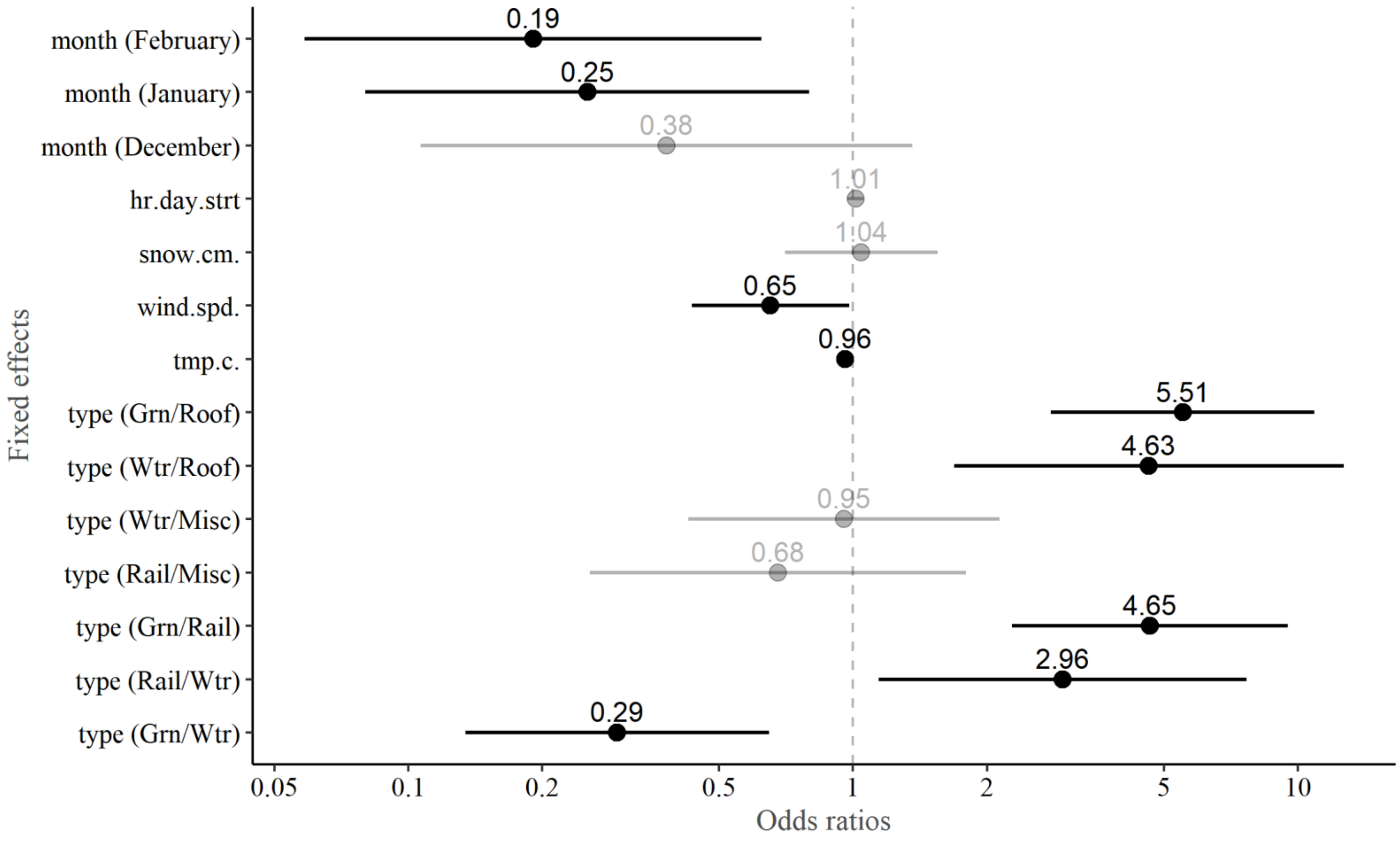

Figure 11. Best linear unbiased predictor values for fixed effects in logistic regression mixed effects models of Canada goose movements intersecting 3.05 km extensions of runway headings 13/31 at Midway International Airport in Chicago, IL, USA during November 2015 – February 2016.

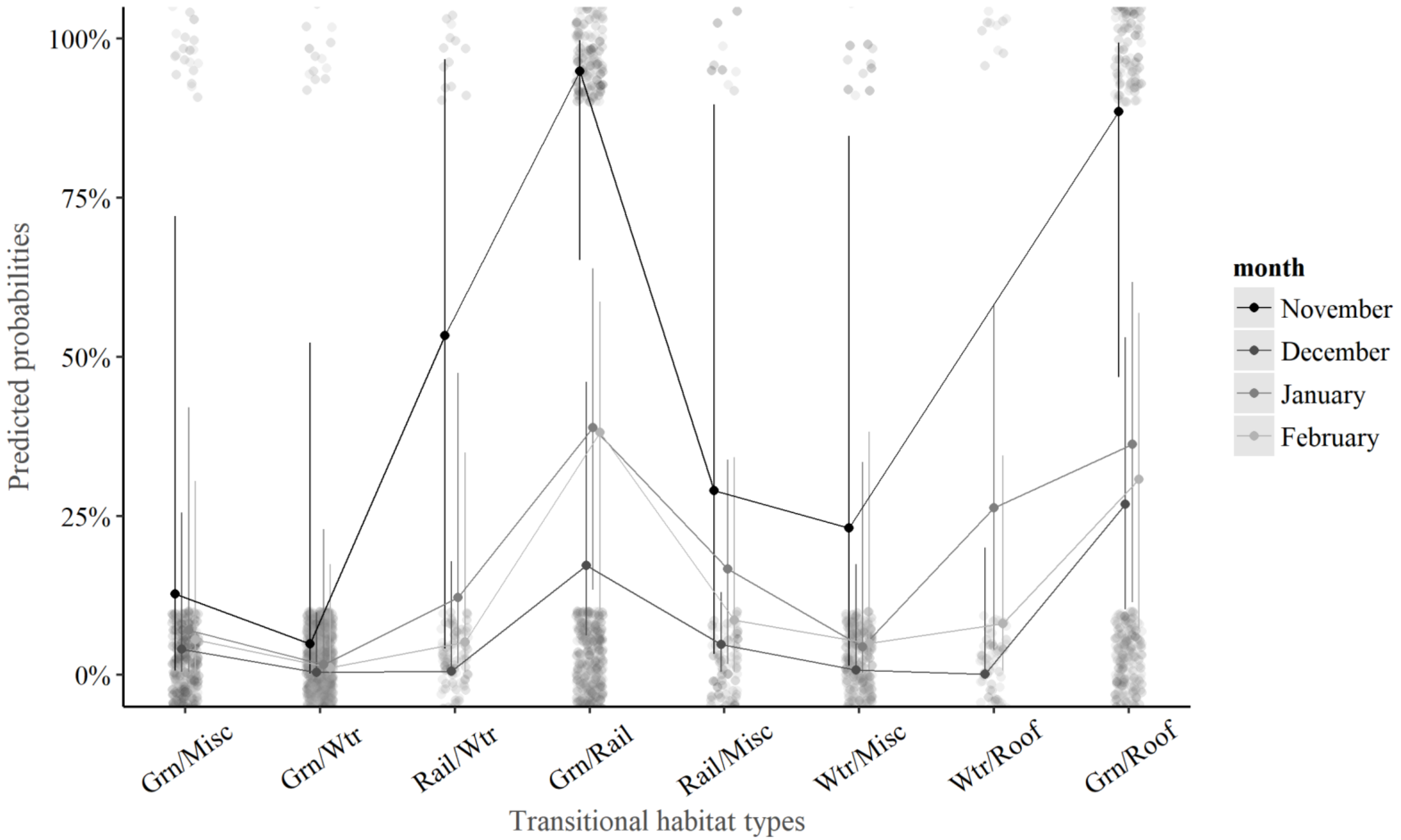

Figure 12. Predicted probabilities with 95% confidence intervals of mixed effects logistic regression model of Canada goose movements intersecting 3.05 km extensions of runway headings 13/31of Midway International Airport in Chicago, IL, USA during winter of 2015 – 2016.

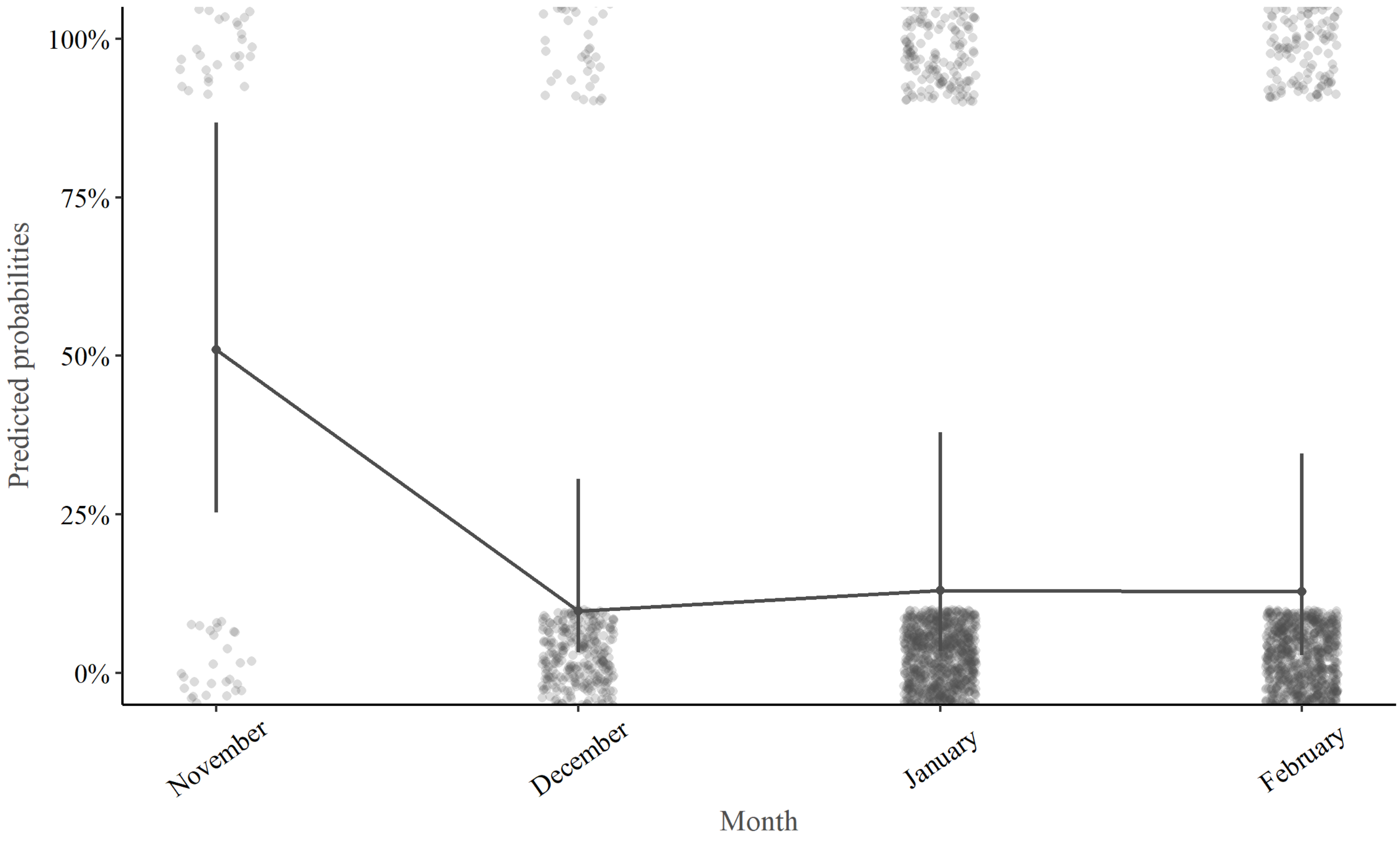

Figure 13. Predicted probabilities by month of Canada goose movement intersection with 3.05 km extensions of runway headings 13/31 at Midway International Airport in Chicago during winter of 2015 – 2016.

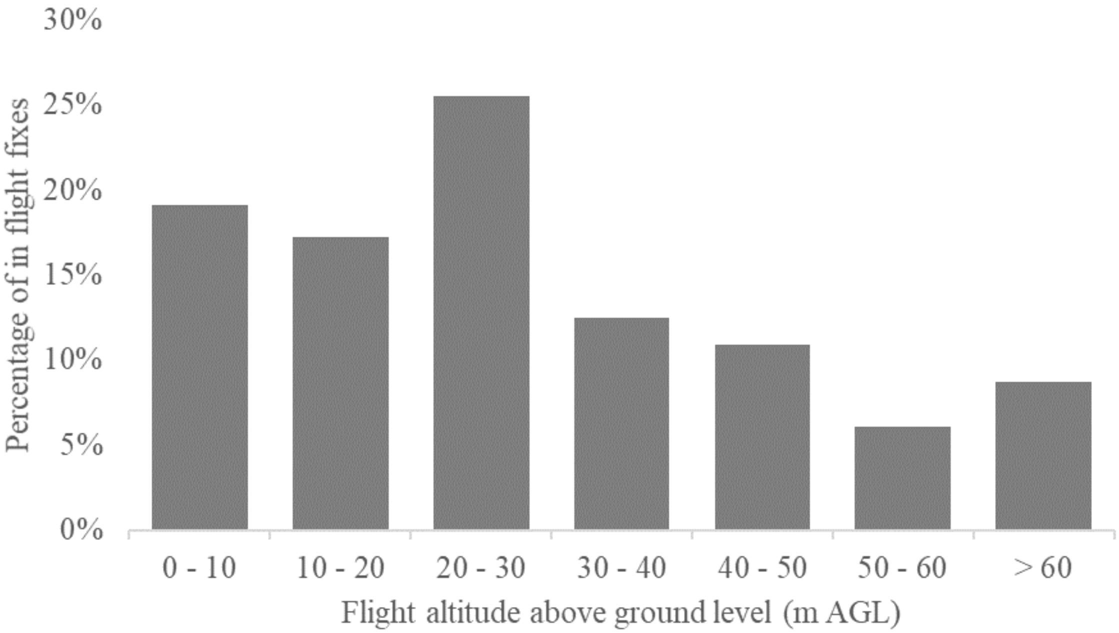

Figure 14. Percentage of in-flight GPS fixes by altitude for Canada geese in the Greater Chicago Metro Area during November 2015 – February 2016.

STUDY 135: HABITAT QUALITY FOR WETLAND BIRDS IN ILLINOIS

Objectives:

1) Estimate habitat quality of a minimum of 50 wetland and deepwater polygons during spring, summer, and autumn for focal wetland wildlife guilds of the Illinois Wetlands Campaign,
2) Develop a model to predict wetland quality for focal species of the Illinois Wetlands Campaign relative to wetland and landscape characteristics,
3) Summarize and distribute these data to agency personnel, research collaborators, the scientific community, and the general public through popular articles, oral presentations, technical reports, peer-reviewed publications, and other means.

Introduction

Although wetland quality has declined over the last 200 years due to a variety of anthropogenic influences, the rate and extent of that decline is unknown (Mitsch and Gosselink 2000). However, migratory wetland birds depend on wetlands to satisfy various habitat needs such as breeding, nesting, brood-rearing, loafing, and refueling for migration, and trends in waterbird populations often parallel the amount and quality of wetland habitat available (Weller and Spatcher 1965, Baldassarre 2014). But, wetland birds may be limited by the availability of suitable habitat during the non-breeding season (e.g. spring and autumn migrations; Morrison 2006, Skagen et al. 2008), especially in highly-modified landscapes like the midwestern United States (O'Neal et al. 2008). Data are needed to both better describe the current level of function of extant wetlands as well as establish baseline data for estimating rate of wetland degradation in the state of Illinois relative to habitat needs for wetland-dependent wildlife. Currently, National Wetland Inventory (NWI) data provide the most comprehensive source of information that can be used to quantify wetland availability and habitat suitability for wetland wildlife. However, waterbirds require functional wetland hydrology and vegetation communities that support their needs during migration. Unfortunately, NWI data do not include descriptions of water depth or seasonality of surface hydrology and assess vegetation cover broadly. Thus, NWI wetland estimates likely overestimate the amount of wetland and deepwater habitat available to wetland wildlife and lacks insight into habitat quality of available habitats, especially during spring and autumn migrations. Moreover, current wetland availability estimates in Illinois are not corrected for wetlands which have suitable hydrology and may not provide habitat of sufficient quality to be useful to many species of wetland wildlife (e.g., power plant cooling lakes, borrow pits along interstates, ponds in urban developments, etc.). A major assumption of many conservation plans is that foraging habitat is most limiting during spring and autumn migration in non-breeding regions such as Illinois (e.g., Soulliere et al. 2007). Aquatic habitats with extensive disturbance or those lacking aquatic vegetation likely provide little value as foraging habitats (Stafford et al. 2010, Hagy et al. 2017), and information to describe the actual availability of wetland habitat of suitable quality for migrating wetland bird species in Illinois is lacking.

We assessed the functional quantity (i.e., relative value to focal species of the wetland area actually inundated by water to the appropriate depths) of wetlands currently assumed to be available to waterbirds and other wetland-dependent organisms during spring, summer, and autumn in Illinois. This information can then be used to develop fine-scale wetland conservation objectives for wetland-dependent organisms at different times of the year. Moreover, an index of wetland quality can be used to estimate values (e.g., foraging habitat quality, breeding habitat quality, etc.), risk of conversion to other types or drainage, and habitat availability relative to specific taxa. Understanding the status of average wetland quality and the rate of change in wetland quality is critical for appropriate planning objectives. This study will provide estimates of current functional quality of wetlands for waterbirds allowing a more precise development of wetland enhancement and restoration implementation objectives.

Methods

We stratified Illinois by natural division and allocated survey effort in proportion to wetland density within natural divisions. We consolidated NWI polygons into 6 classes (Freshwater Pond, Lake, Freshwater Emergent [herbaceous only], Freshwater Forested/Scrub-Shrub, Riverine, and Other; hereafter NWI Wetland Type Abbreviations will be used see Table 11) based on our focal species guilds in 3 different seasons (spring [15 Feb – 15 April] – migrating waterfowl, summer [15 April – 15 June] – breeding marsh birds, and autumn [25 July – 10 September] – migrating shorebirds) (Table 12). We determined our maximum sampling effort (i.e., ~60 sites/season) given temporal and monetary constraints and used total wetland area to determine the number of sample plots in each natural division with Neyman allocation. We then used the Reversed Randomized Quadrant-Recursive Raster tool in ArcMap (ESRI 2011) to assign plot locations within wetland area outlined by the NWI inside each natural division, which created a more spatially-balanced sample population than simple random allocation. We also generated a second set of plots using the same methodology which served as a backup sample population if a primary plot could not be sampled due to landowner permission or safety logistics. We established 25-ha plots as sample units on both public and private land, and after receiving landowner permission, we selected approximately 60 plots and conducted intensive ground surveys (Fig. 15). At times, plots were modified based on landowner permission, but most plots (90%) achieved the size of 25 ha. During 2015, aerial photographs were obtained from 2,000–4,500 ft above ground level for later digitizing of inundation boundaries and wetland habitat classification for comparison with ground surveys to see if blind-digitizing methods could be used to increase sample sizes of plots. However, we conducted a digitization experiment in autumn 2015 where field personnel blindly digitized habitat boundaries that were surveyed by a different individual on the ground. Digitizing error rates were deemed excessive (4–11% mean error) and wetland classification errors were frequent (Hagy et al. 2016). Due to classification errors, we did not utilize aerial imagery without ground truthing for 2016 and 2017. We conducted ground surveys within the following natural divisions: Grand Prairie, and Middle Mississippi River Borders natural divisions; the Rock River Hill Country and the Wisconsin Driftless divisions; the Illinois / Mississippi River Sand Areas; Major Water Bodies; and the Upper Mississippi / Illinois River Bottomlands natural division (Fig. 15).

During ground reconnaissance, we traveled along surface inundation boundaries within or around each NWI polygon (e.g., emergent, forested/scrub-shrub, lake, pond, riverine, or other; Table 11), tracked water and vegetation boundaries using GPS units, and recorded surface water and vegetation coverage as a percentage of each polygon using visual estimation. For each NWI polygon (e.g. Fig. 15), we recorded proportion of inundated area with shallow inundation (i.e. <45 cm deep; maximum foraging depth of dabbling ducks); coverage of dense emergent (e.g., cattail [*Typha* spp.]), herbaceous (e.g., moist-soil vegetation), submersed and floating-leaved aquatic vegetation; and other habitat characteristics. We estimated the proportion of each polygon containing mudflats, as well as the proportion of each polygon with very shallow inundation (i.e., <10 cm; maximum foraging depth for medium to large shorebirds) with sparse vegetation cover (i.e., <30%). We also recorded management practices (e.g., mowing, burning, food plots, etc.), and observers noted potential hydrological and wetland habitat stressors (e.g., levees, invasive species, drainage ditches, etc.). In 2015, we assessed wetland vegetation community composition and condition using a modified version of the Environmental Protection

Agency's National Wetland Condition Assessment rapid assessment method (USA-RAM; Gray et al. 2012). In 2016 and 2017, we used a modified version of the Ohio Rapid Assessment Method (ORAM) Version 5.0 (Mack 2001) to include metrics to evaluate wetland quality and integrity with an emphasis on anthropogenic disturbance. We will use the modified-ORAM and the USA-RAM in 2015 to compare habitat quality for waterbirds between the wetland plots and wetland polygon types.

In the field, we digitized wetland plot inundation and vegetation cover from our GPS tracks and field notes using ArcMap (ESRI 2011) (Fig. 16). Since the majority of sites were visited in spring, summer and autumn, there were approximately 1,000 sites to digitize (e.g., ~60 sites * 3 seasons * 2 agencies * 3 years). The 2015 sites will be completed by the SIU-counterpart John O'Connell in spring of 2018 or soon thereafter. The digitized cover maps of the plots will be used in comparison with visual estimation methods and as a measure of local land-use (i.e., within 25-ha plots) and will be a part of the wetland quantity and quality modeling process.

Wetland characteristics, such as emergent vegetation, surface water seasonality and depth, as well as surrounding landscape can influence animal occupancy rates of wetland complexes. But, associations with intrinsic and extrinsic factors are highly variable in the Midwest, perhaps because habitat is limited (Bolenbaugh et al. 2011). Thus, we considered both intrinsic and extrinsic wetland characteristics as influencing wetland quality and bird use. As intrinsic vegetation characteristics may be less important than wetland surroundings (DeLuca et al. 2004) and size (Brown and Dinsmore 1986) in site occupancy of some species (e.g., waterbirds), we will use ArcMap (ESRI 2011) and available imagery and land-use data (e.g., National Land Cover Database, Homer et al. 2015) to characterize the landscape around each wetland. We will evaluate parameters such as wetland isolation, surrounding buffer characteristics, proximity to developed areas, intensity of surrounding land-use and other factors using available spatial data.

To develop a model to predict wetland quality for focal species of the Illinois Wetlands Campaign relative to wetland and landscape characteristics, we will model intrinsic (i.e., wetland stressors, management, ORAM score etc.) and extrinsic (i.e., surrounding land-use and landscape characteristics) characteristics relative to waterbird habitat quality metrics (e.g., surface water inundation, shallow inundation, vegetation cover and structure, etc.). This and the surrounding landscape analysis work is ongoing and will be completed by summer 2018.

To determine waterbird use of wetlands and develop occupancy models relative to wetland availability and quality, we conducted waterbird surveys for focal waterbird guilds (Table 12). During spring, (i.e., the critical period for dabbling ducks; Feb 15 – mid-April), we conducted three rounds of aerial surveys at two-week intervals spanning spring migration. An aerial observer identified and enumerated waterfowl and other waterbirds as possible by making two or more low-altitude passes over each 25-ha plot in a low-winged aircraft at speeds of approximately 240 kph (Havera 1999). The aerial observer also recorded the habitat type the waterbirds were located in to help determine occupancy by NWI wetland type. In summer (i.e., summer; mid-April – early-June), we conducted call-response surveys for the focal group of secretive marsh birds at a subset of sites with dense persistent emergent vegetation (e.g., *Typha* spp.). During autumn, we conducted shorebird surveys at a subset of plots with exposed mudflats following the aerial survey protocol. During surveys, an observer enumerated shorebirds and split them into body-size classes: small (i.e., peeps and small sandpipers) and large (i.e., Killdeer, *Charadrius vociferus* and larger). Additionally, during ground surveys in all three seasons, we recorded wetland bird abundances through flush counts for comparison with aerial surveys for waterfowl and shorebirds and call-response surveys for secretive marsh birds. We intend to analyze and model factors affecting wetland quality and occupancy by focal species during FY2018.

Results and Discussion

In 2017, we completed fieldwork by mid-September, and approximately 60 sites were visited by both INHS and SIU during spring, summer, and autumn (Table 13). The most common wetland types we encountered during surveys was forested/scrub-Shrub wetlands, followed by emergent, pond, lake, then riverine wetlands (Table 14). As in 2016, we collected data in the field using Archer Units (Juniper System, Version 1 and 2) with global positioning system (GPS) capabilities rather than the GPS's (Garmin GPSMAP 64) that were used in the first year of the project. The Archer Units offered enhanced data collection capabilities (e.g., collecting electronic data, taking photographs), and they enhanced processing data and wetland digitization. Thus far, digitizing for 2016 and 2017 is approximately 80% completed and the estimated completion is January of 2018.

Spring

During ground surveys during mid-February – mid-April 2017, most NWI polygons located within plots were partially inundated according to field estimates; however, average inundation for forested/scrub-shrub and emergent wetlands, important dabbling duck habitat during migration, was <50% (i.e., 31.8% and 45.5% respectively) (Table 15). Many wetland polygons had low percentage of shallowly inundated (<45 cm) habitats. For instance, average cover of shallowly inundated emergent wetland was 33.5%, but we noted high variation (SD) among wetlands. Average cover of non-persistent emergent vegetation and submerged and floating-leaved aquatic vegetation (i.e., aquatic bed) was 4.2% and 3.0% across all polygons with slightly higher levels in emergent wetlands (i.e., 11.9% and 3.0%) (Table 15).

We completed 8 of 9 (88.9%) aerial waterfowl surveys during spring (i.e., 17 February – 13 April); one flight was missed due to weather. We aerially surveyed 102 plots two to three times with surveys at approximately 2-week intervals. We observed 12,324 waterbirds, of which, dabbling ducks were the most numerous (7,768). Mallards (*Anas platyrhynchos*) were the most common species observed (i.e., present in 18.1% of polygons and in 35.2% of plots) followed by American green-winged teal (*Anas crecca*; present in <5% of polygons) (Tables 16-17). Besides dabbling ducks, we observed 1,969 diving ducks, 1,636 geese, and 951 other waterbirds (e.g., herons and egrets [*Ardea* spp.], American coots [*Fulica americana]*, etc.). We detected waterbirds at approximately 30% of monitored NWI polygons, and 73.5% of surveyed plots held waterbirds in at least one survey. Dabbling duck abundances were highest in emergent, pond, and lake polygons (Table 17) and occurred in approximately a quarter of emergent and pond polygons (i.e., 25.0% and 25.6% respectively) and were present in nearly half (i.e. 48%) of lake polygons. Dabbling ducks were rarely observed in forested/scrub-shrub and riverine wetlands (i.e., 13.4% and 12.8%, respectively), but further analysis is needed to assess whether covariates such as wind-speed, surface water, or canopy cover may have influenced waterbird occupancy or the observer's ability to detect waterbirds in forested wetlands. We observed diving ducks, geese, and other waterbirds most frequently and in highest numbers in lake wetlands (Table 17). Additionally, during ground survey flush counts in spring, we observed 5,728 total waterbirds, of which 4,470 (78%) were dabbling ducks, 289 (5%) were secretive marsh birds, and 175 (3%) were shorebirds (Tables 16 and 18). Additional analyses will relate waterbird detections to management practices, percent surface water, and vegetative cover.

Summer

During mid-April – mid-June 2017, we randomly substituted 50.0% of plots dominated by forested polygons with emergent wetland polygons. We did this by increasing the inclusion probability of emergent wetland polygons, as classified by NWI, in the ArcGIS RRQRR tool (ESRI 2011) to better encompass migrating and breeding marsh bird habitat, our focal guild during this period. The summer survey had greater average inundation across polygons (i.e., 79.0%), and average inundation in emergent polygons, considered important for secretive marsh birds, was 62.6%. Cover of dense persistent emergent vegetation was relatively low overall at 3.4% and 6.4% in emergent polygons (Table 15).

We monitored marsh birds at 25 sites with flooded dense persistent emergent vegetation. Within the 25 sites, we conducted call-back surveys at 39 points and repeated these surveys 3 times at biweekly intervals. We detected 128 soras (*Porzana carolina*), 6 American coots (*Fulica americana*), 7 Virginia rails (*Rallus limicola*), 5 pied-billed grebes (*Podilymbus podiceps*), and 3 American bitterns (*Botaurus lentiginosus*) within survey plots (Table 19). Please see the Marsh Bird Project annual report for further information (Bradshaw et al. 2017). Additionally, during ground surveillance, we encountered 152 secretive marsh birds, of which, 64 (42%) were soras and 68 (45%) were American coots (Tables 16 and 18).

Autumn

Inundation was lowest overall in autumn, with average inundation of 53.0% (Table 15). Mudflats comprised a very low proportion of surveyed polygons with the greatest extent (3.8%) occurring in lake polygons. In addition to mudflats, shallowly inundated wetlands that provided shorebird foraging habitat averaged 3.1% of polygons, and we observed the greatest extent of shallow water in lake and emergent wetlands (7.0% and 3.2% respectively, Table 15).

We conducted aerial surveys of shorebirds during August – mid-September at a subset of sites (n=10) in 2016 and 2017 within the Illinois River Valley that contained mudflats during site visits. We completed 4 flights in 2016 and 5 flights in 2017 (Table 20). In 2016, 370 large and 890 small shorebirds were identified in plots, whereas, in 2017, we observed 675 large and 1,123 small shorebirds within plots. Additionally, we incidentally observed 884 shorebirds, of which, 269 (30.4%) were killdeer (*Charadrius vociferus*), 66 (7.5%) yellowlegs (*Tringa* spp.), and 354 (40.0%) were unknown sandpipers (Family Scolopacidae) (Tables 16 and 18).

Following data entry and error checking, we will continue data analyses. We will determine quality of wetland habitats using waterbird quality metrics (e.g., shallow inundation, vegetation communities) and determine intrinsic (e.g., wetland management, stressors) and extrinsic (e.g., surrounding land-use and landscape characteristics) factors that influence wetland quality for waterbirds to develop an index of wetland quality for waterbirds in Illinois. We intend to develop occupancy models for important waterbird guilds outlined in the Illinois Wetlands Campaign and determine intrinsic and extrinsic factors influencing waterbird occupancy and determine whether waterbird use is correlated with important waterbird metrics.

Table 11. Wetland classifications types used in analyses during wetland monitoring in Illinois, 2015–2017. For more information, see the National Wetlands Inventory Mapper (https://www.fws.gov/wetlands/data/Mapper-Wetlands-Legend.html).

Wetland type	NWI code	Cowardin System	Description
Forested/Shrub-scrub	PFO, PSS	Palustrine forested and/or palustrine scrub-shrub	Forested swamp or wetland shrub bog or other wetland with 30% woody vegetation cover >1 meter in height
Emergent	PEM	Palustrine emergent	Herbaceous march, fen, swale and wet meadow, non-woody
Pond	PUB, PAB	Palustrine unconsolidated bottom, palustrine aquatic bed	Pond, small wetland with open water or aquatic bed vegetation only
Riverine	R	Riverine wetland and deepwater	River or stream channel
Lake	L	Lacustrine wetland and deepwater	Lake or reservoir basin
Other	Misc.	Palustrine wetland	Farmed wetland, ditches, saline seep, and other misc. wetland

Table 12. Monitoring periods for focal waterbird groups evaluated at randomly selected wetland plots in Illinois during 2017.

Focal species	Critical period	Range (field surveys)
Dabbling Ducks	Spring	February 15th–mid-April
Marsh Birds	Spring	Mid-April–15th June
Shorebirds	Spring	Mid-April–15th June
	Autumn	End of July–15th September

Table 13. Distribution of wetland monitoring effort in Illinois by season and agency (Illinois Natural History Survey [INHS] and Southern Illinois University [SIU]) during spring, summer, and autumn 2017.

Season	Sites (25-ha plots)	INHS	SIU
Spring	121	58	63
Summer	122	59	63
Autumn	121	58	63

Table 14. Number of National Wetlands Inventory (NWI) cover types (vegetation class) monitored during 2017. Note, we replaced a subset of plots in spring and selected plots with a higher inclusion of emergent sites for summer and autumn, as the focal waterbird guilds (i.e., marsh birds and shorebirds) actively avoid forested wetland types.

Season	NWI(Class)	Overall (n)	INHS	SIU
Spring	Emergent	58	30	28
	Forested/Scrub-shrub	92	40	52
	Lake	37	26	11
	Pond	38	20	18
	Riverine	18	12	6
	Total	243	128	115
Summer	Emergent	72	35	37
	Forested/Scrub-shrub	90	40	50
	Lake	38	25	13
	Pond	38	20	18
	Riverine	16	12	4
	Total	254	132	122
Autumn	Emergent	70	33	37
	Forested/Scrub-shrub	89	38	51
	Lake	41	27	14
	Pond	39	20	19
	Riverine	15	11	4
	Total	254	129	125

Table 15. Proportion (visual estimates) of inundation, shallow water, and important vegetation cover types during 2017 (spring, summer, and autumn) in Illinois (mean±SD). Aquatic bed includes submerged aquatic vegetation (e.g., coontail; *Ceratophyllum demersum*) and floating-leaved aquatic vegetation (e.g., American pondweed; *Potamogeton nodosus*). Non-persistent emergent includes moist-soil vegetation (e.g., smartweed; *Polygonum* spp.), while persistent emergent vegetation includes cattails (e.g., *Typha* spp.). Mudflats are areas of exposed saturated mud with sparse vegetation cover (i.e., <30%), and shorebird habitat includes mudflats and very shallow inundation (i.e., <10cm).

Season	NWI(Class)	n	Inundated polygons (%)	Mean inundation (%)	Shallow <45 cm	Aquatic bed	Non-pers. emergent	Pers. emergent	Mudflats	Shorebird habitat
Spring	Emergent	58	87.9	45.5±34.9	33.5±27.1	3.0±7.4	11.9±19.7	7.0±14.0	0.6±1.6	1.8±5.4
	Forested/Scrub-shrub	92	90.2	31.8±31.1	19.3±21.8	1.2±5.2	1.6±5.1	1.1±4.8	0.5±1.7	1.1±5.5
	Lake	37	97.3	87.4±22.0	28.1±23.4	5.0±15.5	1.2±2.6	1.7±3.7	1.6±4.0	5.4±8.5
	Pond	38	100.0	85.9±23.5	31.3±25.3	5.7±12.1	5.0±12.0	3.9±16.2	1.5±6.6	3.3±6.9
	Riverine	18	100.0	90.4±12.4	21.5±24.2	0.2±0.9	1.6±3.9	0.7±2.8	1.5±4.8	4.9±12.8
	Total	238	95.1	68.2±37.5	26.7±27.3	3.0±8.9	4.2±15.6	2.9±10.0	1.2±3.5	3.3±7.2
Summer	Emergent	72	95.8	62.6±33.7	29.8±22.8	5.8±13.8	17.5±19.6	6.4±11.0	1.9±8.3	1.5±6.4
	Forested/Scrub-shrub	90	96.7	56.0±36.5	18.2±21.6	1.6±5.3	6.8±12.2	1.4±5.5	0.1±0.4	0.1±0.5
	Lake	38	100.0	94.0±15.2	8.7±14.4	6.0±13.7	3.6±7.4	1.4±3.4	0.1±0.6	0.9±4.1
	Pond	38	97.4	87.0±24.1	17.0±21.3	15.3±26.4	7.4±14.3	4.2±15.7	0.0±0.2	1.0±5.7
	Riverine	16	100.0	95.1±10.2	11.9±25.3	0	2.4±5.4	3.4±9.8	0.1±0.3	0.1±0.2
	Total	254	98.0	79.0±32.3	17.9±38.1	5.7±15.2	7.5±17.8	3.4±11.0	0.4±4.1	0.7±3.9
Autumn	Emergent	70	80.0	26.3±29.2	16.6±19.4	4.6±12.1	5.6±11.6	3.2±7.8	1.8±6.2	3.2±9.6
	Forested/Scrub-shrub	89	82.0	15.6±21.8	7.9±10.5	1.9±7.5	1.4±4.3	0.5±1.6	0.9±2.0	1.1±2.2
	Lake	41	97.6	77.6±24.1	30.0±23.0	9.2±18.0	3.0±5.2	1.1±2.5	3.1±6.5	7.0±11.8
	Pond	39	84.6	62.5±37.0	20.8±22.0	18.0±25.7	2.0±4.8	2.6±9.7	1.8±6.3	2.8±7.7
	Riverine	15	100.0	83.1±18.2	28.2±28.0	3.4±12.4	1.9±4.7	2.7±7.2	0.2±0.4	1.5±3.8
	Total	254	88.8	53.0±38.2	20.7±22.9	7.4±18.0	2.8±9.7	2.0±6.9	1.6±4.8	3.1±8.8

Table 16. Scientific names and abbreviations of waterbird taxa and guilds identified during spring aerial wetland surveys and flush counts[a] during ground surveys in spring, summer, and autumn in Illinois during 2017.

Common Name/Species Group	Scientific Name	Abbreviation
Dabbling ducks		
American green-winged teal	*Anas crecca*	AGWT
American wigeon	*Mareca americana*	AMWI
Blue-winged teal	*Spatula discors*	BWTE
Gadwall	*Mareca strepera*	GADW
Mallard	*Anas platyrhynchos*	MALL
Northern pintail	*Anas acuta*	NOPI
Northern shoveler	*Spatula clypeata*	NSHO
Wood duck	*Aix sponsa*	WODU
Diving ducks		
Bufflehead	*Bucephala albeola*	BUFF
Canvasback	*Aythya valisineria*	CANV
Common goldeneye	*Bucephala clangula*	COGO
Common merganser[a]	*Mergus merganser*	COME
Lesser scaup	*Aythya affinis*	LESC
Redhead[a]	*Aythya americana*	REDH
Ring-necked duck	*Aythya collaris*	RNDU
Ruddy duck	*Oxyura jamaicensis*	RUDU
Other waterfowl		
Canada goose	*Branta canadensis*	CAGO
Snow goose	*Chen caerulescens*	LSGO
Swan	*Cygnus* spp.	SWAN
Marsh birds		
American bittern[a]	*Botaurus lentiginosus*	AMBI
American coot	*Fulica americana*	AMCO
Common gallinule[a]	*Gallinula galeata*	COGA
Least bittern[a]	*Ixobrychus exilis*	LEBI
Pied-billed grebe[a]	*Podilymbus podiceps*	PBGR
Sora[a]	*Porzana carolina*	SORA
Virginia rail[a]	*Rallus limicola*	VIRA
Shorebirds		
American woodcock[a]	*Scolopax minor*	AMWO
Black-necked stilt[a]	*Himantopus mexicanus*	BNST
Greater yellowlegs[a]	*Tringa melanoleuca*	GRYE
Killdeer[a]	*Charadrius vociferus*	KILL

Least sandpiper[a]	*Calidris minutilla*	LESA
Lesser yellowlegs[a]	*Tringa flavipes*	LEYE
Pectoral sandpiper[a]	*Calidris melanotos*	PESA
Semipalmated plover[a]	*Charadrius semipalmatus*	SEPL
Snipe[a]	*Gallinago* spp.	SNIPE
Solitary sandpiper[a]	*Tringa solitaria*	SOSA
Spotted sandpiper[a]	*Actitis macularius*	SPSA
Other waterbirds		
American white pelican	*Pelecanus erythrorhynchos*	AWPE
Black-crowned night heron[a]	*Nycticorax nycticorax*	BCNH
Belted kingfisher[a]	*Megaceryle alcyon*	BEKI
Double-crested cormorant	*Phalacrocorax auritus*	DCCO
Great blue heron	*Ardea herodias*	GBHE
Great egret[a]	*Ardea alba*	GREG
Green heron[a]	*Butorides virescens*	GRHE
Gull	Family: Laridae	GULL
Little blue heron[a]	*Egretta caerulea*	LBHE
Sandhill crane	*Grus canadensis*	SACR
Snowy egret[a]	*Egretta thula*	SNEG
Yellow-crowned night heron[a]	*Nyctanassa violacea*	YCNH

[a] Waterbirds observed only during flush counts during spring, summer, or autumn 2017.

Table 17. Waterbird abundance estimates from aerial surveys separated by National Wetlands Inventory (NWI) classifications during spring 2017 in Illinois. We tallied waterbirds within the habitat type they were observed and later cross-referenced habitat types with the NWI wetlands present in plots.

Waterbird guild/species	Emergent (n=120)	Forested/scrub-shrub (n=193)	Lake (n=83)	New (n=62)	Pond (n=82)	Riverine (n=39)	Total (n=579)
Dabbling ducks	2,626	428	1,558	900	2,156	100	7,768
AGWT	715	10	266	250	192	0	1,433
AMWI	0	0	0	5	0	0	5
BWTE	20	5	14	500	99	0	638
GADW	0	20	0	15	90	0	125
MALL	1,766	371	880	130	1,693	97	4,937
NOPI	45	0	60	0	20	0	125
NSHO	80	0	296	0	43	0	419
WODU	0	22	42	0	19	3	86
Diving ducks	260	5	1,572	0	52	80	1,969
BUFF	0	0	93	0	0	5	98
CANV	0	0	54	0	0	0	54
COGO	0	0	5	0	0	0	5
LESC	150	0	908	0	0	0	1,058
RNDU	90	0	350	0	52	60	552
RUDU	20	5	162	0	0	15	202
Geese	122	16	1,212	34	208	44	1,636
CAGO	118	14	212	34	207	44	629
LSGO	4	2	1,000	0	1	0	1,007
Other waterbirds	155	124	612	21	8	31	951
AMCO	128	80	127	0	0	30	365
AWPE	0	0	210	20	0	0	230
DCCO	0	20	4	0	0	0	24
GBHE	6	4	2	0	3	1	16
GULL	20	20	268	0	5	0	313
SACR	1	0	1	0	0	0	2
SWAN	0	0	0	1	0	0	1

Table 18. Waterbird abundance estimates by guild from flush counts during spring, summer, and autumn 2017 in Illinois.

Season	Dabbling ducks	Diving ducks	Total waterfowl	Marsh birds	Shorebirds	Other waterbirds	Total waterbirds
Spring	4,470	496	5,521	289	175	338	6,363
Summer	815	15	1,471	152	248	208	2,080
Autumn	658	0	884	20	884	1,363	3,151

Table 19. Marsh bird detections from call-response surveys during summer 2017 (mid-April–mid-June).

Species	Detections
American Bittern	3
American Coot	6
Black Rail	0
Common Gallinule	1
King Rail	0
Least Bittern	9
Pied-billed Grebe	5
Sora	128
Virginia Rail	7
Yellow Rail	0
Total	159

Table 20. Aerial shorebird abundance estimates by size class[a] during August, 2016–2017. We monitored 25-ha plots (n=10) with potential shorebird habitat (e.g. exposed mudflats and shallow inundation <10 cm) that were located within the Illinois River Valley.

Year	Weekly flights	Large	Small
2016	4	370	890
2017	5	675	1,123

[a] Small (i.e., peeps and small sandpipers) and large (i.e., Killdeer, *Charadrius vociferus* and larger).

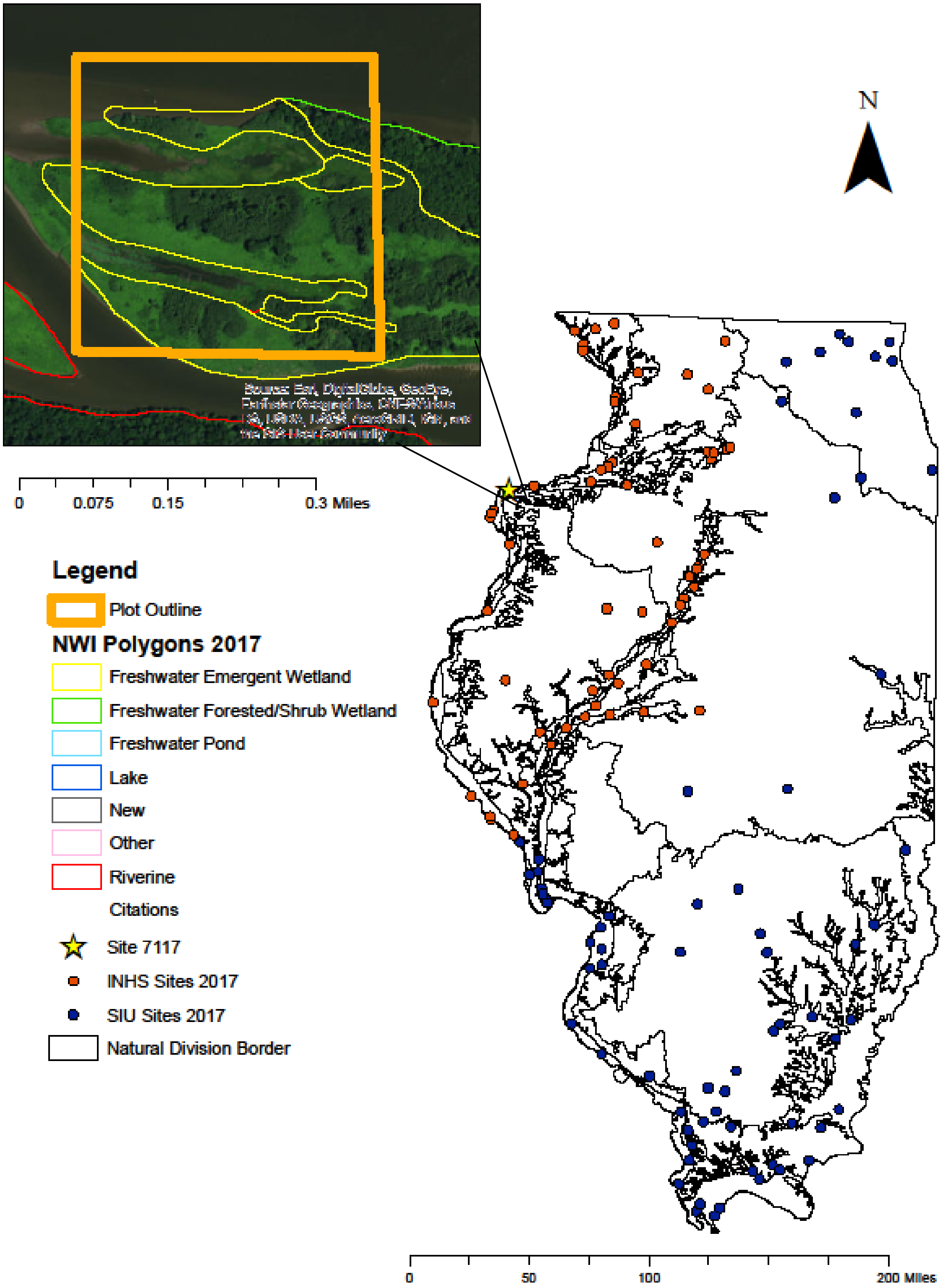

Figure 15. Example plot (Site 7117) with National Wetlands Inventory polygons (emergent, forested/scrub-shrub, and riverine) and 2017 site locations within Illinois Natural Divisions and agencies (INHS and SIU).

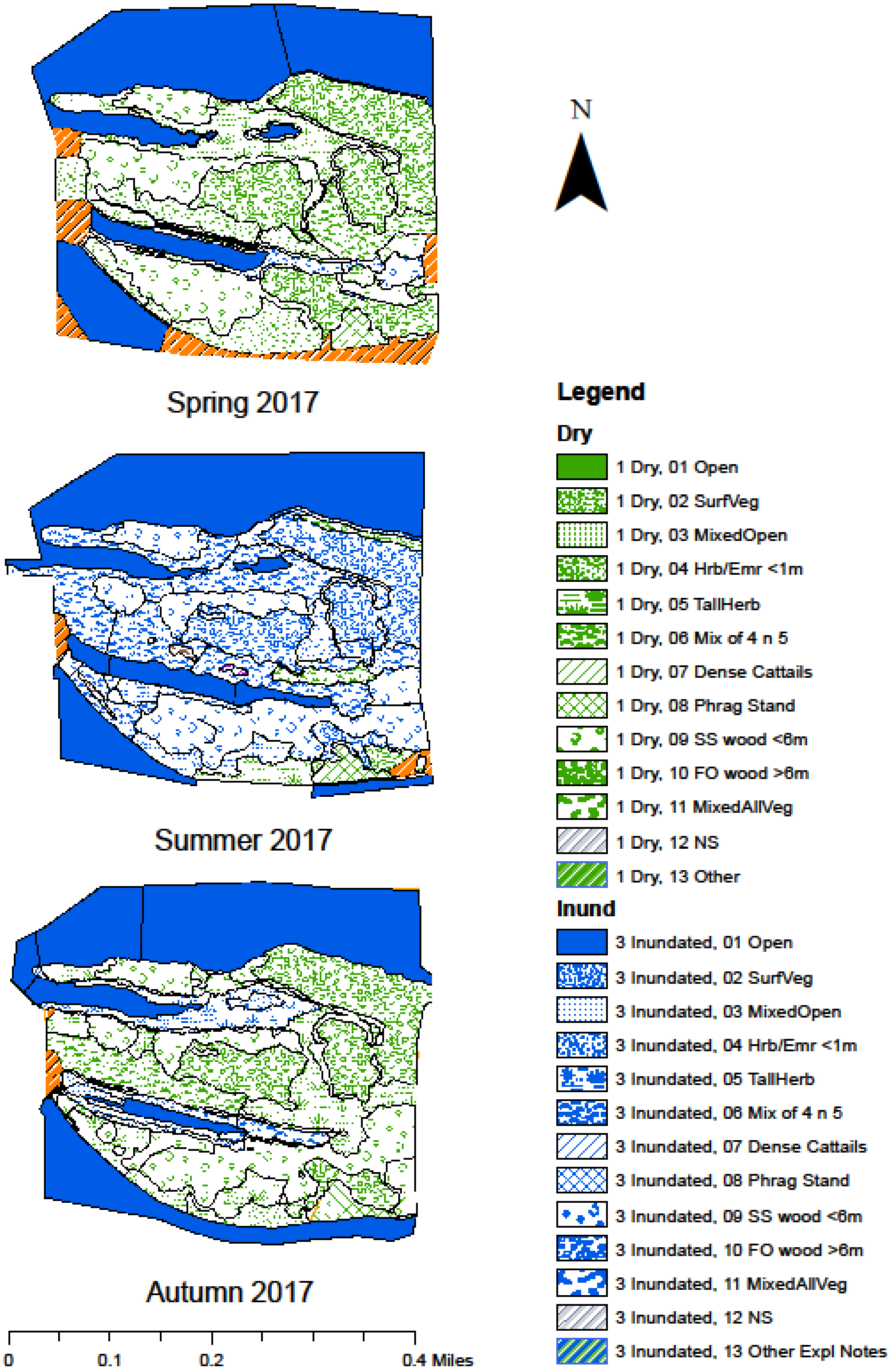

Figure 16. Digitized maps for site 7117 for spring, summer, and autumn 2017.

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Disclaimer

Any opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of TNC, USFWS, IDNR, or other organizations that supported this research.

Submitted by:

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Date: 17 December 2017

Appendix 1. 2016 Autumn Shorebird Inventories of the Central Illinois River by Date and Location

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL - AERIAL SHOREBIRD SURVEY

Date: August 3, 2016		Observer: Aaron Yetter		
LOCATION	% Wet	Big (Killdeer and Up)	Small (Pect's and under)	TOTAL
Turner Lake	95	20	0	20
Lake Depue	95	0	0	0
Coleman Lake	100	0	0	0
Bureau Ponds	10	0	0	0
Goose Lake	60	240	1,595	1,835
Senachwine Lake	95	180	340	520
Hennepin/Hopper	100	0	0	0
Swan Lake	50	100	740	840
Sawmill Lake	95	5	5	10
Billsbach Lake	90	10	55	65
Weis Lake	90	0	110	110
Sparland	95	0	0	0
Wightman Lake	95	0	0	0
Sawyer Slough	90	20	0	20
Hitchcock Slough	95	15	10	25
Babbs Slough	99	5	5	10
Meadow Lake	95	10	0	10
Douglas Lake	50	460	1,615	2,075
Goose Lake	90	460	670	1,130
Upper Peoria	99	0	15	15
Lower Peoria	99	0	35	35
Pekin Lake	100	0	5	5
Powerton Lake	100	0	0	0
Spring Lake	100	0	0	0
Spring Lake Bottoms	5	0	0	0
Goose Lake	80	0	0	0
Rice Lake	90	10	0	10
Big Lake	80	75	360	435
Banner Marsh	100	0	5	5
Duck Creek	100	0	0	0
Clear Lake	95	75	5	80
North Pool	80	1,800	1,360	3,160
South Pool	90	1,270	830	2,100
Quiver Lake	80	30	0	30
Thompson/Flag Lake	99	135	700	835
North Globe	40	0	10	10
Dickson Mounds	100	0	5	5
South Globe	50	0	10	10
Wilder/Bellrose	10	0	0	0
Spoon River Btms	0	0	0	0
Matanza Lake	95	10	0	10
Bath Lake	90	0	0	0
Moscow Lake	90	0	0	0
Jack Lake	100	0	0	0
Grass Lake	95	0	0	0
Anderson Lake	90	0	5	5
Snicarte Slough	50	0	0	0
Ingram Lake	90	5	0	5
Chain Lake	100	0	0	0
Stewart Lake	100	0	0	0
Crane Lake	95	0	50	50
Cuba Island	50	250	220	470
Sanganois	60	515	180	695
Treadway Lake	99	0	50	50
Muscooten Bay	99	0	0	0
Big Prairie	30	160	195	355
Meredosia Lake	80	0	0	0
Smith Lake	95	25	20	45
Spunky Bottoms	10	0	50	50
TOTAL		5,885	9,255	15,140

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL - AERIAL SHOREBIRD SURVEY

Date: August 11, 2016		Observer: Aaron Yetter		
LOCATION	% Wet	Big (Killdeer and Up)	Small (Pectoral and under)	TOTAL
Turner Lake	90	655	30	685
Lake Depue	60	110	30	140
Coleman Lake	99	0	0	0
Bureau Ponds	1	50	0	50
Goose Lake	50	2,480	1,540	4,020
Senachwine Lake	90	960	300	1,260
Hennepin/Hopper	100	0	0	0
Swan Lake	50	700	700	1,400
Sawmill Lake	50	35	260	295
Billsbach Lake	70	0	0	0
Weis Lake	50	550	300	850
Sparland	90	100	100	200
Wightman Lake	90	200	300	500
Sawyer Slough	10	600	0	600
Hitchcock Slough	50	0	0	0
Babbs Slough	99	60	30	90
Meadow Lake	80	50	250	300
Douglas Lake	20	550	400	950
Goose Lake	80	2,400	3,310	5,710
Upper Peoria	99	220	0	220
Lower Peoria	99	10	30	40
Pekin Lake	10	240	220	460
Powerton Lake		0	0	0
Spring Lake	100	0	0	0
Spring Lake Bottoms	5	20	0	20
Goose Lake	80	210	25	235
Rice Lake	90	10	0	10
Big Lake	90	650	120	770
Banner Marsh	95	5	0	5
Duck Creek		0	0	0
Clear Lake	90	2,385	890	3,275
North Pool	80	10,200	7,900	18,100
South Pool	70	7,810	16,550	24,360
Quiver Lake	50	250	0	250
Thompson/Flag Lake	95	945	400	1,345
North Globe	30	260	200	460
Dickson Mounds	100	0	5	5
South Globe	30	35	50	85
Wilder/Bellrose	5	130	10	140
Spoon River Btms	0	0	0	0
Matanza Lake	90	175	55	230
Bath Lake	20	1,040	310	1,350
Moscow Lake	30	1,350	850	2,200
Jack Lake	99	10	20	30
Grass Lake	90	10	0	10
Anderson Lake	80	0	0	0
Snicarte Slough	50	320	500	820
Ingram Lake	90	330	140	470
Chain Lake	90	140	500	640
Stewart Lake	95	30	355	385
Crane Lake	95	0	0	0
Cuba Island	70	1,200	900	2,100
Sanganois	40	615	680	1,295
Treadway Lake	50	640	1,460	2,100
Muscooten Bay	80	0	0	0
Big Prairie	20	930	1,860	2,790
Meredosia Lake	60	155	510	665
Smith Lake	95	30	0	30
Spunky Bottoms	10	330	1,250	1,580
TOTAL		40,185	43,340	83,525

August 3, 2016		5,885	9,255	15,140

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL - AERIAL SHOREBIRD SURVEY

Date: August 18, 2016		Observer: Aaron Yetter		
LOCATION	% Wet	Big (Killdeer and Up)	Small (Pectoral and under)	TOTAL
Turner Lake	90	30	10	40
Lake Depue	100	0	0	0
Coleman Lake	100	0	0	0
Bureau Ponds	10	0	0	0
Goose Lake	90	520	70	590
Senachwine Lake	95	0	0	0
Hennepin/Hopper	100	0	0	0
Swan Lake	50	1,180	125	1,305
Sawmill Lake	90	0	0	0
Billsbach Lake	100	0	0	0
Weis Lake	100	0	0	0
Sparland	100	0	0	0
Wightman Lake	100	0	0	0
Sawyer Slough	100	0	0	0
Hitchcock Slough	100	0	0	0
Babbs Slough	100	0	0	0
Meadow Lake	100	0	0	0
Douglas Lake	30	2,400	600	3,000
Goose Lake	100	0	0	0
Upper Peoria	100	105	0	105
Lower Peoria	100	0	0	0
Pekin Lake	80	850	250	1,100
Powerton Lake				0
Spring Lake	100	0	0	0
Spring Lake Bottoms	10	5	0	5
Goose Lake	80	320	145	465
Rice Lake	90	0	0	0
Big Lake	80	100	50	150
Banner Marsh	95	0	0	0
Duck Creek				0
Clear Lake	90	475	195	670
North Pool	80	7,650	5,200	12,850
South Pool	70	4,060	920	4,980
Quiver Lake	70	60	65	125
Thompson/Flag Lake	95	450	45	495
North Globe	30	110	205	315
Dickson Mounds	100	0	0	0
South Globe	30	295	425	720
Wilder/Bellrose	10	5	0	5
Spoon River Btms	0	0	0	0
Matanza Lake	95	30	15	45
Bath Lake	70	300	400	700
Moscow Lake	70	190	785	975
Jack Lake	100	10	0	10
Grass Lake	100	0	0	0
Anderson Lake	80	105	80	185
Snicarte Slough	80	110	60	170
Ingram Lake	90	510	350	860
Chain Lake	95	75	0	75
Stewart Lake	100	0	0	0
Crane Lake	80	25	0	25
Cuba Island	50	900	400	1,300
Sanganois	60	170	5	175
Treadway Lake	60	210	300	510
Muscooten Bay		0	0	0
Big Prairie	30	710	255	965
Meredosia Lake	70	80	575	655
Smith Lake	90	0	0	0
Spunky Bottoms	10	290	205	495
TOTAL		22,330	11,735	34,065

August 11, 2016		40,185	43,340	83,525
August 3, 2016		5,885	9,255	15,140

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL - AERIAL SHOREBIRD SURVEY

Date: August 25, 2016		Observer: Aaron Yetter		
LOCATION	% Wet	Big (Killdeer and Up)	Small (Pectoral and under)	TOTAL
Turner Lake	100	0	0	0
Lake Depue	100	0	0	0
Coleman Lake	100	0	0	0
Bureau Ponds	10	0	0	0
Goose Lake	95	0	0	0
Senachwine Lake	95	0	0	0
Hennepin/Hopper	100	0	0	0
Swan Lake	60	230	100	330
Sawmill Lake	90	5	0	5
Billsbach Lake	100	0	0	0
Weis Lake	100	0	0	0
Sparland	100	0	0	0
Wightman Lake	100	0	0	0
Sawyer Slough	100	0	0	0
Hitchcock Slough	100	0	0	0
Babbs Slough	100	0	0	0
Meadow Lake	100	0	0	0
Douglas Lake	70	0	100	100
Goose Lake	100	0	0	0
Upper Peoria	100	5	0	5
Lower Peoria	100	0	0	0
Pekin Lake	100	0	0	0
Powerton Lake				
Spring Lake	100	5	0	5
Spring Lake Bottoms	10	5	0	5
Goose Lake	80	0	0	0
Rice Lake	90	0	0	0
Big Lake	90	10	0	10
Banner Marsh	90	0	0	0
Duck Creek				
Clear Lake	95	0	0	0
North Pool	80	860	90	950
South Pool	70	410	680	1,090
Quiver Lake	100	0	0	0
Thompson/Flag Lake	95	145	60	205
North Globe	20	5	0	5
Dickson Mounds	100	0	0	0
South Globe	30	0	0	0
Wilder/Bellrose	30	0	0	0
Spoon River Btms	0	0	0	0
Matanza Lake	95	0	0	0
Bath Lake	90	0	0	0
Moscow Lake	95	25	130	155
Jack Lake	100	0	0	0
Grass Lake	100	0	0	0
Anderson Lake	90	0	0	0
Snicarte Slough	100	0	0	0
Ingram Lake	100	0	0	0
Chain Lake	100	0	0	0
Stewart Lake	100	0	0	0
Crane Lake	70	0	0	0
Cuba Island	70	0	0	0
Sanganois	70	0	0	0
Treadway Lake	80	60	0	60
Muscooten Bay				
Big Prairie	30	275	80	355
Meredosia Lake	70	10	30	40
Smith Lake	80	75	100	175
Spunky Bottoms	40	0	0	0
TOTAL		2,125	1,370	3,495

August 18, 2016		22,130	11,375	34,065
August 11, 2016		40,185	43,340	83,525
August 3, 2016		5,885	9,255	15,140

Appendix 2. 2016 Autumn Waterfowl Inventories of the Upper and Lower Divisions of the Illinois and Central Mississippi Rivers by Date and Location

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 08/31/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	10	0	0	200	0	0	0	150	0	0	0	0	10	0	0	0	0	370	0	0	0	210	310
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
Senachwine Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Hitchcock Slough	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Douglas Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	185	0
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Peoria	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL UPPER			10	0	0	200	0	0	0	150	0	0	0	0	10	0	0	0	0	370	0	0	0	425	310

LOWER ILLINOIS RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	745	0
Rice Lake	95	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	0	0	1,435	0
Big Lake	99	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	610	0
Banner Marsh	95	0	5	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	0	0	200	0
Duck Creek	100	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	25	0
Clear Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	40	0
Chautauqua	90	0	700	0	200	18,700	1,000	0	0	950	0	0	0	0	0	0	0	0	0	21,550	20	0	0	170	0
Emiquon/Spoon Btm	95	0	255	0	300	5,765	860	0	0	910	0	0	0	0	0	0	0	0	0	8,090	70	0	0	3,135	5,470
Grass Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0
Jack Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0
Stewart Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Crane Lake	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Cuba Island	40	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100	175	0	0	1,600	0
Big Lake	30	0	30	0	0	150	0	0	0	0	0	0	0	0	0	0	0	0	0	180	100	0	0	400	0
Spunky Bottoms	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	70	0	10	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0
TOTAL LOWER			1,005	0	500	24,795	1,860	0	0	1,860	0	0	0	0	0	0	0	0	0	30,020	430	0	0	8,485	5,470
TOTAL ILLINOIS			1,015	0	500	24,995	1,860	0	0	2,010	0	0	0	0	10	0	0	0	0	30,390	430	0	0	8,910	5,780
10-Year Average 2006-2015			2,254	0	1,906	16,996	4,601	0	6	2,007	0	0	0	0	0	0	0	0	1	27,771	931	356	1	10,140	626

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 08/31/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	20	0	0	150	0	0	0	40	0	0	0	0	0	0	0	0	0	210	170	0	0	320	0
Arthur Refuge	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	0	100	0
Nauvoo-Ft. Madison	100	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	20	105	0	0	240	0
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0
Henderson Creek	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	170	0
Keithsburg Refuge	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Louisa Refuge	60	0	10	0	0	500	100	0	0	30	0	0	0	0	0	0	0	0	0	640	80	0	0	350	0
TOTAL UPPER			30	0	0	670	100	0	0	70	0	0	0	0	0	0	0	0	0	870	605	0	0	1,220	0

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake	**NOT SURVEYED DUE TO FOG**																								
Gilbert Lake																									
Long Lake																									
Dardenne Club																									
Cuivre Club																									
Batchtown Refuge																									
Cannon Refuge	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Towhead Lake	20	0	5	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0	0
Delair Refuge	60	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0
Shanks Refuge	10	0	5	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0
Meyer-Keokuk	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0
TOTAL LOWER			10	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	60	35	0	0	0	0
TOTAL MISSISSIPPI			40	0	0	720	100	0	0	70	0	0	0	0	0	0	0	0	0	930	640	0	0	1,220	0
10-Year Average 2006-2015			445	0	97	4,532	819	0	0	161	0	0	0	0	0	0	0	0	0	6,054	723	0	0	4,091	11

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 09/06/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	0	0	10	300	100	0	0	5	0	0	0	0	0	0	0	0	0	415	25	0	0	45	160
Goose Lake	100	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	15	0
Senachwine Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	10	0
Hitchcock Slough	100	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
Douglas Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Peoria	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL UPPER			30	0	10	350	100	0	0	5	0	0	0	0	0	0	0	0	0	495	225	0	0	170	160
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	30	0
Rice Lake	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	30	0
Big Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Banner Marsh	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	210	0
Duck Creek	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	15	0
Clear Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chautauqua	90	0	375	0	170	4,900	1,150	0	0	410	0	0	0	0	0	0	0	0	0	7,005	270	0	0	260	0
Emiquon/Spoon Btm	90	0	395	0	235	9,295	570	0	0	0	0	0	0	0	0	0	0	0	0	10,495	230	0	0	1,505	2,020
Grass Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stewart Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crane Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	125	0	0	0	0
Cuba Island	50	0	20	0	0	600	0	0	0	0	0	0	0	0	0	0	0	0	0	620	230	0	0	100	0
Big Lake	30	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50	30	0	0	1,000	0
Spunky Bottoms	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	80	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
TOTAL LOWER			790	0	405	14,850	1,720	0	0	410	0	0	0	0	0	0	0	0	0	18,175	975	0	0	3,150	2,020
TOTAL ILLINOIS			820	0	415	15,200	1,820	0	0	415	0	0	0	0	0	0	0	0	0	18,670	1,200	0	0	3,320	2,180
10-Year Average 2006-2015			2,254	0	1,906	16,996	4,601	0	6	2,007	0	0	0	0	0	0	0	0	1	27,771	931	356	1	10,140	626

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 09/06/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10	25	0	0	75	0
Arthur Refuge	60	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	120	0	0	55	0
Nauvoo-Ft. Madison	100	0	0	0	0	50	60	0	0	0	0	0	0	0	0	0	0	0	0	110	0	0	0	190	0
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0
Henderson Creek	90	0	5	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	0	85	0
Keithsburg Refuge	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Louisa Refuge	50	0	0	0	0	300	0	0	0	0	0	0	0	0	0	0	0	0	0	300	150	0	0	150	0
TOTAL UPPER			25	0	0	365	60	0	0	0	0	0	0	0	0	0	0	0	0	450	305	0	0	585	0
LOWER MISSISSIPPI RIVER VALLEY																									
Swan Lake	60	0	425	0	100	5,830	1,950	0	0	430	0	0	0	0	0	0	0	0	0	8,735	300	0	0	250	0
Gilbert Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	230	0
Long Lake	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dardenne Club	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
Cuivre Club	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Batchtown Refuge	30	0	0	0	0	100	50	0	0	10	0	0	0	0	0	0	0	0	0	160	180	0	0	0	0
Cannon Refuge	1	0	0	0	0	0	10	0	0	5	0	0	0	0	0	0	0	0	0	15	0	0	0	0	0
Towhead Lake	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Delair Refuge	60	0	5	0	0	55	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	0	0
Shanks Refuge	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meyer-Keokuk	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	0	0	0	0
TOTAL LOWER			430	0	100	5,985	2,010	0	0	445	0	0	0	0	0	0	0	0	0	8,970	620	0	0	480	0
TOTAL MISSISSIPPI			455	0	100	6,350	2,070	0	0	445	0	0	0	0	0	0	0	0	0	9,420	925	0	0	1,065	0
10-Year Average 2006-2015			445	0	97	4,532	819	0	0	161	0	0	0	0	0	0	0	0	0	6,054	723	0	0	4,091	11

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 09/14/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	130	0	1,300	3,770	650	0	0	650	0	0	0	0	0	0	0	0	0	6,500	230	0	0	235	6,500
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Senachwine Lake	100	0	5	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	100	0
Hitchcock Slough	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Douglas Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	5	0
Goose Lake	100	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Upper Peoria	100	0	0	0	0	75	0	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0	0	10	0
TOTAL UPPER			140	0	1,300	3,845	660	0	0	650	0	0	0	0	0	0	0	0	0	6,595	430	0	0	350	6,500

LOWER ILLINOIS RIVER VALLEY

Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Banner Marsh	90	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	180	0
Duck Creek	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	215	0
Clear Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	25	0
Chautauqua	90	0	450	0	700	7,000	800	0	0	400	0	0	0	0	0	0	0	0	0	9,350	55	0	0	200	0
Emiquon/Spoon Btm	90	0	2,960	0	2,950	16,550	3,250	295	295	2,950	0	0	0	0	0	0	0	0	0	29,250	220	0	0	955	28,910
Grass Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0
Stewart Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crane Lake	90	0	50	0	50	400	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	0	0
Cuba Island	60	0	150	0	50	320	10	0	0	0	0	0	0	0	0	0	0	0	0	530	230	0	0	10	0
Big Lake	30	0	0	0	0	20	105	0	0	0	0	0	0	0	0	0	0	0	0	125	10	0	0	60	0
Spunky Bottoms	90	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0
Meredosia Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
TOTAL LOWER			3,610	0	3,750	24,510	4,165	295	295	3,350	0	0	0	0	0	0	0	0	0	39,975	780	0	0	1,650	28,910
TOTAL ILLINOIS			3,750	0	5,050	28,355	4,825	295	295	4,000	0	0	0	0	0	0	0	0	0	46,570	1,210	0	0	2,000	35,410
10-Year Average 2006-2015			3,185	0	2,980	21,014	8,256	17	501	2,628	0	0	0	0	0	0	0	0	0	38,580	971	0	1	13,857	3,283

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 09/14/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0	0	0	400	30	0	0	150	125
Arthur Refuge	60	0	20	0	0	150	50	0	0	0	0	0	0	0	0	0	0	0	0	220	400	0	0	90	0
Nauvoo-Ft. Madison	100	0	25	0	0	2,050	200	5	0	0	5	0	5	0	0	0	0	0	0	2,290	215	0	0	1,020	400
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0
Henderson Creek	90	0	0	0	0	500	0	0	0	0	0	0	0	0	0	0	0	0	0	500	100	0	0	100	0
Keithsburg Refuge	100	0	5	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	105	160	0	0	130	10
Louisa Refuge	50	0	0	0	0	1,100	100	0	0	0	0	0	0	0	0	0	0	0	0	1,200	620	0	0	265	0
TOTAL UPPER			50	0	0	4,300	350	5	0	0	5	0	5	0	0	0	0	0	0	4,715	1,625	0	0	1,755	535

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake	70	0	200	0	1,530	3,500	2,000	5	0	200	0	0	0	0	0	0	0	0	0	7,435	350	0	0	65	0
Gilbert Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dardenne Club	10	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
Cuivre Club	10	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
Batchtown Refuge	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Cannon Refuge	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Towhead Lake	30	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0
Delair Refuge	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shanks Refuge	10	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
Meyer-Keokuk	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	45	0
TOTAL LOWER			200	0	1,530	3,630	2,000	5	0	200	0	0	0	0	0	0	0	0	0	7,565	420	0	0	110	0
TOTAL MISSISSIPPI			250	0	1,530	7,930	2,350	10	0	200	5	0	5	0	0	0	0	0	0	12,280	2,045	0	0	1,865	535
10-Year Average 2006-2015			633	0	472	5,284	1,649	8	35	582	0	0	0	0	3	0	0	0	0	8,664	973	0	0	3,579	66

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 09/20/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	585	0	1,170	2,340	1,170	60	60	585	0	0	0	0	60	0	0	0	0	6,030	20	0	0	35	5,730
Goose Lake	95	0	0	0	1,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	200	0	0	260	0
Senachwine Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,200	0	0	0	0
Hitchcock Slough	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Douglas Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Peoria	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL UPPER			585	0	2,170	2,340	1,170	60	60	585	0	0	0	0	60	0	0	0	0	7,030	1,420	0	0	295	5,730
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	35	0
Rice Lake	99	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0
Big Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	0
Banner Marsh	90	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	30	20	0	0	25	0
Duck Creek	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	65	0
Clear Lake	100	0	20	0	50	400	55	0	0	0	0	0	0	0	0	0	0	0	0	525	75	0	0	25	0
Chautauqua	90	0	105	0	1,510	4,000	420	0	0	500	0	0	0	0	0	0	0	0	0	6,535	25	0	0	155	0
Emiquon/Spoon Btm	90	0	2,930	0	6,450	13,235	3,220	200	200	3,030	0	0	0	0	0	0	0	0	0	29,265	30	0	0	1,245	29,210
Grass Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	70	0
Jack Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Stewart Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crane Lake	90	0	5	0	0	300	0	0	0	0	0	0	0	0	0	0	0	0	0	305	0	0	0	120	0
Cuba Island	60	0	0	0	150	2,500	100	0	0	0	0	0	0	0	0	0	0	0	0	2,750	230	0	0	25	0
Big Lake	30	0	5	0	100	130	100	0	0	0	0	0	0	0	0	0	0	0	0	335	0	0	0	5	0
Spunky Bottoms	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL LOWER			3,065	0	8,260	20,645	3,895	200	200	3,530	0	0	0	0	0	0	0	0	0	39,795	445	0	0	1,795	29,210
TOTAL ILLINOIS			3,650	0	10,430	22,985	5,065	260	260	4,115	0	0	0	0	60	0	0	0	0	46,825	1,865	0	0	2,090	34,940
10-Year Average 2006-2015			4,732	0	9,990	17,320	16,923	190	939	5,889	0	0	0	0	0	0	0	0	0	55,983	1,620	0	0	12,479	24,093

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 09/20/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	35	0	0	135	40
Arthur Refuge	90	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	50	350	0	0	220	0
Nauvoo-Ft. Madison	100	0	55	0	0	1,400	100	0	0	150	0	0	0	0	0	0	0	0	0	1,705	5	0	0	465	1,470
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0
Henderson Creek	90	0	15	0	300	100	0	0	0	0	0	0	0	0	0	0	0	0	0	415	10	0	0	330	200
Keithsburg Refuge	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	200
Louisa Refuge	50	0	50	0	400	700	200	0	0	0	0	0	0	0	0	0	0	0	0	1,350	800	0	0	240	0
TOTAL UPPER			120	0	700	2,250	300	0	0	150	0	0	0	0	0	0	0	0	0	3,520	1,260	0	0	1,540	1,910

LOWER MISSISSIPPI RIVER VALLEY

Swan Lake	70	0	100	0	2,700	2,330	200	0	0	0	0	0	0	0	0	0	0	0	0	5,330	680	0	0	10	0
Gilbert Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0
Dardenne Club	10	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Cuivre Club	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Batchtown Refuge	40	0	10	0	50	300	0	0	0	0	0	0	0	0	0	0	0	0	0	360	25	0	0	0	0
Cannon Refuge	1	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0
Towhead Lake	30	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0
Delair Refuge	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shanks Refuge	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meyer-Keokuk	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	0	0	35	0
TOTAL LOWER			110	0	2,750	3,130	200	0	0	0	0	0	0	0	0	0	0	0	0	6,190	1,305	0	0	55	0
TOTAL MISSISSIPPI			230	0	3,450	5,380	500	0	0	150	0	0	0	0	0	0	0	0	0	9,710	2,565	0	0	1,595	1,910
10-Year Average 2006-2015			397	0	1,312	3,047	2,764	0	30	744	0	0	0	0	0	0	0	0	0	8,294	1,311	0	0	4,011	1,024

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 10/10/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	500	0	3,500	500	750	125	500	250	0	125	0	0	3,000	0	0	0	0	9,250	900	0	0	210	19,750
Goose Lake	100	0	5	0	600	10	0	0	0	0	0	0	0	0	0	0	0	0	0	615	20	0	0	305	300
Senachwine Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0	10	0
Hitchcock Slough	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Douglas Lake	100	0	0	0	30	0	30	0	0	0	0	0	0	0	0	0	0	0	0	60	0	0	0	500	0
Goose Lake	100	0	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	0	0	0	30	0
Upper Peoria	100	0	200	0	0	0	0	0	0	0	0	0	0	0	1,875	0	0	0	0	2,075	0	0	0	75	5
TOTAL UPPER			1,005	0	4,130	510	780	125	500	250	0	125	0	0	4,875	0	0	0	0	12,300	995	0	0	1,135	20,055
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Rice Lake	99	0	150	0	25	100	100	0	0	0	0	0	0	0	0	0	0	0	0	375	5	0	0	5	0
Big Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Banner Marsh	99	0	25	0	0	0	60	0	50	0	0	0	0	0	0	0	0	0	0	135	300	0	0	15	0
Duck Creek	100	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	20	40	0	0	20	0
Clear Lake	100	0	10	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	40	0
Chautauqua	99	0	570	0	4,000	100	3,400	20	50	200	0	0	0	0	350	0	0	0	0	8,690	600	0	0	0	400
Emiquon/Spoon Btm	90	0	1,595	0	4,660	3,070	7,780	770	1,535	4,860	0	770	0	0	250	0	0	0	0	25,290	70	0	0	765	129,025
Grass Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Stewart Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	130	0
Crane Lake	90	0	5	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	35	255	0	0	225	100
Cuba Island	60	0	50	0	1,100	50	300	0	0	0	0	0	0	0	0	0	0	0	0	1,500	700	0	0	0	0
Big Lake	40	0	10	0	1,505	0	1,450	0	0	0	0	0	0	0	0	0	0	0	0	2,965	0	0	0	0	0
Spunky Bottoms	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	250	0
Meredosia Lake	90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	20
TOTAL LOWER			2,415	0	11,290	3,320	13,155	790	1,655	5,060	0	770	0	0	600	0	0	0	0	39,055	2,000	0	0	1,600	129,545
TOTAL ILLINOIS			3,420	0	15,420	3,830	13,935	915	2,155	5,310	0	895	0	0	5,475	0	0	0	0	51,355	2,995	0	0	2,735	149,600
10-Year Average 2006-2015			11,958	28	19,035	6,305	18,802	2,223	4,743	3,797	0	400	0	0	927	0	0	0	3	68,222	1,607	0	0	6,015	36,787

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 10/10/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	105	0	0	350	8,050
Arthur Refuge	90	0	0	0	100	50	200	0	0	0	0	0	0	0	0	0	0	0	0	350	280	0	0	0	0
Nauvoo-Ft. Madison	100	0	0	0	0	0	0	0	0	110	0	0	0	0	0	0	0	0	0	110	10	0	0	235	6,100
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Henderson Creek	100	0	120	0	1,100	0	100	0	0	0	0	200	0	0	0	0	0	0	0	1,520	5	0	0	205	2,050
Keithsburg Refuge	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	180	0	0	0	1,500
Louisa Refuge	100	0	0	0	1,600	50	800	0	0	0	0	0	0	0	0	0	0	0	0	2,450	210	0	0	200	2,500
TOTAL UPPER			120	0	2,900	100	1,100	0	0	110	0	200	0	0	0	0	0	0	0	4,530	790	0	0	990	20,200

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake	80	0	560	0	39,480	1,120	11,700	560	1,120	1,680	0	0	0	0	0	0	0	0	0	56,220	650	0	0	80	1,680
Gilbert Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Long Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dardenne Club	60	0	300	0	1,000	0	200	0	0	0	0	0	0	0	0	0	0	0	0	1,500	0	0	0	0	0
Cuivre Club	50	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Batchtown Refuge	100	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	5	0	0	0	0
Cannon Refuge	5	0	0	0	0	0	500	0	0	0	0	0	0	0	0	0	0	0	0	500	0	0	0	0	0
Towhead Lake	50	0	0	0	3,000	500	1,500	0	0	0	0	0	0	0	0	0	0	0	0	5,000	0	0	0	0	0
Delair Refuge	70	0	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	50	0	0	0	0
Shanks Refuge	30	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
Meyer-Keokuk	100	0	0	0	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	55	0	0	10	0
TOTAL LOWER			905	0	43,780	1,620	13,930	560	1,120	1,680	0	0	0	0	0	0	0	0	0	63,595	770	0	0	90	1,680
TOTAL MISSISSIPPI			1,025	0	46,680	1,720	15,030	560	1,120	1,790	0	200	0	0	0	0	0	0	0	68,125	1,560	0	0	1,080	21,880
10-Year Average 2006-2015			1,647	0	4,077	362	2,425	50	795	108	0	130	0	0	0	0	0	0	0	9,593	1,267	0	0	1,307	3,817

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 10/18/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	450	0	4,250	100	900	225	2,650	1,350	225	225	400	0	1,350	0	0	0	0	12,125	705	150	0	110	35,100
Goose Lake	90	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	200	0	0	205	10
Senachwine Lake	100	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	200	0	0	0	0
Hitchcock Slough	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
Douglas Lake	100	0	10	0	600	0	0	0	50	130	0	0	0	0	10	0	0	0	0	800	5	0	0	70	0
Goose Lake	100	0	3,020	0	1,500	0	0	0	0	0	0	0	0	0	500	0	0	0	0	5,020	0	0	0	210	0
Upper Peoria	100	0	10	0	0	0	5	0	0	0	0	0	0	0	40	0	0	0	0	55	15	0	0	220	0
TOTAL UPPER			3,510	0	6,350	100	905	225	2,700	1,480	225	225	400	0	1,900	0	0	0	0	18,020	1,125	150	0	835	35,110
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	99	0	1,600	0	500	0	2,010	0	200	100	0	250	0	0	0	0	0	0	0	4,660	0	0	0	0	0
Big Lake	100	0	20	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	120	0	0	0	30	0
Banner Marsh	99	0	0	0	0	10	5	0	70	0	0	0	0	0	0	0	0	0	0	85	290	100	0	20	0
Duck Creek	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	0	0	5	0
Clear Lake	100	0	100	0	0	0	100	0	0	0	0	0	0	0	250	0	0	0	0	450	70	400	0	0	0
Chautauqua	100	0	195	5	7,300	320	5,140	80	6,000	800	0	100	0	0	2,000	0	0	0	0	21,940	380	20	0	50	300
Emiquon/Spoon Btm	90	0	2,025	0	9,765	1,950	5,850	1,950	9,760	3,995	0	975	500	0	1,450	0	0	0	0	38,220	280	725	0	1,340	156,975
Grass Lake	100	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0
Jack Lake	100	0	10	0	0	0	5	0	0	0	0	0	0	0	300	0	0	0	0	315	0	0	0	5	0
Stewart Lake	100	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	130	0
Crane Lake	95	0	50	0	100	0	10	50	900	100	0	0	0	0	0	0	0	0	0	1,210	300	0	0	40	0
Cuba Island	90	0	180	0	4,500	0	3,500	0	500	200	0	0	0	0	0	0	0	0	0	8,880	450	475	0	0	0
Big Lake	20	0	200	0	4,000	0	2,000	0	0	0	0	100	0	0	30	0	0	0	0	6,330	0	0	0	0	0
Spunky Bottoms	10	0	0	0	0	0	10	0	0	20	0	0	0	0	0	0	0	0	0	30	0	150	0	75	0
Meredosia Lake	60	0	10	0	0	0	0	0	130	50	0	0	0	0	230	0	0	0	0	420	0	140	0	0	0
TOTAL LOWER			4,390	5	26,165	2,280	18,660	2,080	17,680	5,265	0	1,425	500	0	4,260	0	0	0	0	82,710	1,875	2,010	0	1,695	157,275
TOTAL ILLINOIS			7,900	5	32,515	2,380	19,565	2,305	20,380	6,745	225	1,650	900	0	6,160	0	0	0	0	100,730	3,000	2,160	0	2,530	192,385
10-Year Average 2006-2015			20,917	132	25,893	1,921	30,111	3,788	11,586	11,283	2	1,159	37	11	3,631	0	0	0	0	110,472	2,163	19	0	3,134	91,511

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 10/18/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	0	0	50	0	20	0	0	0	0	0	1,200	0	0	0	0	1,270	5	0	0	65	10,900
Arthur Refuge	80	0	10	0	300	0	50	0	100	10	0	0	0	0	0	0	0	0	0	470	370	0	0	55	0
Nauvoo-Ft. Madison	100	0	5	0	100	0	50	0	120	150	0	0	0	0	110	0	0	0	0	535	65	0	0	225	9,700
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	10	200	0	0	0	0
Henderson Creek	100	0	400	0	7,500	100	2,500	100	900	300	50	300	0	0	200	0	0	0	0	12,350	100	400	0	0	3,600
Keithsburg Refuge	100	0	0	0	50	0	0	0	300	0	0	0	0	0	0	0	0	0	0	350	110	0	0	70	1,400
Louisa Refuge	100	0	400	0	5,000	400	3,000	50	1,510	1,000	0	0	0	0	0	0	0	0	0	11,360	270	135	0	170	1,220
TOTAL UPPER			815	0	12,950	500	5,650	150	2,960	1,460	50	300	0	0	1,510	0	0	0	0	26,345	1,120	535	0	585	26,820

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake - Two River NWR	80	0	1,770	0	58,520	440	10,800	440	13,200	4,400	0	1,000	0	0	440	0	0	0	0	91,010	420	200	0	60	9,300
Gilbert Lake - Two Rivers NWR	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Long Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dardenne Club	60	0	400	0	1,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,400	0	0	0	0	0
Cuivre Club	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Batchtown Refuge - Two Rivers NWR	100	0	140	0	600	0	400	0	0	0	0	0	0	0	0	0	0	0	0	1,140	100	0	0	0	0
Cannon Refuge	10	0	0	0	0	0	5,000	0	0	0	0	0	0	0	0	0	0	0	0	5,000	10	0	0	50	100
Towhead Lake	90	0	500	0	7,000	100	2,000	0	400	500	0	0	0	0	0	0	0	0	0	10,500	0	450	0	0	0
Delair Refuge	70	0	50	0	100	50	250	0	105	50	0	0	0	0	0	0	0	0	0	605	390	0	0	0	0
Shanks Refuge	20	0	375	0	200	200	4,000	0	100	50	0	0	0	0	0	0	0	0	0	4,925	0	0	0	0	110
Meyer-Keokuk	100	0	10	0	0	0	40	0	0	0	0	0	0	0	0	0	0	0	0	50	30	0	0	50	0
TOTAL LOWER			3,245	0	67,420	790	22,490	440	13,805	5,000	0	1,000	0	0	440	0	0	0	0	114,630	950	650	0	160	9,510
TOTAL MISSISSIPPI			4,060	0	80,370	1,290	28,140	590	16,765	6,460	50	1,300	0	0	1,950	0	0	0	0	140,975	2,070	1,185	0	745	36,330
10-Year Average 2006-2015			10,043	3	19,228	505	17,043	1,409	5,604	2,973	0	1,679	1	0	1,732	0	0	0	0	60,220	2,807	67	0	1,890	17,573

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 10/24/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	1,200	0	3,000	0	1,800	600	9,000	12,000	0	300	2,200	0	3,000	0	0	0	0	33,100	1,250	0	0	150	27,000
Goose Lake	90	0	0	10	0	0	300	0	0	0	0	0	0	0	50	0	0	0	0	360	5	0	0	185	1,100
Senachwine Lake	100	0	4,005	0	1,500	0	1,000	0	0	30	0	0	0	0	0	0	0	0	0	6,535	0	0	0	30	0
Hitchcock Slough	90	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0
Douglas Lake	100	0	1,500	0	1,500	0	1,230	0	0	1,000	0	2,000	0	0	0	0	0	0	0	7,230	0	0	0	20	0
Goose Lake	100	0	9,600	25	3,000	0	0	0	0	0	0	100	0	0	2,100	0	0	0	0	14,825	5	0	0	50	0
Upper Peoria	100	0	1,050	0	300	0	425	0	0	100	0	0	0	0	5,750	0	0	0	0	7,625	0	0	0	45	120
TOTAL UPPER			17,355	35	9,300	0	4,955	600	9,000	13,130	0	2,400	2,200	0	10,900	0	0	0	0	69,875	1,260	0	0	480	28,220
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	95	0	500	5	60	0	200	0	0	0	0	0	0	0	0	0	0	0	0	765	0	0	0	5	0
Big Lake	100	0	700	5	0	0	5	0	0	0	0	0	0	0	200	0	0	0	0	910	0	0	0	10	550
Banner Marsh	95	0	50	0	0	0	0	0	85	0	0	0	0	0	0	0	0	0	0	135	165	0	0	80	0
Duck Creek	100	0	0	0	0	0	0	0	600	0	0	0	0	0	0	0	0	0	0	600	200	0	0	15	0
Clear Lake	95	0	800	0	0	0	0	0	50	10	0	0	0	0	5	0	0	0	0	865	20	0	0	5	120
Chautauqua	100	0	1,700	0	17,460	0	6,400	0	4,000	2,500	10	0	0	100	3,900	0	0	0	0	36,070	350	10	0	0	1,950
Emiquon/Spoon Btm	90	0	1,065	0	10,100	505	10,100	505	15,150	3,085	0	505	800	50	2,025	0	0	0	0	43,890	275	0	0	460	58,075
Grass Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	0	200	0	0	0	0	150
Stewart Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	250	0	0	0	0	250	0	0	0	10	0
Crane Lake	100	0	25	0	0	0	405	0	300	200	0	50	0	0	500	0	0	0	0	1,480	0	0	0	0	2,700
Cuba Island	90	0	100	0	3,000	0	4,000	0	300	0	0	50	0	0	0	0	0	0	0	7,450	725	100	0	0	100
Big Lake	20	0	200	0	3,600	0	5,000	0	0	100	0	50	0	0	200	0	0	0	0	9,150	0	0	0	0	0
Spunky Bottoms	10	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	5	5	0	0	70	0
Meredosia Lake	70	0	30	0	0	0	15	0	125	0	0	0	0	0	175	0	0	0	0	345	0	0	0	0	700
TOTAL LOWER			5,170	10	34,220	505	26,125	505	20,610	5,900	10	655	800	150	7,455	0	0	0	0	102,115	1,740	110	0	655	64,345
TOTAL ILLINOIS			22,525	45	43,520	505	31,080	1,105	29,610	19,030	10	3,055	3,000	150	18,355	0	0	0	0	171,990	3,000	110	0	1,135	92,565
10-Year Average 2006-2015			44,696	285	45,420	1,521	43,668	4,468	24,639	18,544	678	2,834	483	344	8,557	0	0	0	9	196,146	2,459	27	0	2,074	130,603

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 10/24/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	0	0	0	0	0	100	0	125	0	0	2,600	0	0	0	0	2,825	5	0	0	20	8,800
Arthur Refuge	80	0	100	0	0	0	300	0	50	50	0	0	0	0	0	0	0	0	0	500	100	0	0	20	1,050
Nauvoo-Ft. Madison	100	0	10	0	0	0	1,300	0	0	500	0	10	50	0	2,500	0	0	0	0	4,370	380	0	0	350	14,400
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Henderson Creek	100	0	800	0	4,500	0	3,100	0	500	50	25	500	0	0	400	0	0	0	0	9,875	260	0	0	0	3,500
Keithsburg Refuge	100	0	50	0	0	0	200	0	0	0	0	0	0	0	500	0	0	0	0	750	510	0	0	10	1,500
Louisa Refuge	100	0	500	0	3,000	0	2,000	0	200	300	0	1,000	0	0	15	0	0	0	0	7,015	130	0	0	25	1,700
TOTAL UPPER			1,460	0	7,500	0	6,900	0	750	1,000	25	1,635	50	0	6,015	0	0	0	0	25,335	1,385	0	0	425	30,950
LOWER MISSISSIPPI RIVER VALLEY																									
Swan Lake - Two Rivers NWR	90	0	4,550	0	57,850	100	14,900	1,780	13,850	2,670	0	4,200	0	0	3,900	0	0	0	0	103,800	1,270	0	0	25	2,100
Gilbert Lake - Two Rivers NWR	100	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	100	0	0	0	0
Long Lake	100	0	600	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	0	630	0	0	0	0	0
Dardenne Club	70	0	1,000	0	10,025	0	0	0	300	100	0	0	0	0	0	0	0	0	0	11,425	0	0	0	0	100
Cuivre Club	70	0	300	0	100	0	0	0	300	0	0	0	0	0	0	0	0	0	0	700	0	0	0	0	0
Batchtown Refuge - Two Rivers NWI	100	0	450	0	1,000	0	200	0	0	0	0	100	0	0	0	0	0	0	0	1,750	325	0	0	0	0
Cannon Refuge	10	0	300	0	100	0	500	0	900	0	0	0	0	0	0	0	0	0	0	1,800	120	0	0	0	0
Towhead Lake	90	0	100	0	500	0	2,000	0	0	0	0	0	0	0	0	0	0	0	0	2,600	0	0	0	0	0
Delair Refuge	70	0	200	0	100	300	2,500	0	150	0	0	0	0	0	0	0	0	0	0	3,250	175	0	0	0	0
Shanks Refuge	30	0	0	0	0	0	0	5	10	100	0	0	0	0	0	0	0	0	0	115	10	0	0	0	100
Meyer-Keokuk	100	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	5	0
TOTAL LOWER			7,530	0	69,675	400	20,100	1,785	15,540	2,870	0	4,300	0	0	3,900	0	0	0	0	126,100	2,020	0	0	30	2,300
TOTAL MISSISSIPPI			8,990	0	77,175	400	27,000	1,785	16,290	3,870	25	5,935	50	0	9,915	0	0	0	0	151,435	3,405	0	0	455	33,250
10-Year Average 2006-2015			25,785	26	44,376	272	28,743	1,861	16,827	5,086	456	3,238	150	19	10,313	0	1	0	1	137,153	4,768	129	4	1,321	29,438

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 11/01/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	3,250	0	9,500	0	6,500	325	13,000	6,500	0	325	1,950	0	4,550	0	0	0	0	45,900	500	200	0	500	22,100
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	500	0	0	300	0	0	0	0	800	0	0	0	190	700
Senachwine Lake	100	0	100	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	300	0	0	0	0	100
Hitchcock Slough	100	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	50	0	0	0	5	0
Douglas Lake	100	0	2,150	0	4,000	0	1,000	0	2,000	2,500	0	3,000	0	0	0	0	0	0	0	14,650	5	0	0	50	400
Goose Lake	100	0	5,500	0	5,000	0	0	0	300	500	0	0	0	0	4,300	0	0	0	0	15,600	0	0	0	25	0
Upper Peoria	100	0	200	0	500	0	0	0	50	400	0	0	0	0	9,500	0	0	0	0	10,650	0	0	0	5	100
TOTAL UPPER			11,200	0	19,000	0	7,500	325	15,550	9,900	0	3,825	1,950	0	18,700	0	0	0	0	87,950	505	200	0	775	23,400
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100
Rice Lake	95	0	400	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	600	0	0	0	0	0
Big Lake	100	0	610	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	810	0	0	0	0	200
Banner Marsh	95	0	100	0	0	0	0	0	185	0	0	0	0	0	5	0	0	0	0	290	205	0	0	45	0
Duck Creek	100	0	25	0	0	0	0	0	730	0	0	0	0	0	0	0	0	0	0	755	605	0	0	0	0
Clear Lake	95	0	750	0	0	0	0	0	300	40	0	30	0	0	375	0	0	0	0	1,495	250	0	0	0	0
Chautauqua	95	0	3,345	5	6,000	0	10,200	130	5,815	3,320	0	100	0	0	3,200	0	0	0	0	32,115	590	50	0	105	1,300
Emiquon/Spoon Btm	90	0	5,625	0	5,575	0	6,770	560	16,725	4,500	0	2,230	400	5	2,230	0	0	0	15	44,635	540	0	0	280	67,460
Grass Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack Lake	100	0	0	0	0	0	5	0	220	0	0	0	0	0	0	0	0	0	0	225	0	0	0	0	50
Stewart Lake	100	0	0	0	0	0	0	0	20	0	5	0	0	0	25	0	0	0	0	50	0	0	0	30	0
Crane Lake	100	0	300	0	50	0	510	0	500	150	0	100	0	0	100	0	0	0	0	1,710	100	0	0	0	650
Cuba Island	100	0	1,770	10	4,425	0	7,875	0	2,655	885	0	2,000	0	0	0	0	0	0	0	19,620	400	0	0	5	1,000
Big Lake	20	0	1,010	0	2,010	0	4,000	0	500	500	10	0	0	0	20	0	0	0	0	8,050	0	10	0	0	0
Spunky Bottoms	10	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Meredosia Lake	70	0	25	0	0	0	5	0	320	50	10	0	0	0	10	0	0	0	0	420	0	0	0	100	100
TOTAL LOWER			13,960	15	18,260	0	29,465	690	28,170	9,445	25	4,460	400	5	5,965	0	0	0	15	110,875	2,690	60	0	565	70,860
TOTAL ILLINOIS			25,160	15	37,260	0	36,965	1,015	43,720	19,345	25	8,285	2,350	5	24,665	0	0	0	15	198,825	3,195	260	0	1,340	94,260
10-Year Average 2006-2015			78,332	485	43,844	457	45,961	3,721	34,252	13,498	567	7,746	1,017	237	14,004	0	10	0	2	244,129	2,764	123	2	1,399	106,185

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 11/01/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	100	0	0	0	0	0	100	100	500	400	0	0	5,500	0	0	0	0	6,700	25	0	0	65	17,000
Arthur Refuge	80	0	200	0	300	0	100	0	0	400	0	0	0	0	0	0	0	0	0	1,000	500	0	0	10	100
Nauvoo-Ft. Madison	100	0	200	0	100	0	400	0	2,000	500	500	0	100	100	4,000	0	0	0	0	7,900	50	0	0	220	15,850
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	10	150
Henderson Creek	100	0	405	0	300	0	2,000	0	2,500	900	50	300	0	0	1,000	0	0	0	0	7,455	100	0	0	5	510
Keithsburg Refuge	100	0	100	0	0	0	0	0	100	150	0	70	0	0	0	0	0	0	0	420	430	0	0	100	500
Louisa Refuge	100	0	2,010	0	7,000	0	1,000	300	2,000	1,000	0	2,000	0	0	0	0	0	0	0	15,310	100	0	0	0	750
TOTAL UPPER			3,015	0	7,700	0	3,500	300	6,700	3,050	1,050	2,770	100	100	10,500	0	0	0	0	38,785	1,245	0	0	410	34,860

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake - Two Rivers NWR	95	0	12,200	0	24,400	0	24,400	1,220	24,400	6,100	0	18,300	100	0	6,100	0	0	0	0	117,220	420	150	0	5	6,100
Gilbert Lake - Two Rivers NWR	100	0	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0
Long Lake	90	0	2,000	0	700	0	1,500	0	500	300	0	0	0	0	0	0	0	0	0	5,000	0	0	0	0	0
Dardenne Club	90	0	600	0	4,000	0	200	0	100	400	0	0	0	0	0	0	0	0	0	5,300	0	0	0	0	0
Cuivre Club	70	0	150	0	300	0	0	0	10	0	0	0	0	0	0	0	0	0	0	460	0	0	0	0	25
Batchtown Refuge - Two Rivers NWR	100	0	450	0	1,000	0	200	0	230	200	0	0	0	0	0	0	0	0	0	2,080	45	0	0	0	0
Cannon Refuge	50	0	900	0	2,300	0	1,500	0	500	300	0	0	0	0	0	0	0	0	0	5,500	200	0	0	0	0
Towhead Lake	100	0	1,005	0	2,700	0	4,000	200	2,600	1,000	0	0	0	0	0	0	0	0	0	11,505	25	0	0	0	1,000
Delair Refuge	70	0	700	0	300	0	4,000	0	400	100	0	0	0	0	0	0	0	0	0	5,500	100	0	0	0	0
Shanks Refuge	40	0	1,800	0	1,500	0	2,500	0	500	300	0	0	0	0	0	0	0	0	0	6,600	100	0	0	0	0
Meyer-Keokuk	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL LOWER			19,835	0	37,200	0	38,300	1,420	29,240	8,700	0	18,300	100	0	6,100	0	0	0	0	159,195	890	150	0	5	7,125
TOTAL MISSISSIPPI			22,850	0	44,900	0	41,800	1,720	35,940	11,750	1,050	21,070	200	100	16,600	0	0	0	0	197,980	2,135	150	0	415	41,985
10-Year Average 2006-2015			43,210	20	37,764	3	29,204	979	20,700	4,663	5,350	9,724	3,425	38	8,188	19	120	0	0	163,404	3,886	138	432	1,198	30,913

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 11/07/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	6,200	0	9,300	0	3,100	310	6,200	6,200	0	3,100	1,500	310	2,500	0	0	0	0	38,720	650	10	0	400	27,900
Goose Lake	100	0	1,060	0	0	0	50	0	100	0	0	3,500	0	0	0	0	0	0	0	4,710	0	0	0	55	600
Senachwine Lake	100	0	2,400	25	100	0	0	0	0	0	0	0	0	0	50	5	0	0	0	2,580	250	0	0	40	0
Hitchcock Slough	100	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0
Douglas Lake	100	0	2,500	0	4,000	0	2,500	0	500	500	0	1,500	0	0	0	0	0	0	0	11,500	0	0	0	30	100
Goose Lake	100	0	10,000	100	6,000	0	5,000	0	500	500	0	500	0	0	500	0	0	0	0	23,100	0	0	0	100	0
Upper Peoria	100	0	1,300	0	0	0	0	0	0	0	0	0	0	0	13,500	0	0	0	0	14,800	20	0	0	0	500
TOTAL UPPER			23,480	125	19,400	0	10,650	310	7,300	7,200	0	8,600	1,500	310	16,550	5	0	0	0	95,430	920	10	0	625	29,100

LOWER ILLINOIS RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	100	0	1,000	10	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,130	0	0	0	5	0
Big Lake	100	0	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	400	0	0	0	0	10
Banner Marsh	100	0	250	0	0	0	0	0	290	0	0	0	0	0	0	0	0	0	0	540	225	0	0	15	0
Duck Creek	100	0	1,505	0	0	0	0	0	1,110	5	0	0	0	0	0	0	0	0	0	2,620	45	0	0	5	5
Clear Lake	100	0	500	20	0	0	0	0	0	25	5	0	0	0	1,500	0	0	0	10	2,060	150	0	0	0	0
Chautauqua	100	0	3,020	15	9,550	0	10,760	100	4,125	1,425	0	0	0	10	0	0	0	0	0	29,005	720	0	0	15	700
Emiquon/Spoon Btm	90	0	10,220	0	11,450	0	4,410	2,000	17,160	7,180	0	1,430	3,000	300	4,295	0	0	0	5	61,450	100	0	0	435	81,930
Grass Lake	100	0	10	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	20	0	0	0	0	0
Jack Lake	100	0	10	0	0	0	0	0	0	0	10	0	0	5	0	0	0	0	0	25	0	0	0	0	0
Stewart Lake	100	0	0	0	0	0	5	0	0	0	5	0	0	0	75	0	0	0	0	85	0	0	0	5	0
Crane Lake	100	0	50	0	0	0	100	0	150	0	10	0	0	0	100	0	0	0	0	410	155	0	0	0	100
Cuba Island	100	0	700	0	8,000	0	500	0	1,000	700	0	3,500	0	0	0	0	0	0	0	14,400	350	0	0	10	500
Big Lake	20	0	1,000	0	3,200	0	500	0	200	300	0	0	0	0	0	0	0	0	0	5,200	10	0	0	10	300
Spunky Bottoms	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	70	0	150	0	200	0	50	0	260	10	20	0	0	0	0	0	0	0	0	690	0	0	0	215	5
TOTAL LOWER			18,815	45	32,520	0	16,325	2,100	24,295	9,645	50	4,930	3,000	315	5,980	0	0	0	15	118,035	1,755	0	0	715	83,550
TOTAL ILLINOIS			42,295	170	51,920	0	26,975	2,410	31,595	16,845	50	13,530	4,500	625	22,530	5	0	0	15	213,465	2,675	10	0	1,340	112,650
10-Year Average 2006-2015			128,929	793	40,277	0	60,168	3,846	53,712	17,840	8,073	25,692	2,936	268	21,698	7	149	0	61	364,449	3,410	261	18	585	66,906

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 11/07/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	0	0	0	0	50	0	1,400	500	0	0	3,700	0	0	0	0	5,650	0	0	0	30	19,550
Arthur Refuge	100	0	250	0	50	0	300	20	250	10	0	0	0	0	0	0	0	0	0	880	500	0	0	55	0
Nauvoo-Ft. Madison	100	0	0	0	0	0	100	0	600	200	0	0	300	20	1,020	0	0	0	0	2,240	0	0	0	120	17,100
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0
Henderson Creek	100	0	1,500	0	1,500	0	1,000	0	1,200	400	50	0	200	0	100	0	0	0	0	5,950	210	0	0	20	1,700
Keithsburg Refuge	100	0	150	0	0	0	0	0	400	60	0	130	0	0	10	0	0	0	0	750	485	0	0	60	500
Louisa Refuge	100	0	1,450	0	5,600	0	2,900	0	2,900	710	0	2,500	0	0	0	0	0	0	0	16,060	500	0	0	0	1,400
TOTAL UPPER			3,350	0	7,150	0	4,300	20	5,400	1,380	1,450	3,130	500	20	4,830	0	0	0	0	31,530	1,695	0	0	290	40,250

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake - Two Rivers NWR	100	0	14,350	0	35,875	0	21,525	720	35,875	7,175	0	14,350	0	0	7,175	0	0	0	0	137,045	220	800	0	20	7,175
Gilbert Lake - Two Rivers NWR	100	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	10	0	0	0	0
Long Lake	100	0	2,000	0	100	0	0	0	200	300	0	0	0	0	0	0	0	0	0	2,600	0	0	0	0	100
Dardenne Club	90	0	2,000	0	6,000	0	500	0	500	500	0	0	0	0	0	0	0	0	0	9,500	0	0	0	0	0
Cuivre Club	70	0	1,000	0	1,000	0	0	0	400	100	0	0	0	0	0	0	0	0	0	2,500	0	0	0	0	0
Batchtown Refuge - Two Rivers NWR	100	0	3,900	0	600	0	100	0	500	500	0	1,500	0	0	0	0	0	0	0	7,100	150	0	0	0	0
Cannon Refuge	60	0	7,000	0	25,000	0	3,000	0	1,000	400	0	0	0	0	0	0	0	0	0	36,400	150	0	0	0	100
Towhead Lake	100	0	3,500	0	3,000	0	2,500	0	2,000	1,000	0	0	0	0	0	0	0	0	0	12,000	0	0	0	0	0
Delair Refuge	70	0	2,100	0	1,000	0	300	0	250	100	0	0	0	0	0	0	0	0	0	3,750	350	5	0	0	0
Shanks Refuge	50	0	1,600	0	2,000	0	3,000	0	3,600	500	0	0	0	0	0	0	0	0	0	10,700	0	0	0	0	0
Meyer-Keokuk	100	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	100	0	0	10	50
TOTAL LOWER			37,700	0	74,575	0	30,925	720	44,325	10,575	0	15,850	0	0	7,175	0	0	0	0	221,845	980	805	0	30	7,425
TOTAL MISSISSIPPI			41,050	0	81,725	0	35,225	740	49,725	11,955	1,450	18,980	500	20	12,005	0	0	0	0	253,375	2,675	805	0	320	47,675
10-Year Average 2006-2015			65,728	60	53,897	0	39,646	2,089	31,277	7,603	22,959	20,379	8,658	255	11,962	83	59	0	0	264,655	4,708	151	950	493	25,573

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 11/14/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	3,600	0	5,400	0	1,800	720	5,400	7,200	360	1,800	1,080	180	1,800	0	0	0	0	29,340	550	0	0	200	6,300
Goose Lake	100	0	7,000	10	0	0	2,300	0	0	0	500	2,700	0	0	0	0	0	0	0	12,510	0	0	0	0	300
Senachwine Lake	100	0	10,000	50	2,500	0	0	0	600	0	0	700	0	0	200	0	0	0	0	14,050	200	0	0	0	300
Hitchcock Slough	90	0	300	0	0	0	400	0	0	300	0	0	0	0	0	0	0	0	0	1,000	0	0	0	0	0
Douglas Lake	100	0	12,000	10	5,000	0	2,000	0	1,500	2,500	0	10,000	0	0	0	0	0	0	0	33,010	100	0	0	0	0
Goose Lake	100	0	25,000	200	8,000	0	4,000	0	0	0	1,000	500	0	0	1,000	0	100	0	0	39,800	0	0	0	0	0
Upper Peoria	100	0	4,500	0	0	0	0	0	0	0	5,500	1,000	0	0	14,500	0	0	0	0	25,500	10	0	0	0	600
TOTAL UPPER			62,400	270	20,900	0	10,500	720	7,500	10,000	7,360	16,700	1,080	180	17,500	0	100	0	0	155,210	860	0	0	200	7,500

LOWER ILLINOIS RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	10	0	0	100	0	5	0	0	115	0	0	0	0	0
Rice Lake	95	0	1,200	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,205	15	0	0	0	0
Big Lake	100	0	2,705	10	0	0	0	0	900	0	0	0	0	0	0	0	0	0	0	3,615	0	0	0	0	0
Banner Marsh	100	0	1,210	0	0	0	0	0	1,255	0	0	0	0	0	0	0	0	0	0	2,465	190	0	0	5	10
Duck Creek	100	0	6,100	0	0	0	0	0	2,260	0	0	0	0	0	0	0	0	0	0	8,360	30	0	0	0	0
Clear Lake	100	0	1,860	0	0	0	0	0	50	0	0	0	0	0	2,505	0	0	0	0	4,415	0	0	0	10	0
Chautauqua	100	0	13,400	0	4,200	0	12,300	0	3,100	1,670	210	400	0	10	3,400	0	20	0	10	38,720	710	0	0	5	500
Emiquon/Spoon Btm	90	0	17,295	0	11,440	0	5,875	570	17,145	5,735	1,145	2,285	570	250	1,145	0	250	0	35	63,740	170	50	30	75	50,865
Grass Lake	100	0	410	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	410	0	0	0	0	0
Jack Lake	100	0	4,000	0	0	0	600	0	200	0	0	600	0	0	0	0	0	0	0	5,400	0	0	0	0	0
Stewart Lake	100	0	20	0	0	0	0	0	200	50	0	0	0	0	0	0	0	0	0	270	0	0	0	0	0
Crane Lake	100	0	1,200	0	200	0	500	0	1,000	200	0	300	0	0	0	0	0	0	0	3,400	250	0	0	0	400
Cuba Island	100	0	6,200	0	11,200	0	3,000	0	2,000	600	0	5,000	0	0	0	0	0	0	0	28,000	800	200	5	5	600
Big Lake	20	0	4,000	0	3,000	0	1,500	0	700	600	0	0	0	0	0	0	0	0	0	9,800	10	0	0	0	100
Spunky Bottoms	20	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	100	0	0	0	0	0
Meredosia Lake	70	0	3,050	0	200	0	0	0	3,800	200	500	0	0	0	100	0	0	0	20	7,870	0	0	0	5	0
TOTAL LOWER			62,650	15	30,240	0	23,775	570	32,610	9,055	1,855	8,595	570	260	7,350	0	275	0	65	177,885	2,175	250	35	105	52,475
TOTAL ILLINOIS			125,050	285	51,140	0	34,275	1,290	40,110	19,055	9,215	25,295	1,650	440	24,850	0	375	0	65	333,095	3,035	250	35	305	59,975
10-Year Average 2006-2015			142,735	952	24,028	0	40,082	2,373	40,197	8,189	2,618	16,855	1,358	39	9,257	28	289	0	131	289,131	2,909	257	56	535	39,284

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 11/14/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	0	0	0	0	0	0	3,000	2,500	600	0	4,200	10	0	0	0	10,310	0	0	0	5	4,000
Arthur Refuge	100	0	300	0	800	0	2,300	0	100	1,100	0	0	0	0	0	0	0	0	0	4,600	670	0	0	20	0
Nauvoo-Ft. Madison	100	0	115	0	0	0	300	0	1,000	200	12,000	3,500	3,000	0	7,500	500	200	0	0	28,315	0	0	0	50	20,000
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0
Henderson Creek	100	0	5,500	0	0	0	500	0	1,500	1,200	2,000	0	0	0	1,000	0	10	0	0	11,710	510	0	0	0	0
Keithsburg Refuge	100	0	500	0	100	0	1,000	0	2,200	200	0	0	0	0	0	0	0	0	0	4,000	670	0	0	85	5,010
Louisa Refuge	100	0	2,600	0	4,000	0	1,000	200	1,500	1,000	0	4,000	0	0	100	0	0	0	0	14,400	300	0	0	15	2,010
TOTAL UPPER			9,015	0	4,900	0	5,100	200	6,300	3,700	17,000	10,000	3,600	0	12,800	510	210	0	0	73,335	2,160	0	0	175	31,020
LOWER MISSISSIPPI RIVER VALLEY																									
Swan Lake	100	0	25,050	0	42,250	0	25,050	500	42,250	8,350	500	16,700	500	0	8,350	0	200	0	0	169,700	600	1,620	0	105	5,000
Gilbert Lake	100	0	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	360	0	0	0	0
Long Lake	100	0	2,000	0	1,200	0	500	0	0	0	0	200	0	0	0	0	0	0	0	3,900	0	0	0	0	0
Dardenne Club	90	0	15,000	0	23,000	0	3,000	0	2,000	0	0	0	0	0	0	0	0	0	0	43,000	0	0	0	0	100
Cuivre Club	70	0	4,000	0	1,000	0	500	0	0	0	0	0	0	0	0	0	0	0	0	5,500	100	0	0	0	0
Batchtown Refuge	100	0	3,500	0	500	0	500	0	500	500	0	3,800	0	0	0	0	0	0	0	9,300	1,000	0	0	5	200
Cannon Refuge	60	0	5,000	0	10,000	0	4,000	0	1,000	500	0	0	0	0	0	0	0	0	0	20,500	200	0	0	0	0
Towhead Lake	100	0	2,500	0	1,500	0	6,000	0	500	500	0	0	0	0	0	0	0	0	0	11,000	0	0	0	0	700
Delair Refuge	90	0	3,500	0	1,000	0	4,000	0	1,000	500	0	0	0	0	0	0	0	0	0	10,000	460	250	20	0	0
Shanks Refuge	60	0	5,500	0	4,000	0	6,000	0	4,000	2,500	0	0	0	0	0	0	0	0	0	22,000	50	0	0	0	2,650
Meyer-Keokuk	100	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	120	0	0	0	0
TOTAL LOWER			66,270	0	84,450	0	49,550	500	51,250	12,850	500	20,700	500	0	8,350	0	200	0	0	295,120	2,890	1,870	20	110	8,650
TOTAL MISSISSIPPI			75,285	0	89,350	0	54,650	700	57,550	16,550	17,500	30,700	4,100	0	21,150	510	410	0	0	368,455	5,050	1,870	20	285	39,670
10-Year Average 2006-2015			146,439	411	37,989	0	29,748	2,438	33,980	6,023	19,355	25,616	11,804	233	13,619	126	1,272	3	61	329,121	3,561	184	764	313	16,179

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 11/21/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	5	3,500	0	3,750	0	1,250	100	2,500	5,000	0	1,250	1,250	250	5,000	0	0	0	0	23,850	600	0	0	200	1,250
Goose Lake	100	5	4,600	25	200	0	750	0	0	0	0	3,000	0	0	500	0	10	0	0	9,085	0	0	0	0	0
Senachwine Lake	100	5	5,400	25	100	0	10	0	0	0	0	0	0	0	0	0	0	0	20	5,555	200	0	0	0	0
Hitchcock Slough	100	0	50	0	0	0	325	0	0	300	0	0	0	0	0	0	0	0	0	675	0	0	0	0	0
Douglas Lake	90	0	14,100	0	5,200	0	4,200	0	1,700	1,200	0	6,000	0	0	0	0	100	0	0	32,500	0	0	0	0	0
Goose Lake	90	0	29,000	0	6,000	0	5,000	0	0	0	0	1,000	0	0	200	0	0	0	0	41,200	0	0	0	100	0
Upper Peoria	100	0	4,550	50	0	0	0	0	0	0	3,300	500	0	0	14,900	300	200	10	0	23,810	230	0	0	0	0
TOTAL UPPER			61,200	100	15,250	0	11,535	100	4,200	6,500	3,300	11,750	1,250	250	20,600	300	310	10	20	136,675	1,030	0	0	300	1,250
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	5	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	5	10	0	0	0	0
Rice Lake	100	5	1,300	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	1,400	0	0	0	0	0
Big Lake	100	5	3,320	0	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	3,520	0	0	100	0	0
Banner Marsh	100	5	2,200	5	10	0	0	0	1,520	0	0	0	0	0	0	0	0	0	0	3,735	340	0	0	0	0
Duck Creek	100	0	5,000	0	0	0	0	0	1,520	0	0	0	0	0	0	0	0	0	0	6,520	60	0	0	0	0
Clear Lake	100	5	700	0	0	0	100	0	0	100	0	0	0	0	3,200	0	0	0	0	4,100	0	0	0	0	0
Chautauqua	100	5	9,700	0	6,700	0	16,050	105	2,200	2,500	25	100	0	0	4,300	0	0	0	0	41,680	375	0	0	0	300
Emiquon/Spoon Btm	90	5	5,375	0	9,330	0	2,650	260	5,140	10,300	0	2,540	0	0	1,550	515	1,030	0	35	38,725	120	155	0	110	11,280
Grass Lake	100	10	200	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	210	0	0	0	0	0
Jack Lake	100	10	1,600	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	1,700	0	0	0	0	0
Stewart Lake	100	5	0	0	0	0	0	0	0	0	0	0	0	0	300	0	15	0	0	315	0	0	0	5	0
Crane Lake	100	5	1,300	0	0	0	0	0	0	0	0	0	0	0	200	0	10	0	10	1,520	150	0	0	0	1,000
Cuba Island	100	10	11,100	0	5,000	0	2,500	0	2,500	1,500	0	8,000	0	0	200	0	0	0	0	30,800	500	400	0	0	200
Big Lake	20	10	4,000	0	3,000	0	3,000	0	100	500	0	500	0	0	0	0	0	0	0	11,100	0	0	0	0	0
Spunky Bottoms	20	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	70	10	700	0	100	0	0	0	400	320	0	0	0	0	10	0	0	0	50	1,580	0	0	0	30	0
TOTAL LOWER			46,495	5	24,140	0	24,400	365	13,380	15,520	25	11,140	0	0	9,760	530	1,055	0	95	146,910	1,555	555	100	145	12,780
TOTAL ILLINOIS			107,695	105	39,390	0	35,935	465	17,580	22,020	3,325	22,890	1,250	250	30,360	830	1,365	10	115	283,585	2,585	555	100	445	14,030
10-Year Average 2006-2015			132,781	735	15,585	0	26,213	680	23,134	5,859	1,654	14,334	1,239	41	5,317	593	653	14	116	228,946	3,014	263	82	219	20,246

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 11/21/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	0	0	0	0	0	0	0	0	9,000	800	27,500	0	3,520	700	700	0	0	42,220	0	0	0	5	1,000
Arthur Refuge	100	0	300	0	900	0	2,150	0	220	500	0	0	0	0	0	0	0	0	0	4,070	900	0	0	0	100
Nauvoo-Ft. Madison	100	0	0	0	0	0	100	0	350	50	3,000	1,000	8,000	0	0	1,300	300	0	0	14,100	100	0	0	5	9,200
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	305	0	0	0	0
Henderson Creek	100	0	13,500	0	500	0	1,000	0	300	100	0	0	750	0	0	0	0	0	0	16,150	300	0	0	0	1,000
Keithsburg Refuge	100	0	3,400	0	100	0	200	0	4,900	700	0	0	0	0	0	0	0	0	0	9,300	700	0	0	300	1,300
Louisa Refuge	100	0	2,500	0	1,100	0	1,100	0	1,500	500	0	5,000	50	0	0	0	0	0	0	11,750	400	0	0	5	200
TOTAL UPPER			19,700	0	2,600	0	4,550	0	7,270	1,850	12,000	6,800	36,300	0	3,520	2,000	1,000	0	0	97,590	2,705	0	0	315	12,800
LOWER MISSISSIPPI RIVER VALLEY																									
Swan Lake - Two Rivers NWR	100	0	20,980	0	31,960	0	31,960	3,200	23,970	23,970	200	23,970	500	0	1,600	200	300	0	0	162,810	600	2,100	1,200	100	3,000
Gilbert Lake - Two Rivers NWR	100	0	100	0	100	0	0	0	15	0	0	500	0	0	0	0	0	0	0	715	400	0	0	0	0
Long Lake	100	0	5,000	0	1,500	0	500	0	0	500	0	0	0	0	0	0	0	0	0	7,500	0	0	0	0	0
Dardenne Club	100	0	11,000	0	27,000	0	2,000	0	1,000	0	0	0	0	0	0	0	0	0	0	41,000	0	0	0	0	0
Cuivre Club	100	0	4,000	0	2,000	0	0	0	500	0	0	0	0	0	0	0	0	0	0	6,500	0	0	0	0	100
Batchtown - Two Rivers NWR	100	0	10,100	0	2,000	0	1,300	0	300	450	0	8,000	0	0	50	0	0	0	0	22,200	500	0	0	0	0
Cannon Refuge	60	0	7,100	0	25,000	0	5,000	0	1,000	1,000	0	0	0	0	0	0	0	0	0	39,100	200	0	0	0	0
Towhead Lake	100	0	7,000	0	3,000	0	9,000	0	1,000	1,000	0	3,000	0	0	0	0	0	0	0	24,000	50	0	0	0	400
Delair Refuge	100	0	4,000	0	1,500	0	6,000	0	2,000	1,000	0	0	0	0	0	0	0	0	0	14,500	305	500	0	0	0
Shanks Refuge	70	0	25,300	0	6,000	0	17,000	0	4,000	500	0	0	0	0	0	0	0	0	0	52,800	0	0	0	0	400
Meyer-Keokuk	100	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	160	0	0	0	0
TOTAL LOWER			94,600	0	100,060	0	72,760	3,200	33,785	28,420	200	35,470	500	0	1,650	200	300	0	0	371,145	2,215	2,600	1,200	100	3,900
TOTAL MISSISSIPPI			114,300	0	102,660	0	77,310	3,200	41,055	30,270	12,200	42,270	36,800	0	5,170	2,200	1,300	0	0	468,735	4,920	2,600	1,200	415	16,700
10-Year Average 2006-2015			159,299	387	29,909	0	27,134	562	17,938	4,713	14,890	18,384	45,839	311	8,914	3,174	2,162	138	21	333,775	4,313	537	2,625	210	6,518

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 11/29/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	0	15,000	0	8,650	0	2,150	0	4,300	10,750	0	1,000	300	0	2,500	0	0	0	0	44,650	550	125	0	105	3,150
Goose Lake	100	0	3,000	0	0	0	9,000	0	0	0	100	0	0	0	1,200	0	0	0	0	13,300	100	0	0	110	0
Senachwine Lake	100	0	5,500	15	400	0	1,100	0	0	0	0	0	0	0	0	20	0	0	0	7,035	0	0	0	0	0
Hitchcock Slough	100	0	10	0	0	0	100	0	200	0	0	0	0	0	0	0	0	0	0	310	0	0	0	0	0
Douglas Lake	100	0	17,000	0	6,000	0	1,000	0	500	500	0	2,000	0	0	100	0	0	0	0	27,100	0	0	0	0	0
Goose Lake	100	0	25,000	0	3,000	0	3,000	0	0	0	0	0	0	0	300	0	0	0	0	31,300	0	0	0	100	0
Upper Peoria	100	0	6,500	0	0	0	0	0	0	0	900	0	0	0	11,000	0	0	0	0	18,400	150	0	150	0	0
TOTAL UPPER			72,010	15	18,050	0	16,350	0	5,000	11,250	1,000	3,000	300	0	15,100	20	0	0	0	142,095	800	125	150	315	3,150
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	100	0	325	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	330	0	0	0	5	0
Big Lake	100	0	8,005	5	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8,110	0	0	20	0	0
Banner Marsh	100	0	2,510	0	0	0	600	0	2,500	0	0	0	0	0	0	0	0	0	0	5,610	0	0	0	5	100
Duck Creek	100	0	2,450	0	0	0	0	0	1,550	0	0	5	0	0	0	0	0	0	0	4,005	255	0	0	0	0
Clear Lake	100	0	3,000	15	0	0	100	0	0	100	10	0	0	0	2,460	0	0	0	0	5,685	100	0	0	0	0
Chautauqua	100	0	3,750	10	2,900	0	19,700	0	550	400	50	0	0	0	7,300	0	50	0	0	34,710	1,660	0	0	0	0
Emiquon/Spoon Btm	90	0	9,810	5	9,500	0	6,235	0	9,300	6,240	0	1,000	200	5	3,100	0	205	0	105	45,705	250	500	1,500	95	17,195
Grass Lake	100	0	500	0	0	0	5	0	0	0	0	0	0	0	100	0	0	0	5	610	0	0	0	0	0
Jack Lake	100	0	3,000	0	100	0	0	0	0	0	100	0	0	0	0	0	0	0	0	3,200	10	50	400	0	0
Stewart Lake	100	0	40	0	0	0	0	0	0	0	10	0	0	0	350	0	300	0	0	700	0	0	0	0	0
Crane Lake	100	0	2,500	0	0	0	700	0	100	0	0	0	0	0	0	0	10	0	0	3,310	150	0	0	0	5
Cuba Island	100	0	14,600	0	11,000	0	1,000	0	1,000	500	0	10,000	0	0	0	0	0	0	0	38,100	600	500	1,000	0	0
Big Lake	20	0	5,000	10	2,500	0	100	0	0	500	0	100	0	0	0	0	0	0	0	8,210	0	10	0	0	0
Spunky Bottoms	20	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Meredosia Lake	70	0	415	0	100	0	500	0	500	50	0	0	0	0	0	0	0	0	0	1,565	0	0	0	20	0
TOTAL LOWER			55,905	50	26,200	0	28,940	0	15,500	7,800	70	11,205	200	5	13,310	0	565	0	110	159,860	3,025	1,060	2,920	125	17,300
TOTAL ILLINOIS			127,915	65	44,250	0	45,290	0	20,500	19,050	1,070	14,205	500	5	28,410	20	565	0	110	301,955	3,825	1,185	3,070	440	20,450
10-Year Average 2006-2015			168,703	935	7,770	0	10,701	134	9,952	3,385	969	8,116	1,723	14	5,115	489	314	39	169	218,526	3,560	943	57	93	6,639

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 11/29/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	0	470	0	200	0	100	0	0	0	1,200	1,000	31,500	0	2,400	500	450	20	0	37,840	100	10	0	15	700
Arthur Refuge	100	0	500	0	500	0	700	0	0	1,500	0	0	0	0	0	0	0	0	0	3,200	1,400	100	0	0	0
Nauvoo-Ft. Madison	100	0	100	0	0	0	1,200	0	100	0	4,000	0	6,000	0	2,000	5,000	1,100	0	0	19,500	0	0	0	0	13,500
Ft. Madison-Dallas	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Henderson Creek	100	0	13,200	0	2,000	0	2,000	0	0	300	200	0	0	0	0	25	0	0	0	17,725	550	0	0	0	0
Keithsburg Refuge	100	0	5,100	0	1,000	0	500	0	16,000	0	0	0	0	0	0	0	0	0	0	22,600	600	0	0	310	200
Louisa Refuge	100	0	5,500	0	2,000	0	3,500	0	200	200	0	10,000	200	0	0	0	0	0	0	21,600	1,200	100	0	0	300
TOTAL UPPER			24,870	0	5,700	0	8,000	0	16,300	2,000	5,400	11,000	37,700	0	4,400	5,525	1,550	20	0	122,465	3,850	210	0	325	14,700

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake	100	0	33,600	50	33,600	0	42,000	0	16,800	8,400	0	33,600	100	0	0	0	0	0	0	168,150	1,500	2,220	5,000	0	4,000
Gilbert Lake	100	0	2,200	0	200	0	0	0	0	0	10	5,200	0	0	0	0	0	0	0	7,610	210	0	0	0	0
Long Lake	100	0	8,200	0	1,000	0	300	0	200	500	0	500	0	0	0	0	0	0	0	10,700	0	0	0	0	0
Dardenne Club	100	0	40,000	0	15,000	0	2,000	0	1,000	1,000	0	0	0	0	0	0	0	0	0	59,000	0	0	0	0	100
Cuivre Club	100	0	10,000	0	2,000	0	1,000	0	1,000	1,000	0	0	0	0	0	0	0	0	0	15,000	0	0	0	0	0
Batchtown Refuge	100	0	10,000	0	2,500	0	2,500	0	1,500	1,000	0	16,000	10	0	0	0	0	0	0	33,510	600	0	0	0	0
Cannon Refuge	60	0	41,705	25	18,800	0	23,500	0	4,800	4,700	0	470	0	0	0	0	0	0	0	94,000	150	50	0	0	0
Towhead Lake	100	0	20,000	0	10,000	0	14,000	0	5,200	1,800	0	500	0	0	0	0	0	0	0	51,500	0	0	0	0	4,000
Delair Refuge	100	0	8,000	0	2,000	0	5,000	0	1,000	1,000	0	200	0	0	0	0	0	0	5	17,205	400	2,500	500	0	0
Shanks Refuge	80	0	23,500	0	9,000	0	5,000	0	3,500	3,000	0	0	0	0	0	0	0	0	0	44,000	0	0	0	0	1,000
Meyer-Keokuk	100	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	300	0	0	0	0
TOTAL LOWER			197,225	75	94,100	0	95,300	0	35,000	22,400	10	56,470	110	0	0	0	0	0	5	500,695	3,160	4,770	5,500	0	9,100
TOTAL MISSISSIPPI			222,095	75	99,800	0	103,300	0	51,300	24,400	5,410	67,470	37,810	0	4,400	5,525	1,550	20	5	623,160	7,010	4,980	5,500	325	23,800
10-Year Average 2006-2015			224,491	180	24,166	0	20,802	293	15,149	2,858	12,125	13,805	86,973	826	5,960	6,419	1,951	311	36	416,514	5,771	599	1,389	128	7,089

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 12/7/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	10	9,840	0	2,460	0	1,230	0	2,460	3,690	0	2,460	100	0	0	0	0	0	0	22,240	610	0	0	0	2,460
Goose Lake	100	10	4,600	0	0	0	600	0	0	20	0	3,645	30	0	0	0	10	0	0	8,905	0	0	0	0	10
Senachwine Lake	100	10	14,100	200	1,030	0	0	0	0	0	0	0	50	0	100	0	0	0	0	15,480	250	0	0	0	0
Hitchcock Slough	100	10	300	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	400	0	0	0	0	0
Douglas Lake	100	10	20,200	0	5,000	0	6,000	0	0	200	0	1,000	0	0	0	0	10	0	0	32,410	0	0	0	0	0
Goose Lake	100	5	14,210	50	3,000	0	2,000	0	0	0	400	0	100	0	500	0	0	0	0	20,260	0	0	0	0	0
Upper Peoria	100	5	5,000	100	0	0	0	0	0	0	1,350	500	200	0	4,500	500	0	200	0	12,350	0	0	0	0	0
TOTAL UPPER			68,250	350	11,490	0	9,830	0	2,560	3,910	1,750	7,605	480	0	5,100	500	20	200	0	112,045	860	0	0	0	2,470

LOWER ILLINOIS RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Goose Lake	100	10	700	0	0	0	0	0	0	0	10	50	0	0	0	0	0	0	0	760	40	0	0	0	95
Rice Lake	100	5	200	5	0	0	100	0	50	0	0	0	0	0	5	0	0	0	0	360	80	0	0	0	0
Big Lake	100	10	8,700	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	8,720	0	0	0	0	0
Banner Marsh	100	5	1,220	0	0	0	300	0	2,200	0	0	0	0	0	0	0	0	0	5	3,725	210	0	0	0	0
Duck Creek	100	0	3,000	0	0	0	0	0	900	0	0	30	0	0	0	0	0	0	0	3,930	75	0	0	0	0
Clear Lake	100	10	4,300	10	0	0	200	0	0	0	0	100	0	0	760	0	0	0	0	5,370	30	0	0	0	20
Chautauqua	100	10	7,605	5	0	0	1,130	0	250	150	100	0	0	0	610	0	10	0	0	9,860	445	0	0	0	0
Emiquon/Spoon Btm	90	10	7,795	0	970	0	3,005	0	4,850	1,020	390	195	580	0	970	495	195	20	120	20,605	210	25	0	60	1,940
Grass Lake	100	10	1,100	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	1,120	0	0	0	0	0
Jack Lake	100	10	3,500	0	0	0	0	0	0	0	0	1,000	0	0	100	0	50	0	0	4,650	0	0	0	0	0
Stewart Lake	100	5	570	0	0	0	0	0	50	0	10	50	0	0	250	25	0	0	0	955	0	0	0	0	0
Crane Lake	100	5	13,800	5	100	0	3,010	0	200	0	0	300	0	0	0	0	0	0	0	17,415	100	0	0	0	100
Cuba Island	100	10	7,300	0	500	0	800	0	300	200	0	5,000	0	0	0	0	0	0	0	14,100	650	1,300	0	0	5
Big Lake	20	10	6,000	20	1,000	0	1,500	0	0	500	0	1,000	0	0	0	0	0	0	0	10,020	0	50	0	0	0
Spunky Bottoms	20	40	800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	810	120	0	0	0	0
Meredosia Lake	70	10	2,750	0	0	0	1,000	0	500	200	300	200	0	0	0	0	20	0	0	4,970	0	0	0	0	300
TOTAL LOWER			69,340	45	2,570	0	11,045	0	9,300	2,070	810	7,925	580	0	2,695	540	295	20	135	107,370	1,960	1,375	0	60	2,460
TOTAL ILLINOIS			137,590	395	14,060	0	20,875	0	11,860	5,980	2,560	15,530	1,060	0	7,795	1,040	315	220	135	219,415	2,820	1,375	0	60	4,930
10-Year Average 2006-2015			166,436	1,051	5,733	0	13,758	0	10,665	4,162	1,872	10,737	1,435	36	8,736	744	444	354	302	226,465	5,309	1,133	944	55	9,822

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 12/07/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	5	40	0	0	0	0	0	0	0	9,300	2,500	77,200	50	1,500	3,000	1,200	0	0	94,790	0	0	0	5	500
Arthur Refuge	100	30	3,100	0	100	0	1,600	0	200	100	0	0	0	0	0	0	0	0	0	5,100	1,370	150	0	0	0
Nauvoo-Ft. Madison	100	5	170	0	0	0	2,300	0	0	200	5,000	0	2,000	100	500	2,800	25	15	100	13,210	0	0	0	0	3,100
Ft. Madison-Dallas	100	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Henderson Creek	100	10	20,950	0	0	0	2,500	0	100	200	100	0	100	0	0	0	0	0	0	23,950	150	0	0	150	500
Keithsburg Refuge	100	20	6,830	0	200	0	0	0	7,850	300	0	0	0	0	0	0	0	0	0	15,180	1,325	100	0	205	0
Louisa Refuge	100	50	7,000	0	0	0	100	0	5	100	0	5,000	100	0	0	0	0	0	0	12,305	755	200	0	0	0
TOTAL UPPER			38,100	0	300	0	6,500	0	8,155	900	14,400	7,500	79,400	150	2,000	5,800	1,225	15	100	164,545	3,600	450	0	360	4,100
LOWER MISSISSIPPI RIVER VALLEY																									
Swan Lake - Two River NWR	100	20	25,500	0	3,750	0	15,000	0	15,000	7,500	750	5,000	750	100	3,750	750	750	0	0	78,600	455	600	4,000	0	6,200
Gilbert Lake - Two Rivers NWR	100	10	1,600	0	100	0	100	0	200	200	0	1,300	0	0	0	0	0	0	0	3,500	100	50	0	0	0
Long Lake	100	5	14,000	0	2,500	0	1,250	0	250	500	0	2,500	0	0	0	0	0	0	0	21,000	0	0	0	0	0
Dardenne Club	100	20	50,000	0	26,000	0	1,335	0	1,335	1,335	0	0	0	0	0	0	0	0	0	80,005	0	0	0	0	200
Cuivre Club	100	10	16,000	0	8,000	0	0	0	1,000	0	0	0	0	0	0	0	0	0	0	25,000	0	0	0	0	0
Batchtown - Two Rivers NWR	100	10	32,000	0	3,500	0	7,000	0	3,000	2,300	0	10,000	0	0	0	0	0	0	0	57,800	100	0	0	0	0
Cannon Refuge	70	50	40,000	0	18,500	0	18,000	0	4,500	9,000	0	0	0	0	0	0	0	0	0	90,000	200	100	0	0	0
Towhead Lake	100	10	36,000	0	6,000	0	12,000	0	3,000	3,000	0	6,000	0	0	0	0	0	0	0	66,000	100	2,700	500	0	800
Delair Refuge	100	10	20,000	0	500	0	5,000	0	500	500	0	0	0	0	0	0	0	0	0	26,500	400	0	0	0	0
Shanks Refuge	80	50	49,200	0	12,300	0	8,200	0	8,200	4,100	0	0	0	0	0	0	0	0	0	82,000	50	0	0	0	4,400
Meyer-Keokuk	100	0	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	10	0	0	10	0
TOTAL LOWER			284,350	0	81,150	0	67,885	0	36,985	28,435	750	24,800	750	100	3,750	750	750	0	0	530,455	1,415	3,450	4,500	10	11,600
TOTAL MISSISSIPPI			322,450	0	81,450	0	74,385	0	45,140	29,335	15,150	32,300	80,150	250	5,750	6,550	1,975	15	100	695,000	5,015	3,900	4,500	370	15,700
10-Year Average 2006-2015			254,590	583	33,691	0	14,500	933	12,541	3,607	17,301	20,887	61,663	496	6,395	6,769	2,823	3,541	23	440,341	7,422	1,249	2,920	116	3,793

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 12/12/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	90	6,600	0	1,500	0	0	0	500	1,000	0	0	0	0	0	0	0	0	0	9,600	0	100	0	0	1,100
Goose Lake	100	60	22,000	100	4,000	0	500	0	1,000	2,000	0	2,000	0	0	0	0	0	0	0	31,600	0	0	0	0	100
Senachwine Lake	100	80	9,100	50	0	0	0	0	0	0	0	0	0	0	1,000	2,000	0	50	0	12,200	50	0	0	0	0
Hitchcock Slough	100	80	120	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	120	10	0	0	0	0
Douglas Lake	100	90	7,200	0	2,300	0	3,000	0	0	0	0	0	0	0	0	0	0	0	0	12,500	0	0	0	0	100
Goose Lake	100	80	44,775	225	15,000	0	10,000	0	2,500	1,500	0	0	500	0	1,000	2,000	0	0	0	77,500	0	0	0	0	500
Upper Peoria	100	20	4,800	25	0	0	0	0	0	0	5,700	1,900	15,200	0	5,700	7,600	1,900	310	0	43,135	400	0	0	0	1,700
TOTAL UPPER			94,595	400	22,800	0	13,500	0	4,000	4,500	5,700	3,900	15,700	0	7,700	11,600	1,900	360	0	186,655	460	100	0	0	3,500

LOWER ILLINOIS RIVER VALLEY

Goose Lake	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	100	95	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	125	0	0	0	0
Big Lake	100	95	2,000	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,010	0	0	0	0	0
Banner Marsh	100	70	60	0	0	0	0	0	1,030	10	0	0	0	0	0	0	0	0	0	1,100	210	0	0	5	0
Duck Creek	100	5	29,450	150	0	0	0	0	2,300	0	0	0	0	0	0	0	0	0	0	31,900	1,430	50	0	0	0
Clear Lake	100	99	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	400	0	0	0	0
Chautauqua	100	95	11,010	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	11,030	525	0	0	0	0
Emiquon/Spoon Btm	90	90	12,450	0	0	0	500	0	1,100	100	100	0	55	75	400	400	0	50	100	15,330	400	250	0	50	3,700
Grass Lake	100	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack Lake	100	95	4,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4,000	0	0	0	0	0
Stewart Lake	100	95	0	0	0	0	0	0	0	0	0	0	0	0	0	40	0	0	0	40	0	0	0	0	0
Crane Lake	100	95	17,000	0	0	0	1,000	0	0	0	0	0	0	0	0	0	0	0	0	18,000	0	0	0	0	0
Cuba Island	100	90	14,500	0	500	0	0	0	0	0	0	2,000	0	0	0	0	0	0	0	17,000	600	1,000	0	0	0
Big Lake	20	60	30	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	80	0	0	0	0	20
Spunky Bottoms	60	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	70	60	1,400	0	0	0	0	0	0	0	100	0	10	0	0	100	100	0	0	1,710	250	0	0	0	100
TOTAL LOWER			92,260	160	500	0	1,500	0	4,430	160	220	2,000	65	75	400	540	100	50	100	102,560	3,940	1,300	0	55	3,820
TOTAL ILLINOIS			186,855	560	23,300	0	15,000	0	8,430	4,660	5,920	5,900	15,765	75	8,100	12,140	2,000	410	100	289,215	4,400	1,400	0	55	7,320
10-Year Average 2006-2015			159,249	691	8,449	0	3,874	0	4,884	752	831	4,136	591	29	5,106	1,106	295	829	397	191,218	8,441	2,253	2,361	9	3,253

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 12/12/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	50	0	0	0	0	0	0	0	0	8,400	1,000	61,000	100	2,000	6,500	1,000	100	0	80,100	0	0	0	5	500
Arthur Refuge	100	90	2,200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,200	1,300	0	0	0	0
Nauvoo-Ft. Madison	100	30	3,200	0	500	0	0	0	200	500	15,000	375	89,450	325	500	13,500	3,750	325	0	127,625	200	0	0	0	0
Ft. Madison-Dallas	100	10	0	0	0	0	0	0	0	0	1,000	0	9,000	0	0	700	0	0	0	10,700	0	0	0	0	0
Henderson Creek	100	95	13,000	0	0	0	0	0	0	0	0	0	200	0	0	0	0	0	0	13,200	0	0	0	0	0
Keithsburg Refuge	100	99	7,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7,500	400	250	0	0	0
Louisa Refuge	100	99	14,000	25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14,025	1,060	300	0	0	0
TOTAL UPPER			39,900	25	500	0	0	0	200	500	24,400	1,375	159,650	425	2,500	20,700	4,750	425	0	255,350	2,960	550	0	5	500
LOWER MISSISSIPPI RIVER VALLEY																									
Swan Lake - Two Rivers NWR	100	90	45,000	150	0	0	3,000	0	3,000	0	0	3,000	25	0	100	200	0	0	0	54,475	400	500	0	0	500
Gilbert Lake - Two Rivers NWF	100	70	50	0	0	0	0	0	200	0	0	0	0	0	0	0	0	0	0	250	300	300	0	0	0
Long Lake	100	50	39,000	0	10,000	0	5,000	0	0	0	0	1,000	0	0	0	0	0	0	0	55,000	0	0	0	0	0
Dardenne Club	100	80	60,000	100	40,000	0	5,000	0	5,000	0	0	0	0	0	0	0	0	0	0	110,100	20	0	0	0	0
Cuivre Club	100	70	35,475	275	11,000	0	2,750	0	3,850	1,650	0	0	0	0	0	0	0	0	0	55,000	0	0	0	0	0
Batchtown - Two Rivers NWR	100	80	33,000	0	0	0	2,000	0	0	0	0	8,000	0	0	0	0	0	0	0	43,000	0	0	0	0	0
Cannon Refuge	80	95	35,000	0	10,000	0	2,000	0	1,000	1,000	0	0	0	0	0	0	0	0	0	49,000	0	0	0	0	0
Towhead Lake	100	70	40,000	0	5,000	0	5,000	0	1,000	1,000	0	500	0	0	0	0	0	0	0	52,500	100	1,400	500	0	0
Delair Refuge	100	90	42,000	0	2,000	0	1,000	0	0	0	0	0	0	0	0	0	0	0	0	45,000	300	1,075	0	0	0
Shanks Refuge	80	90	112,800	200	10,000	0	10,000	0	5,000	2,000	0	0	0	0	0	0	0	0	0	140,000	0	0	0	0	300
Meyer-Keokuk	100	5	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	380	0	0	55	0
TOTAL LOWER			442,425	725	88,000	0	35,750	0	19,050	5,650	0	12,500	25	0	100	200	0	0	0	604,425	1,500	3,275	500	55	800
TOTAL MISSISSIPPI			482,325	750	88,500	0	35,750	0	19,250	6,150	24,400	13,875	159,675	425	2,600	20,900	4,750	425	0	859,775	4,460	3,825	500	60	1,300
10-Year Average 2006-2015			180,284	158	12,672	0	11,084	0	7,224	1,122	10,844	10,837	42,946	151	5,859	6,913	2,666	2,549	36	295,796	5,761	1,163	3,031	17	3,507

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 12/21/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	99	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	5	0	0	0	20
Goose Lake	100	99	200	5	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	210	200	0	0	0	0
Senachwine Lake	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	150	0	175	1,300	0	0	0	0
Hitchcock Slough	100	99	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	0	0	0	0	0
Douglas Lake	100	99	55	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	10	0	0	0	0
Goose Lake	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Upper Peoria	100	99	54,410	200	2,000	0	0	0	0	0	10	0	150	0	0	200	0	2,000	0	58,970	1,900	0	0	0	100
TOTAL UPPER			54,975	205	2,000	0	0	0	0	0	10	0	150	0	5	225	0	2,150	0	59,720	3,415	0	0	0	120

LOWER ILLINOIS RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Goose Lake	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rice Lake	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	0	200	250	0	0	0	0
Big Lake	100	100	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0
Banner Marsh	100	99	300	0	0	0	0	0	405	0	0	0	5	0	0	100	0	50	0	860	710	0	0	0	15
Duck Creek	100	20	45,500	100	0	0	0	0	1,200	0	0	0	0	0	0	400	0	920	0	48,120	13,000	4,300	0	0	200
Clear Lake	100	99	0	0	0	0	0	0	5	0	0	0	0	0	0	5	0	0	0	10	5	0	0	0	0
Chautauqua	100	99	5,500	50	0	0	0	0	0	0	0	0	5	0	0	5	0	0	0	5,560	35	0	0	0	0
Emiquon/Spoon Btm	90	99	1,130	0	0	0	0	0	55	0	0	0	5	0	0	15	0	105	0	1,310	890	100	0	0	5
Grass Lake	100	100	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	20	0	0	0	0
Jack Lake	100	99	1,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	1,520	400	0	0	0	0
Stewart Lake	100	99	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Crane Lake	100	99	2,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2,000	300	0	0	0	0
Cuba Island	100	99	8,000	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	8,005	3,100	1,000	0	0	0
Big Lake	20	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spunky Bottoms	60	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	70	99	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	300	300	0	0	0	0
TOTAL LOWER			64,250	150	0	0	0	0	1,665	0	0	0	15	0	0	730	0	1,095	0	67,905	19,010	5,400	0	0	220
TOTAL ILLINOIS			119,225	355	2,000	0	0	0	1,665	0	10	0	165	0	5	955	0	3,245	0	127,625	22,425	5,400	0	0	340
10-Year Average 2006-2015			125,820	712	2,959	0	7,964	7	4,234	2,049	893	4,805	209	36	4,024	1,381	79	1,035	350	156,555	10,438	4,549	4,144	4	2,797

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 12/21/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	99	0	0	0	0	0	0	0	0	50	0	100	0	0	910	0	610	0	1,670	900	0	0	0	0
Arthur Refuge	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nauvoo-Ft. Madison	100	99	900	0	0	0	0	0	0	0	125	150	50	0	0	285	0	2,000	0	3,510	2,100	0	0	0	0
Ft. Madison-Dallas	100	99	400	0	0	0	0	0	0	0	0	0	2,000	0	0	710	0	1,400	0	4,510	1,500	0	0	0	0
Henderson Creek	100	99	1,400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	1,600	1,100	0	0	0	0
Keithsburg Refuge	100	99	300	0	0	0	0	0	0	0	0	0	0	0	0	250	0	0	0	550	1,700	0	0	0	0
Louisa Refuge	100	99	500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	500	0	1,000	1,000	0	0	0	0
TOTAL UPPER			3,500	0	0	0	0	0	0	0	175	150	2,150	0	0	2,155	0	4,710	0	12,840	8,300	0	0	0	0

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake - Two River NWR	100	99	24,200	100	500	0	0	0	0	0	0	4,000	0	0	0	0	0	0	0	28,800	0	0	0	0	0
Gilbert Lake - Two Rivers NWR	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	430	0	0	0
Long Lake	100	95	49,000	0	1,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50,000	200	0	0	0	0
Dardenne Club	100	99	84,000	0	10,000	0	0	0	2,000	0	0	0	0	0	0	0	0	0	0	96,000	0	0	0	0	0
Cuivre Club	100	99	400	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	500	200	0	0	0	0
Batchtown - Two Rivers NWR	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cannon Refuge	80	100	150	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	155	0	0	0	0	0
Towhead Lake	100	90	15,000	100	0	0	0	0	500	0	0	0	0	0	0	0	0	0	0	15,600	80	400	30	0	100
Delair Refuge	100	90	9,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9,000	175	0	0	0	0
Shanks Refuge	80	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0
Meyer-Keokuk	100	95	600	0	0	0	0	0	0	0	0	0	415	0	0	935	0	1,025	0	2,975	3,000	0	0	105	0
TOTAL LOWER			182,450	200	11,505	0	0	0	2,600	0	0	4,000	415	0	0	935	0	1,025	0	203,130	3,855	830	30	105	100
TOTAL MISSISSIPPI			185,950	200	11,505	0	0	0	2,600	0	175	4,150	2,565	0	0	3,090	0	5,735	0	215,970	12,155	830	30	105	100
10-Year Average 2006-2015			193,963	558	12,021	0	12,653	17	7,993	1,488	12,588	12,458	41,112	280	3,684	10,287	1,803	4,819	10	315,734	9,435	2,232	2,551	31	2,706

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 12/27/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	95	100	0	0	0	0	0	0	100	0	0	0	0	0	0	0	10	0	210	400	0	0	0	0
Goose Lake	100	95	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	680	0	780	430	0	0	0	0
Senachwine Lake	100	95	10,000	0	0	0	0	0	0	0	0	0	0	0	0	100	0	460	0	10,560	600	0	0	0	0
Hitchcock Slough	100	95	1,600	0	25	0	0	0	0	0	0	0	0	0	0	0	0	50	0	1,675	1,460	30	0	0	0
Douglas Lake	100	95	800	0	0	0	0	0	0	0	0	0	0	0	0	5	0	135	0	940	0	0	0	0	0
Goose Lake	100	95	1,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,500	600	0	0	0	0
Upper Peoria	100	60	17,100	30	0	0	0	0	0	0	300	0	1,000	0	0	8,100	0	3,300	0	29,830	310	10	0	0	0
TOTAL UPPER			31,200	30	25	0	0	0	0	100	300	0	1,000	0	0	8,205	0	4,635	0	45,495	3,800	40	0	0	0
LOWER ILLINOIS RIVER VALLEY																									
Goose Lake	100	95	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0
Rice Lake	100	95	7,800	0	0	0	0	0	0	0	0	0	0	0	0	120	0	625	0	8,545	1,100	0	0	0	0
Big Lake	100	95	6,800	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,800	0	0	0	0	0
Banner Marsh	100	90	110	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	115	2,130	0	0	0	5
Duck Creek	100	20	26,600	0	0	0	0	0	200	0	0	0	0	0	0	500	0	525	0	27,825	15,500	3,200	100	0	100
Clear Lake	100	90	700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	410	0	1,110	1,310	0	0	0	0
Chautauqua	100	80	6,500	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	6,530	365	500	0	0	0
Emiquon/Spoon Btm	90	80	1,180	0	0	0	0	0	0	0	0	0	0	0	0	1,020	0	635	5	2,840	1,920	225	0	0	0
Grass Lake	100	80	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	45	0	0	0	0	0
Jack Lake	100	80	3,610	0	0	0	0	0	0	0	0	0	0	0	0	150	0	105	0	3,865	15	0	0	0	0
Stewart Lake	100	90	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	5	0	60	0	0	0	0	0
Crane Lake	100	90	900	5	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	915	50	500	0	0	0
Cuba Island	100	80	8,000	0	0	0	0	0	0	0	0	1,000	0	0	0	0	0	0	0	9,000	1,150	200	0	0	0
Big Lake	20	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Spunky Bottoms	10	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	70	90	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	160	375	0	0	0	0
TOTAL LOWER			62,365	5	0	0	0	0	205	0	0	1,000	0	0	0	1,845	0	2,385	5	67,810	23,935	4,625	100	0	105
TOTAL ILLINOIS			93,565	35	25	0	0	0	205	100	300	1,000	1,000	0	0	10,050	0	7,020	5	113,305	27,735	4,665	100	0	105
10-Year Average 2006-2015			92,460	600	72	0	1,441	0	2,476	194	935	2,022	199	42	2,556	1,498	26	2,238	164	107,137	22,547	6,808	8,234	1	1,968

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 12/27/2016 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	95	0	0	0	0	0	0	0	0	0	0	500	5	0	210	0	270	0	985	360	0	0	0	0
Arthur Refuge	100	99	110	0	0	0	0	0	0	0	0	0	20	0	0	5	0	5	0	140	0	0	0	0	0
Nauvoo-Ft. Madison	100	95	405	5	0	0	0	0	0	0	300	300	2,200	0	0	4,080	0	1,760	0	9,050	325	0	0	0	0
Ft. Madison-Dallas	100	90	0	0	0	0	0	0	0	0	0	0	0	0	0	75	0	2,200	0	2,275	500	0	0	0	0
Henderson Creek	100	90	8,100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	8,120	750	0	100	0	0
Keithsburg Refuge	100	95	5,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,000	2,500	200	0	0	0
Louisa Refuge	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	210	0	210	0	0	0	0	0
TOTAL UPPER			13,615	5	0	0	0	0	0	0	300	300	2,720	5	0	4,370	0	4,465	0	25,780	4,435	200	100	0	0

LOWER MISSISSIPPI RIVER VALLEY

Swan Lake - Two Rive	100	50	9,500	0	0	0	0	0	240	0	0	5,000	0	0	0	270	0	55	0	15,065	420	1,000	0	0	0
Gilbert Lake - Two Ri	100	90	150	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	450	700	0	0	0
Long Lake	100	80	15,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15,000	0	0	0	0	0
Dardenne Club	100	40	43,500	0	5,000	0	0	0	2,000	0	0	0	0	0	0	0	0	0	0	50,500	0	0	0	0	0
Cuivre Club	100	20	20,000	0	5,000	0	1,000	0	1,000	0	0	0	0	0	0	0	0	0	0	27,000	0	0	0	0	0
Batchtown Refuge - T	100	70	12,100	0	0	0	0	0	0	0	0	1,000	0	0	0	0	0	0	0	13,100	300	0	0	0	0
Cannon Refuge	80	70	8,200	0	25	0	0	0	0	25	0	0	0	0	0	0	0	0	0	8,250	250	250	0	0	0
Towhead Lake	50	70	6,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6,000	100	50	0	0	0
Delair Refuge	100	70	12,100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12,100	900	1,800	200	0	0
Shanks Refuge	800	90	24,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	24,000	30	0	0	0	0
Meyer-Keokuk	100	5	210	0	0	0	0	0	0	0	0	0	200	0	0	310	0	35	0	755	620	0	0	60	0
TOTAL LOWER			150,760	0	10,025	0	1,000	0	3,240	25	0	6,000	200	0	0	580	0	90	0	171,920	3,070	3,800	200	60	0
TOTAL MISSISSIPPI			164,375	5	10,025	0	1,000	0	3,240	25	300	6,300	2,920	5	0	4,950	0	4,555	0	197,700	7,505	4,000	300	60	0
10-Year Average 2006-2015			175,532	319	8,089	0	2,584	3	3,746	663	9,660	10,301	55,874	188	3,411	7,906	1,795	8,518	0	290,548	11,743	5,438	4,501	46	2,226

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER ILLINOIS RIVER VALLEY Date: 01/05/2017 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Hennepin/Hopper	100	99	0	0	0	0	0	0	100	200	0	0	0	0	0	0	0	500	0	800	20	0	0	0	0
Goose Lake	90	99	8,180	10	0	0	0	0	0	0	0	0	0	0	0	50	0	30	0	8,270	0	0	0	0	0
Senachwine Lake	100	95	500	0	0	0	0	0	0	0	0	0	0	0	0	1,300	0	205	0	2,005	300	0	0	0	0
Hitchcock Slough	100	99	300	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	305	730	50	0	0	0
Douglas Lake	100	99	5,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,000	500	0	0	0	0
Goose Lake	100	99	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0
Upper Peoria	100	90	10,000	0	0	0	0	0	0	0	0	0	0	0	0	3,000	0	2,200	0	15,200	25	0	0	0	0
TOTAL UPPER			23,990	15	0	0	0	0	100	200	0	0	0	0	0	4,350	0	2,935	0	31,590	1,575	50	0	0	0

LOWER ILLINOIS RIVER VALLEY

Goose Lake	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	150	0	180	20	0	0	0	0
Rice Lake	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	55	0	55	30	0	0	0	0
Big Lake	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	5	0	0	0	0	0
Banner Marsh	100	99	80	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	85	1,115	100	5	0	10
Duck Creek	100	0	50,500	0	0	0	0	0	700	0	0	0	0	0	0	0	0	750	0	51,950	4,100	2,300	0	0	100
Clear Lake	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	100	350	0	0	0	0
Chautauqua	100	99	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	200	0	0	0	0
Emiquon/Spoon Btm	90	99	300	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	450	1,140	900	0	0	10
Grass Lake	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	0	105	50	100	0	0	0
Jack Lake	100	99	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	110	0	0	0	0	0
Stewart Lake	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	150	0	150	200	0	0	0	0
Crane Lake	100	99	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	100	0	0	0	0
Cuba Island	100	99	8,000	20	0	0	0	0	0	0	0	500	0	0	0	0	0	0	0	8,520	1,200	4,000	0	0	0
Big Lake	20	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	0	0	0
Spunky Bottoms	50	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Meredosia Lake	70	99	400	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	400	600	0	0	0	0
TOTAL LOWER			59,355	20	0	0	0	0	700	0	0	500	0	0	0	30	0	1,570	0	62,175	9,130	7,400	5	0	120
TOTAL ILLINOIS			83,345	35	0	0	0	0	800	200	0	500	0	0	0	4,380	0	4,505	0	93,765	10,705	7,450	5	0	120
10-Year Average 2006-2015			43,774	188	100	0	0	0	854	39	159	1,588	716	1	644	3,142	7	2,201	69	53,482	15,531	7,847	3,781	13	673

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

UPPER MISSISSIPPI RIVER VALLEY Date: 01/05/2017 Observer: Aaron Yetter

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Keokuk-Nauvoo	100	99	0	0	0	0	0	0	0	0	0	0	2,450	0	0	450	0	200	0	3,100	510	0	0	0	0
Arthur Refuge	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nauvoo-Ft. Madison	100	95	0	0	0	0	0	0	0	0	1,500	700	3,100	0	0	3,010	0	950	0	9,260	45	0	0	0	0
Ft. Madison-Dallas	100	95	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	5	0	105	430	0	0	0	0
Henderson Creek	100	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Keithsburg Refuge	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	300	0	0	0
Louisa Refuge	100	99	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	260	0	270	10	0	0	0	0
TOTAL UPPER			0	0	0	0	0	0	0	0	1,500	700	5,550	0	0	3,570	0	1,415	0	12,735	1,995	300	0	0	0

LOWER MISSISSIPPI RIVER VALLEY

LOCATION	%WET	%ICE	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO
Swan Lake - Two Rivers NWR	100	99	6,100	0	0	0	0	0	0	0	0	2,000	0	0	0	0	0	0	0	8,100	410	0	0	0	10
Gilbert Lake - Two Rivers NWF	100	99	200	0	0	0	0	0	0	0	0	0	10	0	0	0	0	5	0	215	200	200	0	0	0
Long Lake	100	99	11,200	25	500	0	0	0	100	0	0	0	0	0	0	0	0	0	0	11,825	0	0	0	0	0
Dardenne Club	100	95	127,000	100	2,000	0	0	0	0	0	0	3,000	5	0	0	0	0	0	0	132,105	2,100	500	0	0	0
Cuivre Club	100	95	48,000	0	2,000	0	0	0	0	0	0	0	5	0	0	0	0	10	0	50,015	0	0	0	0	0
Batchtown - Two Rivers NWR	100	95	9,700	0	500	0	0	0	0	0	0	1,600	5	0	0	0	0	10	0	11,815	0	0	0	0	0
Cannon Refuge	80	99	5,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5,000	100	0	0	0	0
Towhead Lake	20	99	700	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	700	50	2,010	0	0	0
Delair Refuge	100	95	33,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	33,000	800	5,000	0	0	0
Shanks Refuge	80	99	12,000	5	100	0	0	0	0	0	0	10	0	0	0	0	0	0	0	12,115	300	0	0	0	0
Meyer-Keokuk	100	70	850	0	0	0	0	0	0	0	0	0	300	0	0	5	0	200	0	1,355	1,070	0	0	0	0
TOTAL LOWER			253,750	130	5,100	0	0	0	100	0	0	6,610	325	0	0	5	0	225	0	266,245	5,030	7,710	0	0	10
TOTAL MISSISSIPPI			253,750	130	5,100	0	0	0	100	0	1,500	7,310	5,875	0	0	3,575	0	1,640	0	278,980	7,025	8,010	0	0	10
10-Year Average 2006-2015			135,652	94	3,224	0	1,250	0	1,413	200	6,363	2,834	63,347	6	641	4,236	841	4,796	0	224,896	10,409	5,696	2,018	6	208

Appendix 3. 2017 Spring Waterfowl Inventories of the Central Illinois River by Date and Location

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA
ILLINOIS RIVER VALLEY Date: February 14, 2017 Observer: Aaron Yetter

																							Eagle			
LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO	AD	IMM	DCCO	SWAN
Turner Lake	30	0	0	0	0	0	0	0	0	0	0	0	0	5	0	110	0	145	290	0	0	0	0	2	1	0	0
Depue, Spring	100	5	0	0	0	0	0	0	0	0	0	0	0	0	0	800	0	905	450	0	0	0	0	4	3	0	0
Coleman Lake	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	245	0	295	170	0	0	0	0	3	3	0	0
Bureau Ponds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	2	1	0	0
Goose Lake	5,600	0	3,200	0	0	0	0	0	0	1,500	500	0	0	0	0	915	0	11,715	1,405	2,700	2,000	0	0	1	3	0	100
Senachwine Lake	1,500	0	0	0	0	0	0	0	300	0	0	0	0	500	0	1,330	0	3,630	0	0	0	0	0	2	0	0	0
Hennepin/Hopper	100	0	0	0	0	0	0	0	0	500	0	0	0	350	0	855	0	1,805	835	3,000	0	0	0	1	0	0	5
Swan Lake	1,700	0	2,900	0	0	20	0	0	0	0	0	0	0	50	0	300	0	4,970	515	0	0	0	0	1	0	0	10
Sawmill Lake	510	0	1,000	0	0	0	0	0	0	0	0	0	0	10	0	150	0	1,670	0	600	0	20	0	3	1	0	0
Billsbach Lake	510	0	100	0	0	0	0	0	0	0	0	0	0	0	0	70	0	680	930	50	0	0	0	0	1	0	0
Weis Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0	120	200	0	0	0	0	0	1	0	0
Sparland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Wightman Lake	100	0	0	0	0	0	0	0	0	10	0	0	0	50	0	100	0	260	650	0	0	0	0	0	0	0	0
Sawyer Slough	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	240	20	0	0	0	0	0	0	0	0
Hitchcock Slough	1,620	0	0	0	0	0	0	0	0	0	0	0	0	0	0	60	0	1,680	200	0	0	0	0	0	0	0	0
Babbs Slough	1,000	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	1,050	130	0	0	0	0	0	0	0	0
Meadow Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Douglas Lake	11,400	0	1,300	0	0	0	100	0	0	510	400	0	0	0	0	410	0	14,120	600	3,000	2,500	0	0	0	0	0	0
Goose Lake	7,800	0	1,600	0	0	0	0	0	0	0	0	0	0	10	0	500	0	9,910	1,100	200	0	5	0	0	0	0	0
Upper Peoria	800	10	0	0	0	0	0	0	1,750	200	1,500	0	0	800	0	450	0	5,510	10	0	0	0	0	2	0	0	0
Lower Peoria	0	0	0	0	0	0	0	0	250	0	0	0	0	100	0	50	0	400	0	0	0	0	0	0	0	0	0
Pekin Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Powerton Lake	1,500	0	0	0	0	0	50	0	0	0	0	50	0	0	0	0	0	1,600	350	1,900	60,000	5	0	1	0	0	0
Spring Lake	100	0	0	0	0	0	100	0	0	0	0	0	0	0	0	10	0	210	60	0	0	0	0	0	0	0	105
Spring Lake Bottoms	1,400	0	50	0	0	0	410	0	0	500	0	0	0	0	0	0	0	2,360	250	1,000	17,000	0	0	0	0	0	0
Goose Lake	280	0	10	0	0	0	0	0	0	0	0	0	0	0	5	20	0	315	10	50	0	10	0	0	0	0	0
Rice Lake	6,900	0	200	0	50	0	350	0	0	560	0	0	0	5	0	65	0	8,130	555	500	0	0	0	2	0	0	80
Big Lake	3,000	0	10	0	0	0	0	0	0	2,000	0	0	0	0	0	115	0	5,125	10	0	0	0	0	2	1	0	0
Banner Marsh	1,720	0	10	0	0	0	1,820	0	0	0	0	0	0	0	0	0	0	3,550	510	0	0	5	0	0	0	0	75
Duck Creek	850	0	0	0	0	0	0	0	0	0	0	0	0	0	0	25	0	875	155	12,700	15,000	0	0	0	0	0	15
Clear Lake	700	0	0	0	0	0	0	0	400	100	0	0	0	0	0	50	0	1,250	245	0	700	0	0	2	4	0	0
North Pool	610	0	250	0	600	0	500	0	50	0	0	0	300	0	0	0	0	2,310	450	0	100	0	0	1	0	0	0
South Pool	7,150	0	220	0	1,500	0	0	0	100	0	0	0	0	100	0	10	0	9,080	440	10	10,600	0	0	2	2	0	0
Quiver Creek	2,100	0	0	0	0	0	1,850	0	0	0	0	0	0	0	0	0	0	3,950	500	0	0	0	0	0	0	0	0
Quiver Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	1	3	0	0
Thompson/Flag Lake	750	0	500	0	200	0	850	200	400	600	900	120	200	1,700	50	5,000	40	11,510	335	100	5,000	100	500	8	31	0	220
North Globe	1,000	0	3,800	0	300	0	20	200	0	0	0	0	0	0	0	10	0	5,330	100	600	0	0	0	1	2	0	0
Dickson Mounds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Globe	100	0	5,600	0	0	0	0	50	0	0	0	0	0	0	0	10	0	5,760	5	200	0	0	0	0	6	0	320
Wilder/Bellrose	5,000	0	10,000	0	0	0	100	100	0	1,000	0	200	0	0	0	0	0	16,400	50	0	0	0	0	0	0	0	10
Spoon River Btms	200	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	200	0	0	200	0	0	1	0	0	0
Matanza Lake	3,300	0	300	0	0	0	0	0	0	0	0	0	0	0	10	0	0	3,610	135	0	0	0	0	0	0	0	0
Bath Lake	2,350	0	500	0	0	0	0	0	0	2,200	200	0	0	0	0	0	0	5,250	105	500	0	0	0	0	0	0	10
Moscow Lake	100	0	10	0	0	0	10	5	0	10	0	0	0	20	0	15	0	170	0	0	200	0	0	0	0	0	0
Jack Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	110	0	0	5,000	0	0	2	1	0	0
Grass Lake	500	0	50	0	0	0	10	0	0	0	0	0	10	0	0	40	0	610	15	0	17,000	0	0	4	1	0	0
Anderson Lake	5,000	0	8,000	0	3,000	0	200	0	300	2,000	1,000	0	0	0	0	40	0	19,540	1,500	3,000	0	0	0	2	1	0	0
Snicarte Slough	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	0	30	0	0	0	0	0	0	0	0	0
Ingram Lake	300	0	0	0	0	0	0	0	50	200	0	0	50	230	0	310	10	1,150	0	0	0	0	0	1	0	0	0
Chain Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	200	0	0	0	0	0	1	1	0	0
Stewart Lake	0	0	0	0	0	0	0	0	50	100	0	0	0	580	0	300	0	1,030	0	0	0	0	0	5	2	0	0
Crane Lake	2,200	0	1,600	0	300	0	400	0	0	200	0	0	0	0	0	0	0	4,700	305	1,100	5,000	0	0	0	2	0	200
Cuba Island	1,600	0	0	0	500	0	600	0	0	3,000	0	0	0	0	0	0	0	5,700	320	300	0	0	0	0	0	0	150
Sanganois	1,200	0	100	0	0	0	0	0	0	2,000	0	0	0	0	0	100	10	3,410	200	0	0	0	0	2	0	0	0
Treadway Lake	120	0	0	0	100	0	0	0	0	0	0	0	0	200	0	0	0	420	0	0	0	0	0	3	4	0	0
Muscooten Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	5,200	0	12,000	0	100	0	100	100	0	1,000	0	0	0	0	0	0	0	18,500	300	300	5,000	0	0	3	2	0	0
Meredosia Lake	1,700	0	500	0	0	0	200	0	0	1,000	0	0	0	0	10	10	0	3,420	110	1,200	21,000	0	0	2	3	0	0
Smith Lake	0	0	100	0	0	0	0	0	10	0	0	0	0	0	0	0	0	110	400	50	0	0	0	2	1	0	10
Spunky Bottoms	8,400	0	7,500	0	1,000	0	0	0	0	1,000	100	0	0	0	0	0	0	18,000	600	3,000	0	0	0	0	1	0	50
TOTAL	98,490	15	61,410	0	7,650	20	7,720	655	3,660	20,190	4,600	370	560	4,710	75	12,835	60	223,020	15,580	36,060	166,300	145	500	69	82	0	1,360

* over 200,000 snows on Chautauqua NWR on the return flight north bound to the Upper Illinois River

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA
ILLINOIS RIVER VALLEY Date: February 21, 2017 Observer: Aaron Yetter

																							Eagle			
LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO	AD	IMM	DCCO	SWAN
Turner Lake																		0	0	0	0	0	0	0	0	0	0
Depue, Spring																		0	0	0	0	0	0	0	0	0	0
Coleman Lake																		0	0	0	0	0	0	0	0	0	0
Bureau Ponds																		0	0	0	0	0	0	0	0	0	0
Goose Lake																		0	0	0	0	0	0	0	0	0	0
Senachwine Lake									**FOG No Survey**									0	0	0	0	0	0	0	0	0	0
Hennepin/Hopper																		0	0	0	0	0	0	0	0	0	0
Swan Lake																		0	0	0	0	0	0	0	0	0	0
Sawmill Lake																		0	0	0	0	0	0	0	0	0	0
Billsbach Lake																		0	0	0	0	0	0	0	0	0	0
Weis Lake																		0	0	0	0	0	0	0	0	0	0
Sparland	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	5	100	0	0	0	0	0	0	0	0
Wightman Lake	160	0	30	0	0	0	300	0	0	0	0	0	0	0	0	0	0	490	50	0	0	0	0	1	1	0	0
Sawyer Slough	100	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0	0	500	10	0	0	0	0	0	0	0	0
Hitchcock Slough	3,500	0	500	0	400	0	100	0	0	0	100	0	0	0	0	0	0	4,600	0	0	0	0	0	0	0	0	0
Babbs Slough	3,400	5	30	0	50	0	500	0	0	10	0	0	0	10	0	0	0	4,005	70	0	0	0	0	0	0	0	0
Meadow Lake	400	0	0	0	10	0	0	50	0	0	0	0	0	0	0	0	0	460	0	0	0	0	0	0	0	0	0
Douglas Lake	5,100	0	2,100	0	900	0	800	0	100	6,000	300	500	0	0	0	0	0	15,800	0	4,000	0	0	0	0	0	0	0
Goose Lake	17,400	10	700	0	800	0	0	600	400	100	0	0	200	0	0	30	0	20,240	100	500	200	20	0	0	0	0	0
Upper Peoria	6,020	0	5	0	100	0	300	0	7,010	100	1,400	10	8,600	115	0	5	0	23,665	155	50	0	20	0	3	0	0	0
Lower Peoria	5	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	25	20	0	0	0	0	0	0	0	0
Pekin Lake	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	0
Powerton Lake	300	0	0	0	300	0	160	210	20	0	0	0	0	0	0	5	0	995	30	0	0	0	150	0	0	0	0
Spring Lake	0	0	0	0	0	0	400	20	0	0	0	0	0	0	0	0	0	420	180	0	0	0	100	0	0	0	125
Spring Lake Bottoms	100	0	0	0	0	0	250	60	0	1,310	0	0	0	0	0	0	0	1,720	250	500	0	0	0	0	0	0	0
Goose Lake	500	0	200	0	400	0	0	100	0	0	0	0	0	0	0	0	0	1,200	0	0	0	0	0	0	0	5	0
Rice Lake	1,400	0	200	0	500	0	0	400	0	2,000	0	0	0	0	0	5	0	4,505	200	2,000	0	0	0	0	0	0	50
Big Lake	700	0	200	0	0	0	100	300	1,100	2,000	0	20	0	50	0	110	0	4,580	10	0	75,000	0	0	0	1	0	0
Banner Marsh	105	0	0	0	100	10	1,150	20	0	0	0	0	0	0	0	0	0	1,385	405	450	0	0	5	0	0	0	55
Duck Creek	10	0	0	0	0	10	1,010	0	0	1,000	0	0	0	0	0	200	0	2,230	10	2,000	0	0	600	0	0	0	50
Clear Lake	2,550	0	100	0	1,410	0	200	500	1,500	100	100	0	0	50	0	0	0	6,510	40	0	0	0	0	0	1	0	5
North Pool	1,105	0	100	0	4,000	0	800	800	50	0	100	0	5,000	0	150	0	0	12,105	100	0	0	0	0	0	0	0	0
South Pool	1,000	0	0	0	700	0	300	0	1,000	5,000	10	0	100	0	5	10	0	8,125	375	0	150,000	0	0	0	2	0	0
Quiver Creek	1,360	0	100	0	500	0	1,100	0	0	0	0	0	0	0	0	0	0	3,060	30	0	0	0	0	0	0	0	0
Quiver Lake	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
Thompson/Flag Lake	9,500	0	700	0	4,600	200	18,900	3,400	1,700	2,800	2,400	150	6,600	1,400	100	600	10	53,060	310	5,700	52,010	450	11,700	0	2	0	75
North Globe	400	0	200	0	500	0	300	200	0	0	0	0	0	0	0	0	0	1,600	0	0	5	0	0	0	0	0	0
Dickson Mounds	5	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	15	0	0	0	0	0	0	0	0	0
South Globe	2,905	0	150	0	2,300	0	0	0	0	0	0	0	0	0	0	0	0	5,355	0	400	0	0	0	1	0	0	100
Wilder/Bellrose	2,200	0	500	0	0	50	200	0	0	4,800	300	300	0	0	0	0	0	8,350	0	0	0	0	0	0	0	0	25
Spoon River Btms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matanza Lake	1,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1,000	5	0	0	0	0	0	0	0	0
Bath Lake	505	0	300	0	1,000	0	0	300	0	0	0	0	0	0	0	0	0	2,105	20	200	0	0	0	0	0	0	0
Moscow Lake	10	0	0	0	50	0	300	0	0	0	0	0	0	0	0	0	0	360	0	0	0	0	0	1	2	0	0
Jack Lake	310	0	0	0	200	0	0	0	100	0	0	0	5	0	0	0	0	615	5	0	0	0	0	0	3	0	0
Grass Lake	1,100	0	0	0	0	0	0	0	0	500	0	0	0	0	0	0	0	1,600	105	100	2,000	0	0	0	3	0	0
Anderson Lake	3,000	0	2,000	0	8,000	0	300	2,000	100	4,000	0	0	0	0	0	0	0	19,400	10	9,000	30,000	0	0	1	1	0	0
Snicarte Slough	210	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	220	5	0	0	0	0	0	0	0	0
Ingram Lake	5,100	0	500	0	0	0	500	500	400	0	0	300	0	0	0	0	0	7,300	0	0	0	0	0	0	0	0	0
Chain Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	4	0	0
Stewart Lake	600	0	0	0	0	0	0	0	3,000	0	0	0	2,500	1,100	0	100	0	7,300	0	0	0	300	0	2	2	0	0
Crane Lake	10,000	0	2,200	0	2,000	0	1,200	2,000	200	2,500	0	0	0	0	10	0	0	20,110	10	1,000	8,000	0	0	0	0	0	70
Cuba Island	500	0	100	0	1,100	0	1,050	100	0	6,000	0	0	0	0	0	0	0	8,850	310	0	0	0	0	0	0	0	10
Sanganois	2,500	0	500	0	400	0	200	250	0	25	0	0	0	0	0	0	0	3,875	0	0	0	0	0	0	0	0	0
Treadway Lake	1,850	0	100	0	600	0	1,000	200	0	50	0	0	0	0	0	0	0	3,800	0	0	0	10	0	5	9	0	0
Muscooten Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	10,300	0	7,010	0	3,100	0	700	1,000	0	3,600	200	0	0	0	0	0	0	25,910	10	2,500	20,000	0	0	1	0	0	0
Meredosia Lake	0	0	0	0	0	0	450	50	1,500	1,200	100	0	600	0	250	0	0	4,150	25	3,000	500	10	0	2	1	0	0
Smith Lake	4,000	0	0	0	1,600	0	100	500	0	200	0	0	0	0	0	0	0	6,400	35	200	9,500	0	0	0	0	0	0
Spunky Bottoms	1,200	0	50	0	2,500	0	50	100	0	0	0	0	0	0	0	0	10	3,910	15	3,000	10,000	0	0	2	3	0	0
TOTAL	102,415	15	18,575	0	38,520	270	32,720	13,690	18,205	43,295	5,010	1,280	23,605	2,725	525	1,065	30	301,945	3,000	34,600	357,215	810	12,555	22	35	5	565

Feb 14, 2017 Totals	98,490	15	61,410	0	7,650	20	7,720	655	3,660	20,190	4,600	370	560	4,710	75	12,835	60	223,020	15,580	36,060	166,300	145	500	69	82	0	1,360

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

ILLINOIS RIVER VALLEY Date: March 2, 2017 Observer: Aaron Yetter

																								Eagle			
LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO	AD	IMM	DCCO	SWAN
Turner Lake	0	0	0	0	100	0	150	0	0	100	0	0	0	0	0	0	0	350	10	0	0	0	0	0	0	0	0
Depue, Spring	100	0	0	0	0	0	200	0	20	500	0	0	0	0	0	5	0	825	10	0	0	0	0	0	4	0	0
Coleman Lake	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	70	5	0	0	0	0	0	0	0	0
Bureau Ponds	930	5	0	0	0	0	100	150	0	0	0	0	0	25	50	5	0	1,265	25	0	0	0	0	0	0	0	0
Goose Lake	1,900	0	1,000	0	900	0	0	0	0	110	300	0	0	0	10	0	5	4,225	0	0	0	0	0	2	0	0	0
Senachwine Lake	1,250	5	0	0	200	0	50	0	0	0	0	0	60	0	0	0	0	1,565	0	0	3,000	0	0	1	1	0	0
Hennepin/Hopper	110	0	0	0	0	0	100	410	1,000	2,105	30	10	300	5	100	5	0	4,175	355	600	5	0	1,100	0	1	0	5
Swan Lake	100	0	0	0	300	0	0	0	0	0	0	0	0	0	0	0	0	400	0	0	0	0	0	1	0	0	0
Sawmill Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Billsbach Lake	660	0	25	0	300	0	30	110	50	0	0	0	0	0	0	0	0	1,175	0	0	0	5	0	1	0	0	0
Weis Lake	0	0	0	0	50	0	0	10	110	0	0	0	0	0	0	0	0	170	5	400	20	0	0	0	0	0	0
Sparland	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	10	0	0	0	0	2	1	0	0
Wightman Lake	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	20	0	0	0	0	0	3	0	0
Sawyer Slough	0	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Hitchcock Slough	300	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	5	325	0	0	0	0	0	0	0	0	0
Babbs Slough	465	0	0	0	100	0	30	50	250	0	0	0	1,350	0	0	0	0	2,245	20	0	0	0	0	1	0	0	0
Meadow Lake	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	10	5	0	0	0	0	1	0	0	0
Douglas Lake	11,300	10	100	0	400	0	50	50	0	5,000	0	0	10	0	0	0	0	16,920	5	1,500	4,000	0	100	0	0	0	0
Goose Lake	2,000	0	50	0	900	0	100	0	250	0	210	20	1,000	0	0	0	0	4,530	50	0	0	0	0	0	2	0	0
Upper Peoria	2,100	0	0	0	0	0	50	0	16,900	200	2,500	10	4,200	0	0	0	0	25,960	35	0	0	0	300	0	0	0	0
Lower Peoria	1,800	0	0	0	600	0	100	0	110	0	0	0	0	0	0	0	0	2,610	425	200	0	0	10	0	0	0	0
Pekin Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
Powerton Lake	70	0	0	0	0	0	105	0	0	0	0	0	0	0	5	0	0	180	40	0	5	0	420	0	0	0	0
Spring Lake	10	0	0	0	0	0	160	50	0	0	0	0	0	0	5	0	0	225	130	0	0	0	0	0	0	0	125
Spring Lake Bottoms	250	0	0	0	200	0	230	100	0	3,000	0	0	0	0	0	0	0	3,780	50	300	0	0	0	0	0	0	0
Goose Lake	1,450	0	0	0	100	0	5	100	0	0	0	0	0	0	0	0	0	1,655	105	0	0	0	0	0	0	0	0
Rice Lake	470	5	100	0	555	0	5	200	30	200	0	0	0	5	0	0	0	1,570	30	0	0	0	0	0	1	0	5
Big Lake	55	0	10	0	10	0	0	0	0	0	0	0	0	0	0	0	0	75	0	0	0	0	0	0	0	0	0
Banner Marsh	200	0	0	0	0	0	680	60	0	0	0	0	0	0	30	15	0	985	145	0	0	0	50	0	0	0	85
Duck Creek	200	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	220	40	510	100	0	10	1	0	0	0
Clear Lake	500	0	30	0	785	0	0	1,350	220	0	10	20	0	0	5	0	0	2,920	15	0	0	550	0	0	9	0	0
North Pool	600	0	100	0	0	0	100	1,100	1,700	0	50	0	700	0	15	0	0	4,365	5	0	0	100	200	0	0	0	0
South Pool	160	0	50	0	610	0	100	250	20	0	0	0	50	0	10	0	10	1,260	20	15	27,500	0	0	0	0	0	0
Quiver Creek	600	0	0	0	1,600	0	1,400	150	0	0	0	0	0	0	5	0	0	3,755	65	0	0	0	0	2	0	0	2
Quiver Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0
Thompson/Flag Lake	1,000	0	300	0	1,900	50	1,410	800	550	100	550	20	850	0	380	5	0	7,915	110	100	4,000	0	34,400	3	5	0	75
North Globe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Dickson Mounds	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0
South Globe	20	0	15	0	300	0	0	30	0	0	0	0	0	0	0	0	0	365	50	0	0	0	0	0	0	0	0
Wilder/Bellrose	10,200	0	100	0	200	0	500	200	300	6,000	10	25	0	0	0	0	0	17,535	0	0	0	0	0	0	0	0	0
Spoon River Btms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matanza Lake	350	0	0	0	400	0	0	100	0	0	0	0	0	0	0	0	0	850	5	0	0	300	0	0	0	0	0
Bath Lake	115	0	0	0	700	0	5	110	200	0	150	0	0	0	0	0	0	1,280	15	0	0	530	0	0	1	0	0
Moscow Lake	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	5
Jack Lake	0	0	0	0	0	0	0	0	10	0	0	0	10	0	0	0	0	20	0	0	0	0	0	1	0	0	0
Grass Lake	360	0	0	0	100	0	0	0	0	0	0	0	0	0	5	0	0	465	25	0	0	5	0	0	0	0	0
Anderson Lake	200	0	0	0	1,700	0	0	200	0	0	0	0	0	0	0	0	0	2,100	0	0	25	75	0	3	1	0	0
Snicarte Slough	100	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	300	0	0	0	300	0	0	2	0	0
Ingram Lake	55	0	0	0	100	0	0	0	310	0	0	0	600	0	0	0	5	1,070	25	0	0	0	0	0	1	0	0
Chain Lake	0	0	0	0	600	0	0	0	10	0	0	0	0	0	0	0	0	610	10	0	0	0	0	0	0	0	0
Stewart Lake	20	0	0	0	200	0	0	5	375	0	0	0	1,900	0	0	0	0	2,500	0	0	0	0	0	0	0	0	0
Crane Lake	1,350	0	0	0	100	0	200	550	100	5,700	0	0	0	0	5	0	0	8,005	350	150	10,000	0	0	1	1	0	5
Cuba Island	5,700	0	0	0	700	0	800	250	0	7,100	10	0	0	0	0	0	0	14,560	10	3,700	2,000	0	100	0	2	0	45
Sanganois	800	0	0	0	3,300	0	400	0	0	100	0	0	0	0	0	0	0	4,600	60	0	0	0	100	0	0	0	0
Treadway Lake	5	0	0	0	0	0	0	0	300	3,000	50	0	0	0	10	0	0	3,365	15	0	0	0	0	1	1	0	0
Muscooten Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	300	0	320	0	1,500	10	0	300	0	200	0	0	0	0	0	0	0	2,630	50	1,000	1,500	0	1,000	2	1	0	0
Meredosia Lake	2,200	0	400	0	700	0	0	900	250	3,200	10	0	200	0	125	0	0	7,985	25	1,000	1,000	5	500	1	0	0	0
Smith Lake	80	0	70	0	2,380	0	110	0	0	0	0	0	0	0	0	0	0	2,640	30	50	0	0	0	0	0	0	0
Spunky Bottoms	15	0	0	0	400	0	0	50	0	0	0	0	0	0	0	0	0	465	10	0	0	0	0	1	1	0	0
TOTAL	50,620	25	2,685	0	23,300	60	7,190	7,665	23,065	36,615	3,880	105	11,230	35	760	45	35	167,315	2,420	9,525	53,155	1,870	38,290	27	42	0	352

Feb 14, 2017 Totals	98,490	15	61,410	0	7,650	20	7,720	655	3,660	20,190	4,600	370	560	4,710	75	12,835	60	223,020	15,580	36,060	166,300	145	500	69	82	0	1,360
Feb 21, 2017 Totals	102,415	15	18,575	0	38,520	270	32,720	13,690	18,205	43,295	5,010	1,280	23,605	2,725	525	1,065	30	301,945	3,000	34,600	357,215	810	12,555	22	35	5	565

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA
ILLINOIS RIVER VALLEY Date: March 9, 2017 Observer: Aaron Yetter

																								Eagle			
LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO	AD	IMM	DCCO	SWAN
Turner Lake	330	0	50	0	0	0	10	0	80	0	0	0	0	0	0	0	0	470	5	0	0	205	0	0	0	0	0
Depue, Spring	210	0	0	0	200	0	400	300	500	500	200	50	0	0	0	0	0	2,360	15	30	0	25	0	1	0	0	0
Coleman Lake	200	0	0	0	0	5	15	30	0	0	0	0	0	0	0	0	0	250	5	0	0	5	0	0	0	0	0
Bureau Ponds	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	1	0	0	0
Goose Lake	2,760	0	610	0	6,500	0	0	1,800	650	0	300	0	200	0	0	0	0	12,820	10	0	0	200	0	3	7	0	0
Senachwine Lake	250	5	0	0	800	0	0	0	450	0	0	0	800	0	0	0	0	2,305	0	0	0	0	0	1	2	0	0
Hennepin/Hopper	100	0	0	0	100	0	200	1,610	700	1,510	100	0	3,000	0	0	5	0	7,325	10	0	0	0	5,200	0	0	0	5
Swan Lake	270	0	0	0	50	0	10	0	0	5	0	0	0	0	20	5	0	360	15	0	0	0	0	3	0	0	0
Sawmill Lake	20	0	0	0	100	0	50	0	0	0	0	0	100	0	0	0	0	270	5	0	0	0	0	2	0	0	0
Billsbach Lake	0	0	0	0	100	0	0	0	210	50	0	0	450	0	0	0	0	810	5	0	0	0	0	0	0	0	0
Weis Lake	100	0	50	0	200	0	50	100	0	0	0	0	100	0	0	0	0	600	20	0	0	0	0	0	0	0	0
Sparland	20	0	0	0	0	0	0	0	110	0	0	0	100	0	0	10	0	240	0	0	0	0	0	1	0	0	0
Wightman Lake	100	0	0	0	0	0	300	200	100	200	10	0	5	0	0	0	0	915	0	0	0	0	0	0	0	0	0
Sawyer Slough	0	0	0	0	0	10	100	130	500	0	0	0	200	0	0	0	0	940	0	0	0	0	0	0	0	0	0
Hitchcock Slough	50	0	0	0	100	0	10	20	500	0	0	0	300	0	0	0	0	980	5	0	0	0	0	0	0	0	0
Babbs Slough	130	0	0	0	250	0	0	0	100	100	0	0	0	0	0	0	0	580	5	0	0	0	150	0	1	0	0
Meadow Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	1	0	0
Douglas Lake	13,200	0	500	0	6,600	0	300	200	1,100	8,600	100	35	0	0	10	0	10	30,655	0	500	4,000	0	2,200	0	0	0	0
Goose Lake	5,110	0	100	0	4,200	10	30	400	2,200	100	20	0	4,300	0	0	0	0	16,470	20	0	0	0	0	0	0	0	0
Upper Peoria	1,700	0	0	0	3,500	0	200	300	45,820	510	510	0	15,300	0	100	10	0	67,950	70	0	0	0	0	1	0	0	0
Lower Peoria	5	0	0	0	0	0	0	0	350	0	0	0	10	0	0	0	0	365	5	0	0	0	0	0	0	0	0
Pekin Lake	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	1	0	0	0
Powerton Lake	10	0	0	0	200	0	250	50	250	0	0	0	50	0	0	0	0	810	35	0	0	0	500	0	0	0	0
Spring Lake	10	0	0	0	0	0	300	150	20	0	0	0	0	0	0	0	0	480	0	0	0	50	2,000	0	0	0	35
Spring Lake Bottoms	120	0	0	0	25	0	350	700	10	420	0	0	0	0	0	0	0	1,625	10	0	0	0	1,000	0	0	0	5
Goose Lake	150	0	0	0	10	0	20	0	0	0	0	0	0	0	10	0	0	190	20	0	0	10	0	0	0	0	0
Rice Lake	255	0	0	0	570	0	100	1,220	100	400	0	0	0	0	0	0	0	2,645	10	0	0	0	0	1	1	0	5
Big Lake	10	0	0	0	0	0	0	0	100	0	0	0	20	0	0	0	5	135	0	0	0	15	100	0	0	0	0
Banner Marsh	50	0	0	0	15	0	1,165	210	0	0	0	0	0	0	0	0	0	1,440	110	200	0	0	260	0	0	0	25
Duck Creek	30	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	80	40	0	300	0	0	2	0	0	0
Clear Lake	250	0	0	0	300	0	100	400	550	0	0	0	550	0	0	0	0	2,150	30	0	0	0	0	0	3	0	0
North Pool	200	0	0	0	2,000	0	150	5,400	3,460	0	0	0	500	0	0	0	0	11,710	10	0	0	5	0	0	0	0	5
South Pool	500	0	0	0	1,800	0	100	100	670	100	0	0	960	0	10	0	0	4,240	5	0	2,000	0	0	0	1	0	0
Quiver Creek	350	0	0	0	2,200	0	980	550	0	0	0	0	0	0	0	0	0	4,080	35	0	0	0	0	0	0	0	5
Quiver Lake	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	10	0	0	0	0	0	2	0	0
Thompson/Flag Lak	1,050	0	120	10	7,500	0	2,000	3,000	2,360	500	300	15	3,200	0	570	5	0	20,630	50	300	10	135	42,600	0	2	5	60
North Globe	0	0	0	0	150	0	100	200	0	0	0	0	0	0	0	0	0	450	0	0	0	0	0	0	0	0	0
Dickson Mounds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Globe	125	0	0	0	610	0	0	300	0	0	0	0	0	0	0	10	0	1,045	0	0	0	0	0	0	0	0	0
Wilder/Bellrose	500	0	0	0	500	0	100	2,000	100	1,500	0	0	0	0	0	0	0	4,700	10	0	0	0	1,000	0	0	0	0
Spoon River Btms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matanza Lake	0	0	0	0	0	0	0	0	30	0	0	0	0	0	0	0	0	30	0	0	0	55	0	0	0	0	0
Bath Lake	210	0	0	0	1,600	0	50	200	100	20	0	0	0	0	0	0	0	2,180	10	75	0	0	0	0	1	0	0
Moscow Lake	0	0	0	0	200	0	0	30	10	0	0	0	0	0	0	0	0	240	20	0	0	0	0	0	0	0	5
Jack Lake	100	0	0	0	200	0	0	100	0	0	0	0	20	0	0	0	0	420	0	0	0	0	0	1	0	0	0
Grass Lake	100	0	0	0	200	0	0	0	0	0	0	0	0	0	0	0	0	300	35	0	0	0	0	0	0	0	0
Anderson Lake	0	0	0	0	2,700	0	60	110	210	0	0	0	0	0	0	0	0	3,080	0	0	20	0	0	0	0	0	0
Snicarte Slough	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	10	5	0	0	200	0	0	0	0	0
Ingram Lake	15	0	0	0	100	0	0	0	300	0	0	0	0	0	50	0	0	465	0	0	0	300	0	0	1	0	0
Chain Lake	0	0	0	0	0	0	0	0	300	0	0	0	300	0	0	0	0	600	5	0	0	500	0	1	0	0	0
Stewart Lake	0	0	0	0	0	0	0	0	1,500	0	0	0	20	0	0	0	0	1,520	0	0	0	0	0	0	3	10	0
Crane Lake	110	0	0	0	1,400	0	205	1,000	1,500	20	0	0	400	0	20	0	0	4,655	10	0	2,000	100	100	0	2	0	10
Cuba Island	500	0	300	0	4,300	0	1,300	3,700	200	5,500	0	0	0	0	0	0	0	15,800	200	600	0	100	100	0	0	0	5
Sanganois	100	0	0	0	300	0	0	250	0	0	0	0	0	0	0	0	0	650	10	0	0	600	0	0	1	0	0
Treadway Lake	0	0	0	0	100	0	0	0	200	100	0	0	0	0	0	0	0	400	0	0	0	1,900	0	2	2	0	0
Muscooten Bay	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	50	0	0	0	0	0	1	2	0	0
Big Lake	100	0	0	0	1,300	0	50	2,150	800	0	0	0	200	0	0	0	0	4,600	50	600	500	0	500	0	0	20	0
Meredosia Lake	170	0	0	0	300	0	260	2,150	2,100	800	0	0	350	0	0	0	0	6,130	30	0	300	110	0	1	1	5	0
Smith Lake	50	0	50	0	400	0	150	300	200	0	0	0	0	0	0	0	0	1,150	60	150	500	0	0	0	0	0	0
Spunky Bottoms	0	0	0	0	400	0	0	0	0	0	0	0	0	0	0	0	0	400	10	0	0	10	0	0	3	0	0
TOTAL	29,640	5	1,780	10	52,090	25	9,515	29,410	68,440	20,935	1,540	100	31,435	0	790	45	15	245,775	1,020	2,455	9,630	4,525	55,710	23	36	40	165

Feb 14, 2017 Totals	98,490	15	61,410	0	7,650	20	7,720	655	3,660	20,190	4,600	370	560	4,710	75	12,835	60	223,020	15,580	36,060	166,300	145	500	69	82	0	1,360
Feb 21, 2017 Totals	102,415	15	18,575	0	38,520	270	32,720	13,690	18,205	43,295	5,010	1,280	23,605	2,725	525	1,065	30	301,945	3,000	34,600	357,215	810	12,555	22	35	5	565
Mar 2, 2017 Totals	50,620	25	2,685	0	23,300	60	7,190	7,665	23,065	36,615	3,880	105	11,230	35	760	45	35	167,315	2,420	9,525	53,155	1,870	38,290	27	42	0	352

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA
ILLINOIS RIVER VALLEY Date: March 16, 2017 Observer: Aaron Yetter

																							Eagle			
LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO	AD	IMM	DCCO	SWAN
Turner Lake	370	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	5	380	5	0	0	0	0	0	0	0	0
Depue, Spring	300	0	0	0	150	0	500	200	200	100	100	0	0	0	0	100	0	1,650	25	0	0	20	0	0	3	0	0
Coleman Lake	20	0	0	0	0	0	220	100	0	0	0	0	0	0	0	0	0	340	5	0	0	0	10	0	0	0	0
Bureau Ponds	50	0	0	0	100	0	0	100	0	0	0	0	0	0	0	0	0	250	10	0	0	0	0	0	0	0	0
Goose Lake	820	0	300	0	2,700	0	230	640	50	0	0	0	0	0	0	5	0	4,745	10	0	0	0	0	2	1	0	0
Senachwine Lake	500	0	0	0	0	0	10	50	200	0	0	0	200	0	20	10	0	990	0	0	100	25	0	0	0	0	0
Hennepin/Hopper	1,000	0	100	0	500	0	1,000	2,000	3,000	150	500	0	2,000	0	0	0	0	10,250	35	300	0	0	1,400	0	0	0	0
Swan Lake	105	0	0	0	390	0	100	250	0	0	0	0	0	0	0	0	0	845	10	0	0	0	10	0	0	0	0
Sawmill Lake	100	0	0	0	300	0	100	100	220	0	0	0	50	0	0	0	0	870	0	0	0	0	0	1	2	0	0
Billsbach Lake	120	0	10	0	100	0	100	0	330	10	0	0	0	0	0	0	0	670	15	0	0	200	0	2	0	0	0
Weis Lake	100	0	0	0	200	0	0	100	0	0	0	0	0	0	0	0	0	400	0	0	0	0	0	0	0	0	0
Sparland	0	0	0	0	0	0	300	0	0	0	0	0	0	0	0	0	0	300	0	0	0	1,100	0	1	0	0	0
Wightman Lake	200	0	0	0	100	0	300	200	900	100	0	0	0	0	0	50	0	1,850	20	0	0	0	0	0	0	0	0
Sawyer Slough	0	0	0	0	200	0	0	50	0	0	0	0	0	0	0	0	0	250	5	0	0	0	0	0	0	0	0
Hitchcock Slough	1,100	0	0	0	100	0	100	1,100	600	300	0	0	0	0	0	0	0	3,300	0	0	0	5	0	0	0	0	0
Babbs Slough	510	0	0	0	200	0	5	700	950	50	0	0	800	0	50	0	0	3,265	5	0	0	0	0	0	0	0	0
Meadow Lake	100	0	0	0	0	0	0	0	500	20	0	0	0	0	0	0	0	620	0	0	0	5	0	4	0	0	0
Douglas Lake	7,300	0	0	0	4,800	0	1,100	900	1,600	3,200	0	0	0	0	0	0	0	18,900	50	1,000	1,000	0	0	0	0	0	0
Goose Lake	12,600	0	0	0	11,410	0	100	600	1,400	500	10	0	200	0	0	0	0	26,820	0	0	0	5	0	0	0	0	0
Upper Peoria	600	0	0	0	1,200	0	300	800	33,700	0	300	0	5,000	0	0	0	0	41,900	110	0	0	0	0	1	0	0	0
Lower Peoria	335	0	0	0	500	0	0	0	115	0	5	0	110	0	0	0	0	1,065	40	0	0	0	0	1	3	0	0
Pekin Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	0
Powerton Lake	10	0	0	0	250	0	115	0	20	0	0	0	5	0	0	0	0	400	55	0	0	0	550	4	0	0	0
Spring Lake	175	0	0	0	0	0	235	100	100	10	0	0	0	0	0	0	0	620	70	0	0	0	3,000	1	0	0	30
Spring Lake Bottoms	200	0	0	0	350	0	200	350	50	250	0	0	0	0	0	0	0	1,400	25	0	0	0	100	0	0	0	5
Goose Lake	20	0	0	0	10	0	0	0	0	0	0	0	20	0	0	0	5	55	5	0	0	0	0	0	0	0	0
Rice Lake	1,680	0	0	0	2,250	0	120	1,200	5	300	0	0	0	0	0	40	0	5,595	20	0	0	0	0	1	1	0	15
Big Lake	1,160	0	0	0	100	0	25	100	40	0	0	0	200	10	5	100	10	1,750	50	0	0	0	100	0	0	0	0
Banner Marsh	720	0	0	0	250	0	4,070	240	510	50	0	0	0	0	0	5	10	5,855	385	200	0	0	2,500	0	0	0	50
Duck Creek	20	0	0	0	0	0	5	0	0	0	0	0	10	0	0	15	0	50	50	0	0	0	0	1	0	400	5
Clear Lake	1,905	0	0	0	470	0	100	1,100	20	10	0	0	6,000	20	20	0	10	9,655	5	150	200	0	0	0	0	0	0
North Pool	200	0	0	0	500	0	0	1,000	6,500	0	300	0	1,200	0	0	0	0	9,700	105	0	0	0	0	0	0	0	0
South Pool	500	0	0	0	700	0	250	650	2,000	0	0	0	6,900	50	40	10	0	11,100	120	20	500	0	400	0	2	0	0
Quiver Creek	970	0	0	0	1,550	10	1,700	720	0	0	0	0	0	0	0	0	0	4,950	55	0	0	0	0	2	0	0	5
Quiver Lake	200	0	0	0	100	0	0	0	0	0	0	0	0	0	0	0	0	300	10	0	0	5	0	0	1	0	0
Thompson/Flag Lake	500	0	0	0	3,100	0	4,500	1,300	3,300	500	200	110	3,500	300	715	185	10	18,220	35	1,250	0	200	54,400	1	3	10	120
North Globe	0	0	0	0	70	0	0	30	0	0	0	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Dickson Mounds	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0
South Globe	5	0	0	0	200	0	0	50	0	0	0	0	0	0	0	0	0	255	5	0	0	0	0	0	0	0	0
Wilder/Bellrose	1,800	0	50	0	100	0	200	700	0	100	0	0	0	0	0	0	0	2,950	0	0	0	0	100	0	0	0	0
Spoon River Btms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matanza Lake	100	0	0	0	150	0	0	50	10	0	0	0	500	0	0	0	0	810	5	0	0	0	0	1	0	0	0
Bath Lake	500	0	0	0	400	0	50	50	350	50	0	0	0	0	0	0	0	1,400	5	0	0	0	0	0	0	0	0
Moscow Lake	120	0	50	0	550	0	10	20	10	500	0	0	10	0	0	0	0	1,270	20	0	0	0	0	0	0	0	0
Jack Lake	1,400	0	0	0	1,100	0	0	50	0	0	0	0	0	0	0	0	0	2,550	5	200	10	0	0	1	1	0	0
Grass Lake	250	0	0	0	100	0	0	100	0	0	0	0	0	0	0	0	0	450	20	0	0	0	10	1	0	0	0
Anderson Lake	0	0	0	0	2,200	0	0	0	60	0	0	0	0	10	0	5	0	2,275	15	0	0	0	0	0	1	0	0
Snicarte Slough	200	0	0	0	50	0	10	0	0	0	0	0	10	0	10	0	0	280	0	0	0	0	0	0	0	0	0
Ingram Lake	0	0	0	0	250	0	0	150	50	500	0	0	400	0	10	0	0	1,360	5	0	0	830	0	1	0	0	0
Chain Lake	15	0	0	0	20	0	0	0	100	0	0	0	2,100	5	0	5	30	2,275	0	0	0	600	0	0	3	0	0
Stewart Lake	0	0	0	0	0	0	0	0	230	0	0	0	3,170	0	0	0	5	3,405	0	0	0	5	0	0	0	0	0
Crane Lake	720	0	50	0	1,300	0	100	600	100	3,200	0	0	100	0	0	0	0	6,170	200	0	900	280	500	0	0	0	0
Cuba Island	3,900	0	50	0	2,200	50	1,500	3,700	10	3,200	0	0	0	0	0	0	0	14,610	120	0	0	0	1,100	0	0	0	5
Sanganois	250	0	0	0	300	0	0	0	10	0	0	0	0	0	30	5	0	595	0	0	0	200	0	0	0	0	0
Treadway Lake	150	0	0	0	1,200	0	50	600	1,000	0	0	0	110	0	10	0	0	3,120	5	0	0	300	0	0	2	0	0
Muscooten Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	200	0	0	0	200	0	150	900	600	100	0	10	0	0	10	0	0	2,170	5	0	0	0	1,100	3	0	0	0
Meredosia Lake	1,870	0	0	0	300	0	600	1,500	960	150	10	20	550	50	40	0	0	6,050	20	10	200	200	0	0	0	0	0
Smith Lake	60	0	200	0	200	0	100	300	50	0	0	0	0	0	0	0	0	910	15	500	700	0	0	0	0	0	0
Spunky Bottoms	15	0	0	0	360	0	100	100	0	0	0	0	0	0	15	0	5	595	0	0	0	0	0	1	1	0	0
TOTAL	46,045	0	810	0	43,835	60	18,655	23,550	59,855	13,350	1,425	140	33,145	445	975	535	90	242,915	1,780	3,630	3,610	3,980	65,280	31	26	410	235

Feb 14, 2017 Totals	98,490	15	61,410	0	7,650	20	7,720	655	3,660	20,190	4,600	370	560	4,710	75	12,835	60	223,020	15,580	36,060	166,300	145	500	69	82	0	1,360
Feb 21, 2017 Totals	102,415	15	18,575	0	38,520	270	32,720	13,690	18,205	43,295	5,010	1,280	23,605	2,725	525	1,065	30	301,945	3,000	34,600	357,215	810	12,555	22	35	5	565
Mar 2, 2017 Totals	50,620	25	2,685	0	23,300	60	7,190	7,665	23,065	36,615	3,880	105	11,230	35	760	45	35	167,315	2,420	9,525	53,155	1,870	38,290	27	42	0	352
Mar 9, 2017 Totals	29,640	5	1,780	10	52,090	25	9,515	29,410	68,440	20,935	1,540	100	31,435	0	790	45	15	245,775	1,020	2,455	9,630	4,525	55,710	23	36	40	165

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA
ILLINOIS RIVER VALLEY Date: March 28, 2017 Observer: Aaron Yetter

																								Eagle			
LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO	AD	IMM	DCCO	SWAN
Turner Lake	10	0	0	0	500	0	0	50	0	0	0	0	0	0	0	0	5	565	0	0	0	0	0	0	0	0	0
Depue, Spring	5	0	0	0	200	0	400	100	200	10	0	0	0	0	0	0	0	915	10	0	0	0	0	0	0	0	0
Coleman Lake	0	0	0	0	5	10	100	100	0	0	0	0	0	0	0	0	0	215	20	0	0	0	200	0	0	10	0
Bureau Ponds	220	0	0	0	1,050	0	30	300	0	0	0	0	0	0	0	0	0	1,600	60	0	0	0	0	2	0	30	0
Goose Lake	280	5	0	0	3,400	0	100	1,500	500	200	0	25	250	0	0	0	0	6,260	5	0	0	20	2,100	0	1	0	0
Senachwine Lake	120	0	0	50	850	0	0	0	300	0	0	0	300	0	0	0	0	1,620	15	0	0	360	1,000	0	0	10	0
Hennepin/Hopper	200	0	0	0	100	10	250	700	400	10	160	0	2,000	0	0	5	5	3,840	25	1,000	50	150	16,700	0	0	0	5
Swan Lake	0	0	0	0	430	0	110	560	0	0	0	0	0	0	5	0	0	1,105	10	0	0	0	0	0	0	0	0
Sawmill Lake	0	0	0	0	0	0	0	0	80	0	0	0	105	0	0	0	0	185	30	0	0	55	0	0	0	10	0
Billsbach Lake	25	0	0	0	10	0	5	20	270	15	0	0	1,750	0	0	0	0	2,095	0	100	0	20	0	2	0	0	0
Weis Lake	10	0	0	0	200	0	10	400	650	0	0	0	1,000	0	20	0	0	2,290	5	0	0	0	200	0	0	0	0
Sparland	0	0	0	0	0	0	0	0	360	5	0	0	1,010	0	10	0	0	1,385	0	0	0	100	0	1	0	0	0
Wightman Lake	10	0	0	0	400	0	20	400	150	0	0	0	420	0	0	0	0	1,400	5	0	0	5	200	0	1	0	0
Sawyer Slough	10	0	0	0	50	0	10	100	50	0	0	0	0	0	0	0	0	220	5	0	0	250	0	0	0	0	0
Hitchcock Slough	0	0	0	0	100	0	0	400	200	100	0	0	600	0	10	0	0	1,410	0	0	0	0	0	1	0	0	0
Babbs Slough	10	0	0	0	650	10	0	800	250	0	10	0	1,400	0	0	0	0	3,130	50	0	0	75	0	0	0	0	0
Meadow Lake	10	0	0	0	100	0	0	200	1,000	0	0	0	1,100	0	0	0	0	2,410	10	0	0	0	0	0	0	0	0
Douglas Lake	100	0	0	100	3,900	0	250	950	100	500	0	0	1,100	0	0	0	0	7,000	0	0	0	1,100	1,800	0	0	0	0
Goose Lake	100	0	0	0	6,200	0	0	1,000	1,300	0	0	0	1,220	0	0	0	0	9,820	0	0	10	0	0	0	5	0	0
Upper Peoria	20	0	0	0	900	0	0	5	26,700	0	0	0	18,700	0	10	0	0	46,335	15	0	0	930	2,450	1	0	0	0
Lower Peoria	0	0	0	0	0	0	0	0	80	0	0	0	30	0	0	0	0	110	5	0	0	0	215	0	0	0	0
Pekin Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20	0
Powerton Lake	10	0	0	0	200	0	20	0	0	0	0	0	0	0	0	0	0	230	45	0	0	0	2,600	0	3	0	5
Spring Lake	10	0	0	0	0	0	350	0	50	20	0	0	0	0	0	0	0	430	40	0	0	0	8,050	1	0	0	75
Spring Lake Bottoms	210	0	0	0	200	0	800	1,100	150	600	0	0	0	0	30	0	10	3,100	50	0	0	0	1,000	0	0	0	5
Goose Lake	100	0	0	0	740	0	50	450	0	0	0	0	0	0	0	0	0	1,340	20	0	0	155	100	2	5	0	0
Rice Lake	60	0	0	120	1,120	0	10	570	50	200	0	0	0	0	0	0	0	2,130	0	0	0	3,510	0	1	1	0	15
Big Lake	50	0	0	0	500	0	150	200	400	0	0	0	130	0	0	0	0	1,430	50	0	0	5,600	1,500	2	4	0	0
Banner Marsh	100	0	0	0	100	100	1,920	270	0	50	0	0	0	0	0	0	0	2,540	55	400	10	50	3,000	0	1	0	115
Duck Creek	0	0	0	0	0	0	20	50	0	0	0	0	5	0	0	0	0	75	15	10	0	0	0	0	0	10	5
Clear Lake	0	0	0	0	500	0	0	1,000	750	0	0	0	6,600	0	0	0	0	8,850	15	0	0	200	100	2	2	0	0
North Pool	200	0	0	300	3,900	0	400	2,500	1,600	300	0	0	3,300	0	0	0	0	12,500	25	0	0	0	2,300	1	0	0	0
South Pool	60	0	0	200	1,210	0	150	1,000	105	0	0	0	510	0	10	0	0	3,245	5	0	0	5	350	0	0	0	0
Quiver Creek	130	0	0	10	550	0	560	200	0	20	0	0	0	0	0	0	0	1,470	30	0	0	0	0	1	1	0	5
Quiver Lake	10	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	30	0	0	0	0	0	1	1	5	0
Thompson/Flag Lake	450	0	0	100	2,300	205	3,300	3,500	1,350	100	200	10	4,200	0	110	0	10	15,835	70	310	60	290	48,900	2	0	300	40
North Globe	0	0	0	0	200	0	0	150	0	0	0	0	0	0	0	0	0	350	0	0	0	0	0	0	1	0	0
Dickson Mounds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Globe	20	0	0	0	420	0	0	100	0	5	0	0	0	0	0	0	0	545	15	0	0	0	0	0	0	20	0
Wilder/Bellrose	110	0	10	0	100	0	20	450	0	10	0	0	0	0	0	0	0	700	5	0	0	0	500	0	0	0	0
Spoon River Btms	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Matanza Lake	200	0	0	0	200	0	0	150	160	0	0	0	150	0	0	0	0	860	15	0	0	425	0	0	1	20	0
Bath Lake	60	0	0	0	3,610	0	0	50	100	0	10	0	80	0	0	0	0	3,910	5	0	0	0	0	0	0	0	0
Moscow Lake	10	0	0	20	700	0	50	260	0	0	0	0	0	0	0	0	0	1,040	10	0	0	0	0	0	0	0	0
Jack Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	300	0	0	0	3	0	20	0
Grass Lake	120	0	0	0	100	0	0	0	210	0	0	0	500	0	0	0	0	930	20	0	0	0	0	0	0	500	0
Anderson Lake	10	0	0	0	350	5	10	0	0	0	0	0	0	0	0	0	0	375	25	0	10	10	1,100	0	0	600	0
Snicarte Slough	20	0	0	0	10	0	0	0	0	20	0	0	0	0	0	0	0	50	10	0	0	0	0	0	0	0	0
Ingram Lake	10	0	0	0	500	0	0	50	20	0	0	0	1,750	0	0	0	0	2,330	0	0	0	100	0	0	0	0	0
Chain Lake	0	0	0	0	100	0	0	0	400	0	0	0	350	0	0	0	0	850	0	0	0	110	0	0	0	0	0
Stewart Lake	0	0	0	0	200	0	0	100	100	0	0	0	4,600	0	0	0	10	5,010	0	0	0	0	0	0	4	0	0
Crane Lake	60	0	0	0	1,800	0	10	1,950	105	300	0	0	0	0	0	0	0	4,225	35	0	400	0	3,300	0	0	10	0
Cuba Island	550	0	0	0	600	0	700	1,900	100	200	0	0	0	0	0	0	0	4,050	40	0	0	0	1,600	0	1	0	0
Sanganois	60	0	0	10	1,030	0	50	170	0	50	0	0	0	0	0	0	0	1,370	0	0	0	0	0	0	0	0	0
Treadway Lake	10	0	0	0	300	0	0	200	100	200	0	0	0	0	0	0	0	810	0	0	0	55	0	2	4	400	0
Muscooten Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	100	0	0	400	1,200	0	150	1,550	0	200	0	0	100	0	0	0	0	3,700	15	100	600	960	1,500	0	0	0	0
Meredosia Lake	10	0	0	150	470	0	200	780	850	30	0	0	200	0	10	0	0	2,700	15	0	500	260	2,900	1	5	0	0
Smith Lake	30	0	0	0	200	0	30	100	0	0	0	0	0	0	0	0	0	360	60	0	0	370	0	1	0	0	0
Spunky Bottoms	0	0	0	125	400	0	0	100	0	0	0	0	0	0	0	0	0	625	0	0	0	475	0	1	4	0	0
TOTAL	3,900	5	10	1,585	42,855	340	10,235	26,485	39,190	3,165	380	35	53,460	0	215	5	40	181,905	970	2,220	1,640	15,640	103,665	28	45	1,965	270

Feb 14, 2017 Totals	98,490	15	61,410	0	7,650	20	7,720	655	3,660	20,190	4,600	370	560	4,710	75	12,835	60	223,020	15,580	36,060	166,300	145	500	69	82	0	1,360
Feb 21, 2017 Totals	102,415	15	18,575	0	38,520	270	32,720	13,690	18,205	43,295	5,010	1,280	23,605	2,725	525	1,065	30	301,945	3,000	34,600	357,215	810	12,555	22	35	5	565
Mar 2, 2017 Totals	50,620	25	2,685	0	23,300	60	7,190	7,665	23,065	36,615	3,880	105	11,230	35	760	45	35	167,315	2,420	9,525	53,155	1,870	38,290	27	42	0	352
Mar 9, 2017 Totals	29,640	5	1,780	10	52,090	25	9,515	29,410	68,440	20,935	1,540	100	31,435	0	790	45	15	245,775	1,020	2,455	9,630	4,525	55,710	23	36	40	165
Mar 16, 2017 Totals	46,045	0	810	0	43,835	60	18,655	23,550	59,855	13,350	1,425	140	33,145	445	975	535	90	242,915	1,780	3,630	3,610	3,980	65,280	31	26	410	235

ILLINOIS NATURAL HISTORY SURVEY WATERFOWL AERIAL INVENTORY DATA

ILLINOIS RIVER VALLEY Date: April 14, 2017 Observer: Aaron Yetter

																							Eagle			
LOCATION	MALL	ABDU	NOPI	BWTE	AGWT	AMWI	GADW	NSHO	LESC	RNDU	CANV	REDH	RUDU	COGO	BUFF	COME	HOME	TOTAL DUCKS	CAGO	GWFG	LSGO	AWPE	AMCO	AD	IMM	DCCO	SWAN
Turner Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	5	50	0	0	5	0
Depue, Spring	0	0	0	0	0	0	5	0	20	0	0	0	0	0	0	0	0	25	5	0	0	5	10	0	0	10	0
Coleman Lake	10	0	0	150	0	0	0	10	0	0	0	0	0	0	0	0	0	170	15	0	0	0	0	1	0	10	0
Bureau Ponds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Goose Lake	15	0	0	0	0	0	0	0	0	0	0	0	35	0	0	0	0	50	15	0	0	0	0	1	1	15	0
Senachwine Lake	0	0	0	300	50	0	0	25	0	0	0	0	20	0	0	0	0	395	5	0	0	280	0	1	0	5	0
Hennepin/Hopper	20	0	0	20	20	0	5	280	10	0	0	0	30	0	0	0	0	385	10	0	0	155	1,950	0	1	420	5
Swan Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sawmill Lake	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	10	0	0	0	20	0	1	0	10	0
Billsbach Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0
Weis Lake	0	0	0	0	0	0	0	0	0	0	0	0	50	0	0	0	0	50	0	0	0	0	0	0	0	0	0
Sparland	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	1	0	100	0
Wightman Lake	0	0	0	50	50	0	0	20	0	0	0	0	0	0	0	0	0	120	5	0	0	5	200	0	0	0	0
Sawyer Slough	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	5	10	0	0	0	0	0	0	5	0
Hitchcock Slough	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	5	0	0	0	5	0	0	0	10	0
Babbs Slough	0	0	0	0	0	0	0	0	10	0	0	0	105	0	0	0	0	115	0	0	0	60	0	0	0	5	0
Meadow Lake	0	0	0	0	0	0	0	0	5	0	0	0	20	0	0	0	0	25	5	0	0	0	0	0	0	0	0
Douglas Lake	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	0	500	650	0	0	0	0
Goose Lake	0	0	0	0	0	0	150	10	0	0	0	0	250	0	0	0	0	410	0	0	0	355	0	0	0	0	0
Upper Peoria	0	0	0	0	0	0	25	5	490	0	0	0	905	0	0	10	0	1,435	25	0	0	435	0	1	1	30	0
Lower Peoria	0	0	0	0	0	0	20	5	0	0	0	0	0	0	0	0	0	25	5	0	0	5	0	0	0	0	0
Pekin Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	150	0
Powerton Lake	0	0	0	0	0	0	10	0	0	0	0	0	20	0	0	5	0	35	25	0	0	50	355	0	0	25	0
Spring Lake	0	0	0	0	50	0	0	0	0	0	0	0	0	0	0	0	0	50	60	0	0	0	5,200	1	0	0	90
Spring Lake Bottoms	0	0	0	300	150	0	260	100	0	0	0	0	0	0	0	0	0	810	20	0	0	0	100	0	0	0	5
Goose Lake	0	0	0	50	30	0	10	5	0	0	0	0	0	0	0	0	0	95	5	0	0	25	10	2	0	0	0
Rice Lake	0	0	0	100	25	0	0	25	0	0	0	0	10	0	0	0	0	160	5	0	0	75	0	2	0	0	0
Big Lake	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	10	0	1	110	0
Banner Marsh	0	0	0	0	0	0	535	0	0	0	0	0	0	0	0	0	0	535	80	0	0	30	2,250	0	0	0	100
Duck Creek	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	20	0	0	60	0	0	0	530	0
Clear Lake	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	0	20	10	0	0	80	0	0	0	0	5
North Pool	20	0	0	770	100	0	0	420	10	0	0	0	0	0	0	20	0	1,340	0	0	0	50	610	0	0	0	0
South Pool	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	210	500	2	1	0	0
Quiver Creek	5	0	0	150	40	0	35	15	0	0	0	0	0	0	0	0	0	245	60	0	0	0	0	1	0	0	0
Quiver Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	50	0	0	0	0	0
Thompson/Flag Lake	40	0	0	200	160	0	275	370	170	0	0	0	1,450	0	10	0	0	2,675	55	0	0	410	8,300	0	1	260	30
North Globe	15	0	0	1,100	300	0	50	50	0	0	0	0	0	0	0	0	0	1,515	0	0	0	20	0	0	0	0	0
Dickson Mounds	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
South Globe	0	0	0	0	0	0	0	20	0	0	0	0	0	0	0	0	0	20	0	0	0	5	0	0	0	0	0
Wilder/Bellrose	20	0	0	30	100	0	0	10	0	0	0	0	0	0	0	0	0	160	5	0	0	30	10	0	2	0	0
Spoon River Btms	0	0	0	120	50	0	5	30	0	0	0	0	0	0	0	0	0	205	0	0	0	0	0	0	1	0	0
Matanza Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	5	0	0	0	0
Bath Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Moscow Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jack Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
Grass Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Anderson Lake	0	0	0	0	0	0	0	50	0	0	0	0	0	0	0	0	0	50	0	0	0	50	100	4	2	0	0
Snicarte Slough	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ingram Lake	0	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	20	0	0	0	0	0	0	0	0	0
Chain Lake	0	0	0	0	0	0	0	0	0	0	0	0	100	0	0	0	0	100	0	0	0	0	0	0	0	0	0
Stewart Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	20	0	0	0	0	0
Crane Lake	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	10	25	0	0	0	0	0	0	0	0
Cuba Island	0	0	0	10	50	0	10	20	0	0	0	0	0	0	0	0	0	90	30	10	0	25	220	0	1	0	0
Sanganois	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	0	0
Treadway Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	5	0	0	0	5	0
Muscooten Bay	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Big Lake	10	0	0	400	50	0	20	20	0	0	0	0	30	0	0	0	0	530	15	0	0	100	170	4	2	0	0
Meredosia Lake	0	0	0	110	70	0	0	50	5	0	0	0	35	0	0	0	0	270	20	0	0	5	420	0	0	0	0
Smith Lake	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	0	1	1	0	0
Spunky Bottoms	100	0	0	2,050	700	0	200	500	0	0	0	0	0	0	0	0	0	3,550	10	0	0	150	20	0	0	105	0
TOTAL	275	0	0	5,940	1,995	0	1,625	2,050	725	0	0	0	3,095	0	10	35	0	15,750	620	10	0	3,285	21,140	26	15	1,810	235

Feb 14, 2017 Totals	98,490	15	61,410	0	7,650	20	7,720	655	3,660	20,190	4,600	370	560	4,710	75	12,835	60	223,020	15,580	36,060	166,300	145	500	69	82	0	1,360
Feb 21, 2017 Totals	102,415	15	18,575	0	38,520	270	32,720	13,690	18,205	43,295	5,010	1,280	23,605	2,725	525	1,065	30	301,945	3,000	34,600	357,215	810	12,555	22	35	5	565
Mar 2, 2017 Totals	50,620	25	2,685	0	23,300	60	7,190	7,665	23,065	36,615	3,880	105	11,230	35	760	45	35	167,315	2,420	9,525	53,155	1,870	38,290	27	42	0	352
Mar 9, 2017 Totals	29,640	5	1,780	10	52,090	25	9,515	29,410	68,440	20,935	1,540	100	31,435	0	790	45	15	245,775	1,020	2,455	9,630	4,525	55,710	23	36	40	165
Mar 16, 2017 Totals	46,045	0	810	0	43,835	60	18,655	23,550	59,855	13,350	1,425	140	33,145	445	975	535	90	242,915	1,780	3,630	3,610	3,980	65,280	31	26	410	235
Mar 28, 2017 Totals	3,900	5	10	1,585	42,855	340	10,235	26,485	39,190	3,165	380	35	53,460	0	215	5	40	181,905	970	2,220	1,640	15,640	103,665	28	45	1,965	270

Appendix 4. Thesis and Manuscript Describing the Ecology of Canada Geese in the Greater Chicago Metropolitan Area of Illinois.

ECOLOGY OF WINTERING CANADA GEESE IN THE GREATER CHICAGO METROPOLITAN AREA

BY

BRETT EUGENE DORAK

THESIS

Submitted in partial fulfillment of the requirements
for the degree of Master of Science in Natural Resources and Environmental Sciences
in the Graduate College of the
University of Illinois at Urbana-Champaign, 2016

Urbana, Illinois

Master's Committee:

Associate Professor Michael P. Ward, Co-Chair
Adjunct Assistant Professor Heath M. Hagy, Co-Chair
Associate Professor Michael W. Eichholz, Southern Illinois University

ABSTRACT

Canada geese (*Branta canadensis*) breed in subarctic and temperate areas of North America, but both populations typically winter in temperate regions of the northern United States. During winter, Canada geese are increasingly using urban areas, but data are lacking on habitat use and selection, movements, potential thermal benefits of selected habitats, and survival of Canada geese during late autumn and winter in urban areas. I captured Canada geese during November–February 2014–2016 in the Greater Chicago Metropolitan Area (GCMA) in northeastern, Illinois, USA and fitted 41 geese with solar-powered GPS transmitters. Neck collar-mounted transmitters operated on the cellular phone network and collected hourly locations (n = 39,392). Canada geese selected green spaces (59.8%) in greater proportion than available (14%), but I also documented geese using novel habitats such as rooftops and rail yards (i.e., industrial urban; 11.3%). Habitat use shifted away from green spaces (36%) to industrial urban habitats (10.4%), riverine (12.8%), and deep-water habitats (37.8%) as temperatures decreased below the lower critical limit for Canada geese (i.e., temperature at which increased thermoregulatory costs are incurred to maintain core body temperature). During periods when temperature decreased and snow depth increased geese increasingly used industrial urban habitats. Both snow depth and minimum daily temperatures were associated with decreased movement distances within habitats. Movements by Canada geese within rail yard ($\bar{x}$ = 224.0 m, SE = 13.0) and green space habitats ($\bar{x}$ = 145.6 m, SE = 3.4) were the longest for any habitat type, while movements by geese in deep-water habitats ($\bar{x}$ = 85.7 m, SE = 3) and rooftop habitats ($\bar{x}$ = 52.9 m, SE = 5.5) were the shortest. When temperatures were below the lower critical temperature (-6 ^{o}C) Canada geese transitioned from deep-water to green space habitat in greater proportion than all other possible transitions between habitat types. Proportion of use of green space habitat increased during diurnal hours. Both deep-water and riverine habitats had greater proportional use during earlier morning hours than later in the day. Conversely, proportional use increased from midday to early evening in industrial urban habitat where proportional use increased during midday to early evening. All habitats had similar daily low temperatures, deep-water (+3.5 °C) and industrial urban habitat (+3.2 °C) did have warmer daily high temperatures than green space. The majority of transmittered Canada geese (85%) wintering in the GCMA never migrated south and no geese made foraging flights outside of the GCMA to agricultural fields. Winter survival was 100% for Canada geese remaining in the GCMA and 48% for geese that left the GCMA, with all mortality due to hunting. Since geese did not make foraging flights to agricultural fields, hunting may not be a viable option to reduce urban populations or change movement patterns during winter. Future research should test targeted harassment at industrial urban habitats, such as rooftops and deep-water habitats to see if Canada geese could be forced to leave urban areas.

DEDICATION

This thesis would not have been possible if it were not for all the sacrifices of my beautiful wife Sheena, daughter Una, and amazing dog Gunner throughout the years. You have opened my eyes to a completely new world I never thought possible and continually push me to be my best while following my dreams. I love you all from the bottom of my heart.

To my mom, you have always shown me what hard work and perseverance can accomplish. You set a standard for determination and grit, while having the biggest heart in the world. Thanks mumma!

To my dad, you introduced me to the outdoors and instilled a respect for the natural world from an early age. You constantly pushed me to do my best and you were always there for me no matter what. Thanks dude!

Finally, but not least, to my amazing brother Taylor I just want to say, "Thank you". Growing up together over the years has blessed me with so many fond memories and I could not have asked for a better brother by my side. Your attitude towards life has always impressed me and I hope that you know that. Thanks T-man!

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None of this would have been possible if it were not for my co-advisors, Dr. Mike Ward and Dr. Heath Hagy. Words cannot begin to describe how thankful I am that you guys took a chance with me. I do not know what you were thinking when you threw a small town boy in the big city of Chicago, but everything went as well as could have been expected. It has been an amazing few years and I have learned more than I ever thought possible. You two are incredibly gifted gentlemen and scholars. You guys will never know how much this experience has meant to me.

Dr. Michael Eichholz and Dr. Brian Washburn I want to thank you two for all the help and input over the years. The insight and knowledge you have provided along the way has been greatly appreciated.

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I also want to thank Randy Smith, Dan Holm, and Roy Domazlicky with the Illinois Department of Natural Resources as well as Scott Beckerman, Craig Bloomquist, Craig Pullins, and Travis Guerrant with the USDA APHIS Wildlife Services for realizing the need for research on Canada geese in the GCMA. I thank the Illinois Department of Natural Resources, Chicago Park District, the Forest Preserve Districts of Cook and Du Page Counties, Chicago Metropolitan Water Reclamation District, Midway International Airport, USDA Wildlife Services, and Southern Illinois University for funding, access to lands, and in-kind support. I would also like to thank Terry and Lee Cunningham for providing a wonderful place to stay while I conducted my fieldwork.

A major tip of the hat goes to the men and women of the United States of America who legally purchased firearms and ammunition to help fund W-182-R and W-43-R- through the Federal Aid in Wildlife Restoration Act (Pittman-Robertson Act). It is dedicated funding and responsible management that make this country and our resources what they are today. God Bless America!

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CHAPTER 1: HABITAT SELECTION OF CANADA GEESE IN AN URBAN ENVIRONMENT DURING WINTER

1.1 ABSTRACT

Canada geese (*Branta canadensis*) breed in subarctic and temperate areas of North America, but both populations typically winter in temperate regions of the northern United States. During winter, Canada geese are increasingly using urban areas, but data are lacking on habitat use and selection and survival during late autumn and winter in urban areas. I captured Canada geese during November–February 2014–2016 and fitted 41 geese with solar-powered GPS transmitters that were affixed to neck collars. Transmitters operated on the cellular phone network and collected hourly locations (n = 39,392). Canada geese selected green spaces (59.8%) in greater proportion than available (14%), but I also documented geese using novel habitats such as rooftops and rail yards (i.e., industrial urban; 11.3%). Habitat use shifted away from green spaces (36%) to industrial urban habitats (10.4%), riverine (12.8%), and deep-water habitats (37.8%) as temperatures decreased below the lower critical limit for Canada geese (i.e., temperature at which increased thermoregulatory costs are incurred to maintain core body temperature). The majority of transmittered Canada geese (85%) wintering in the GCMA never migrated south and no geese made foraging flights outside of the urban areas to agricultural fields. Winter survival was 100% for Canada geese remaining in the GCMA and 48% for geese that left the GCMA, with all mortality due to hunting. During periods when temperature decreased and snow depth increased geese increasingly used industrial urban areas (i.e., rooftops and rail yards), which may increase risk for collisions with aircraft nearby Midway International Airport. Since Canada geese did not make foraging flights to agricultural fields, hunting may not be a viable option to reduce urban populations or change movement patterns during winter and

targeted harassment at industrial urban, green space, and deep-water habitats may force geese to leave urban areas and subsequently allow the population to be more effectively managed through hunting.

1.2 INTRODUCTION

Waterfowl select habitats during non-breeding periods (e.g., migration, winter) that provide the resources required to maintain a favorable energy balance over time as well as maximize survival (Baldassarre and Bolen 2006). Urban areas provide the necessary resources needed for survival, but they often require waterfowl to use novel habitats and behave differently than individuals using traditional habitats (Marzluff 2001, Zuckerberg et al. 2011). Urban areas at the northern extent of wintering ranges provide resources (e.g., green spaces, waste from agricultural refining operations, thermal cover, etc), sanctuary from hunting and other predators, and reduced energy expenditure associated with migrating (Conover and Chasko 1985, Guthery et al. 2005, Anderies et al. 2007, Zuckerberg et al. 2011). Use of urban areas by Canada geese has been shown to increase clutch size, nest success, and annual survival compared to rural areas (Raveling 1981, Paine et al. 2003, Balkcom 2010). Additionally, subarctic-breeding Canada geese have shifted their winter range northward (Gates et al. 2001, Scribner et al. 2003). Specifically, the Mississippi Valley population of sub-arctic breeding Canada geese (*B.c. interior*) have shifted their wintering range northward from southern Illinois and northwest Kentucky to northern Illinois and southern Wisconsin (Craven et al. 1986, Gates et al. 2001, AGJV 2013). Migrating Canada geese may join with geese in urban areas creating large concentrations, which can create conflicts with humans (Conover and Chasko 1985, Smith et al. 1999)

Wildlife populations have traditionally been managed through hunting; hunting can keep populations in balance with available resources, maintain current population levels, or remove nuisance animals with an end goal of reducing the population (Witmer and Whittaker 2001). Local regulations in urban areas that limit hunting, public perception, and mixing of different Canada goose populations with different management objectives can create challenges (Coluccy et al. 2001, Unites States Fish and Wildlife Service 2015). Due to differences in population sizes and trajectories of temperate-breeding (increasing populations; *B.c. maxima*) and migratory populations of subarctic-breeding (stable or decreasing populations; *B.c. interior*) Canada geese, hunting season structure is set to allow liberal harvest of temperate-breeding populations while minimizing over harvest of subarctic-breeding populations (Scribner et al. 2003, United States Fish and Wildlife Service 2015). However, hunting is not permitted in many urban areas and limited data are available to determine susceptibility of geese using urban areas during winter to hunting mortality when geese migrate south following cold-weather events, make foraging flights to agricultural fields, or are displaced by already abundant numbers of geese using a limited number of available habitats.

Management of Canada geese in urban areas is particularly important because large populations or dense concentrations of Canada geese can pose threats to humans, including contamination of water sources (Allan et al, 1995), aggressive behavior towards humans (Smith et al. 1999), disease transmission (Smith et al. 1999, Kullas et al, 2002), and strikes with aircraft (Dolbeer et al. 2000). Canada geese are the largest bird commonly struck by aircraft in North America and because of their size and flocking behavior were responsible for 1,403 recorded bird strikes to civil aircrafts from 1990 to 2012 (Dolbeer and Eschenfelder 2003, Dunning 2008, Dolbeer et al. 2014). Noteworthy goose-aircraft strikes include a $190 million U.S. Air Force aircraft, which resulted in the death of 24 airmen (Dolbeer et al. 2000, Richardson and West 2000), and U.S. Airways Flight 1549 that crash-landed in the Hudson River in New York after striking multiple subarctic-breeding Canada geese (Marra et al. 2009). Thus, Canada geese can pose risks to human health and safety in urban areas, especially during winter when large flocks congregate around limited resources.

I studied the ecology of Canada geese wintering in or migrating through a large urban area during late autumn and winter to better understand habitat use and selection, survival within and outside of the urban areas, and vulnerability to hunting and other potential management strategies. Specifically, my objectives were to: (1) determine the areas in which geese spent the majority of their time (i.e., 50% utilization distribution-core use areas) and the extent of area commonly used by geese (i.e., 95% utilization distribution), (2) identify habitat use and selection, (3) estimate survival within and outside of urban areas and identify cause of mortality (e.g., hunting), and (4) describe phenology of Canada geese within and nearby the Greater Chicago Metropolitan Area during autumn and winter as it relates to the hunting season. I expected that Canada geese would use large green spaces and deep-water areas near warm-water discharges for roosting and conduct daily feeding flights out of the urban areas to agricultural fields for foraging (Conover and Chasko 1985, Havera 1999, Smith et al. 1999). I expected that survival of Canada geese in the urban area would be greater than rural areas because of increased risk of predation (i.e., hunting; Balkom 2010).

1.3 METHODS AND MATERIALS

Study Area

Canada geese were captured in the Greater Chicago Metropolitan Area (GCMA; 915 km^2) located in northeastern Illinois, USA (Fig 1.1) during late autumn and winter. The GCMA included portions of three counties (Cook, Du Page, and Will). The GCMA is heavily urbanized, but did have agricultural fields present within the GCMA boundaries (United States Department of Agriculture 2015). The GCMA averages 43 days annually below freezing, with 7 days below -18 °C. November has an average high of 9 °C and a low of 0 °C, December has an average high temperature is 2 °C with a low of -6 °C, January has an average is a high of 0 °C and a low of -9 °C, and February has an average high of 2 °C and low of -7 °C (NOAA 2015*a*). Chicago averages approximately 93 cm of snowfall annually (NOAA 2015*a*). The GCMA has an estimated temperate-breeding Canada goose population exceeding 30,000 individuals (Paine et al. 2003) and a human population of 9.4 million, including the city of Chicago and surrounding suburbs (United States Census Bureau 2013).

Field Methods

During 13 November 2014 through 28 February 2015 and 14 November 2015 through 29 February 2016, I captured and attached transmitters to 41 Canada geese within the GCMA. I focused my capture efforts at sites nearby Midway International Airport (41º47'6.5"N, 87º45'6"W) such as large parks, cemeteries, and the Stickney Water Reclamation Plant because of their available habitat and increased risk of goose-aircraft collisions when Canada geese concentrated at these locations throughout the fall and winter months (Fig 1.2). Standard waterfowl capture techniques (e.g., rocket nets and cannon nets) could not be used in most urban areas, so cast nets and small animal net guns (Wildlife Capture Services, Flagstaff, Arizona, USA) were used for most capture attempts. After a Canada goose was captured, I determined sex and age using cloacal inversion and feather characteristics and then obtained morphological measurements (i.e., mass, skull length, culmen length, tarsus length; Moser and Rolley 1990, Moser et al. 1991) as potential indicators of body condition. All length measurements were taken using a caliper (nearest 0.1 mm) and mass was obtained using a Rapala mini digital scale (nearest 0.01 km). An aluminum tarsal band and a GPS transmitter affixed to a white plastic waterfowl neck collar with black alphanumeric codes was then placed on each goose prior to release (Castelli and Trost 1996, Coluccy et al. 2002, Caswell et al. 2012).

Transmitters (n = 10 in 2014–2015 and n = 31 in 2015–2016) were deployed during four times periods each year (mid November, early December and mid December, and early January) to account for temporal variation and across seven different capture locations to account for spatial variation (Table 1.1). Transmitters recovered from hunters (n = 3) were redeployed during the late February (Table 1.1). Transmitters included solar-powered GPS units from Cellular Tracking Technologies in Somerset, Pennsylvania, USA, and operated on the Global System for Mobile communications network and were configured to acquire a GPS location once per hour. Generation 2 models were used during 2014–2015 ($\bar{x}$ = 69.7 grams, SE = 0.2) and Generation 3 transmitters were used during 2015–2016 ($\bar{x}$ = 62.2 grams, SE = 0.2). Transmitters were < 2% of the body mass of Canada geese ($\bar{x}$ = 4,713 grams, SE =10.6) and all Canada geese were captured and handled using the approved methods detailed by the University of Illinois Institutional Animal Care and Use Committee (Protocol # 14155).

Data Analysis

I removed locations from the day of capture from analysis, except for survival analysis, to minimize potential influences on movements and habitat use. Transmitters required a once-weekly cellular connection to program their duty cycle to the standardized rate of 1 location/hour for the entire day and upload locations to an accessible database. Depending on deployment, some transmitters did not link properly so data from transmitters with less than 10 days of data collection were removed from analysis (n = 1 in 2014–2015 and n = 4 in 2015–2016). Locations with only one satellite fix or with a horizontal dilution of precision value above 5 were removed because GPS coordinates were either not obtained or they had extremely low accuracy (Cellular

Tracking Technologies 2015). All analyses were performed using R Version 3.1.3 (R Core Team 2015).

To determine spatial habitat use, I used a dynamic Brownian Bridge Movement Model (dBBMM) to estimate the 50% and 95% utilization distribution (UD; km^2) using the adehabitatHR, rgdall, and move packages (Calenge 2006, Bivand 2015, Kranstauber and Smolla 2015). I estimated 50% utilization distributions (hereafter, core use areas) to target specific areas used by Canada geese during winter where management actions may need to focus and the 95% UD to represent total spatial use of Canada geese during winter. A dBBMM is a more appropriate method to estimate spatial habitat use than home range or kernel density estimates because it incorporates the temporal structure of the locations to estimate potential trajectories of the segments between those locations using a maximum likelihood function (Horne et al. 2007, Kranstauber et al. 2012). The dBBMM also provides a more accurate estimate than home range analysis for systematically collected data because the locations are not independent (Burt 1943, Worton 1989, Fieberg et al. 2010). If a Canada goose emigrated (i.e., did not return during the remainder of the year) from the GCMA, all locations from migration date forward were removed from 50% core use area and 95% UD analysis. Data collected from winter 2014–2015 were limited due to transmitter battery recharging issues with Generation 2 models (n = 9 transmitters, $\bar{x}$ = 10.5 locations/transmitter/day, SE = 2.9, range 2.0–26.4) compared to winter 2015–2016 when Generation 3 models provided increased battery life and efficiency (n = 27 transmitters, $\bar{x}$ = 20.8 locations/transmitter/day, SE = 0.4, range 15.4–23.3). Time between locations was greater for Generation 2 models in 2014–2015 ($\bar{x}$ = 274.1 min, SE = 75.2) than Generation 3 models in 2015–2016 ($\bar{x}$ = 70.1 min, SE = 1.3). All locations obtained from 15 November–28 February of both years (n = 3,496 in 2014–2015 and n = 35,896 in 2015–2016) were used to calculate 50% core use areas and 95% UD estimates. I also classified the autumn and winter period into three distinct periods using feeding flight and activity data from Raveling et al. (1972); early winter (15 November–31 December), mid winter (1 January–31 January), and late winter (1 February–28 February). I used mean imputation to fill in missing data for time period analysis, which simultaneously retained important 50% core use area and 95% UD information (Zar 2010). Transmitters ($n = 6$) from 2014–2015 that were present in the GCMA during 2015–2016 were not used for analysis during the second year because of limited locations with poor temporal spacing (i.e., weeks between locations) and low accuracy. I removed one location from analysis (Museum of Science and Industry) due to a limited sample size of Canada geese ($n = 2$). In separate linear mixed models using the lme function in the nlme package (Pinheiro et al. 2016) I analyzed the response variables of 50% core use areas and 95% UD against the predictor variable of time period (i.e., early, mid-, and late winter) with location of capture and year as random effects. Statistical significance for all analyses was inferred if $P \leq 0.05$. Mean 95% UD were plotted by location for visual representation of variation across locations.

To identify habitat use and selection, I plotted all locations of Canada geese ($n = 39{,}392$) on Google Earth Pro using the rgdall and adehabitatLT packages (Calenge 2006, Bivand 2015). Habitats were classified as green space, riverine, deep-water, industrial urban, or residential using available aerial imagery and ancillary information. Green spaces were typically large parks, cemeteries, and other large grass areas that contained a mixture of ponds, trees and shrubs, large sports fields, and golf courses within their boundaries (Table 1.2). I also included small grass lawns and areas between buildings in the green space habitat. Riverine habitat consisted of the Des Plaines and Calumet Rivers. Deep-water habitats were defined as the Chicago Sanitary and Ship Canal, which had steep concrete walls and warm water discharges along the canal corridor, and the Stickney Water Reclamation Plant, which was a mixture of gravel embankments and grass near deep-water settling ponds (*n* = 96). Deep-water habitat remained ice-free throughout the entire winter due to constant moving water within the settling ponds and warm-water discharge and barge traffic within the canal. Industrial urban habitats were defined as rooftops, which were typically large flat industrial buildings and retail stores, and adjacent rail yards composed of large complex series of railroad tracks where railcars were loaded, unloaded, and stored. Residential habitats were typically houses and developments, parking lots, and miscellaneous other land uses occurring in residential areas. To determine availability of the aforementioned use areas within the GCMA, I used a random number generator to create 500 locations within the study area and then classified each location using the same methods as was used for habitat use locations. I compared habitat use and availability across the entire autumn and winter period for both years and when the temperature dropped below the theoretical lower critical temperature (LCT) for Canada geese (Batt et al. 1992). The LCT is estimated using the resting metabolic rate and is the point where the ambient temperature is below the thermoneutral zone and heat is required to maintain body temperature, typically through metabolizing endogenous reserves. I am using the theoretical LCT of -6 ^{o}C for Canada geese as my threshold with knowledge that this is not a discrete threshold and that the LCT varies by individual through a complex interplay of physiological and behavioral adaptations. Additionally, I compared use across the 3 time periods (early, mid-, late winter). I conducted a Chi-squared test to compare proportional habitat use against proportion of availability for years (including all locations and below LCT) and across the time periods setting statistical significance for all analyses at $P < 0.05$ (Campbell 2007, Richardson 2011). Phenology of spring and fall migration dates was determined once a goose either left or entered the GCMA.

To address habitat use and selection, I used the resource selection function (RSF) with an exponential link to estimate *w*(x), which is the proportion of used locations with characteristics x, divided by the proportion of available locations with characteristics x (McDonlad 2013). When *w*(x) > 1, the habitat type is selected and Canada geese are not in that location by random chance. When *w*(x) = 1, presence in a habitat is random, and when *w*(x) < 1 Canada geese are avoiding these habitat types. I determined habitat use by taking all locations (*n* = 39,392) and creating a table of counts of Canada geese in habitat types and I then generated available habitat points (1 per used location) as a random draw, with replacement, from the sample of 500 random habitat locations used to generate habitat availability. This action doubled the dataset providing 78,784 locations used to estimate the RSF *w*(x). I then classified used locations and available locations belonging to the aforementioned 5 different habitat types and assumed that there was no change in urban habitat across years. I expected the relationship between habitat use and snow depth and minimum daily temperature to be curvilinear. Using the RSF, I analyzed habitat use as a function of habitat type (i.e., green space, riverine, deep-water, industrial urban, and residential), time of day (i.e., diurnal or nocturnal), and snow depth (cm). In a separate RSF analysis, I analyzed habitat use as a function of habitat type, time of day, and minimum daily temperature (°C) (Manly et al. 2007, McDonald 2013, Nielson and Sawyer 2013). The diurnal time period was set at 0500–1900 to account for crepuscular movements and the nocturnal time period was 1901–0459. I expected that there would be a threshold in both snow depth and minimum daily temperature so I used a quadratic term. I also expected the affect of snow depth and time of day (i.e., nocturnal or diurnal) to vary in habitat types and that is why I used an interaction term. Covariates of daily snow depth and daily minimum temperature were used because of their correlation with Canada goose activity patterns and weather data were obtained from the weather station at Midway International Airport (Raveling et al. 1972, Weather Underground 2016). I plotted the parameter estimates to make predictions of RSF *w*(x) (relative probability of a Canada goose using a particular habitat) within the range of minimum daily temperatures and snow depth data (Neter et al. 1996). I ran a smoothing factor for the plots to interpolate the predicted RSF *w*(x) between large gaps in snow depth data.

Winter survival (*S*) with 95% confidence intervals (CI) was calculated using the Known-Fate model in Program MARK because transmitters provided fine-scale data and status (i.e., alive or dead) of all Canada geese ($n = 41$) was known (Cooch and White 2016). I assumed that all transmittered Canada geese were mutually exclusive and because of spatial variation in transmitter deployment, I used a staggered entry design with paired entries with "0" in the first position to indicate a Canada goose was not transmittered yet and "1" in the first position for individuals that were transmittered. The second position in the pair was "0" if the Canada goose survived to the end of the interval or "1" if it died sometime during the interval. I broke down time intervals into weeks ($n = 15$) and then grouped them into the 3 time periods (i.e., early, mid-, late winter). A body condition index (BCI) was developed by regressing the residuals from an ordinary least-squares regression of massagainst an index of body size (Devries et al. 2008). The body size index was calculated by running a principal component analysis of all structural morphological measurements (skull, culmen, and tarsus) obtained at capture with the prcomp function in Program R and the first principal component (PC1) was used as the index of body size (Arsnoe et al. 2011). I created 6 models to evaluate the effects of BCI, group (remained in GCMA or migrated from GCMA), and time period on survival and ranked models using Akaike's information criterion adjusted for a small sample size (AIC_c; Burnham and Anderson 2002). I summed model weights (w_i) of top models to determine relative variable importance.

1.4 RESULTS

Neither the 50% core use areas ($\bar{x}$ = 0.7 km^2, SE = 0.3, $F_{1,95}$ = 1.3, P = 0.26) nor the 95% UD ($\bar{x}$ = 24.5 km^2, SE = 5.2, $F_{1,95}$ = 0.37, P = 0.54) of Canada geese (n = 36) varied by time period (Figure 1.3). Canada geese selected green space (59.8%), deep-water (15.2%), industrial urban (11.3%), and riverine (8.1%) habitats in greater proportion than their availability ($P \leq 0.05$) (Table 1.3). When temperatures were below the LCT, Canada geese increased use of deep-water (+245.6%) and riverine habitats (+158.0%) while decreasing their use of green space (-60.2%; Table 1.3). Green space was selected more than any other habitat and used in disproportion to available green space during the early winter time period (80.4%), but selection of green space declined during mid winter (52.2%) and late winter (52.8%; P < 0. 01; Table 1.4). Canada geese increased use of deep-water habitat throughout the time periods from 0.7% in early winter to 41.7% during mid winter and 37.5% in late winter (Table 1.4). Similarly, increased use of industrial urban habitats was observed from early winter (6.8%) to mid winter (11.3%) and late winter (14.2%; Table 1.4).

Snow depth ($F_{1, 78,728}$ = 119.23, P < 0.01), minimum daily temperature ($F_{1, 78,728}$ = 183.56, P < 0.01), time of day ($F_{1, 78,728}$ = 9.19, P < 0.01), and all interactions (P < 0.01) affected habitat use. The resource selection function (RSF) w(x) was above 1 for every habitat type except residential indicating that Canada geese selected green space, industrial urban, riverine, and deep-water habitats, but avoided residential habitats (Figures 1.4–1.13). As snow depth increased the RSF w(x) increased for industrial urban, riverine, and deep-water habitats, while use of green space decreased (Figure 1.4, Figure 1.5, Figure 1.7, Figure 1.8). Residential habitat had the lowest RSF w(x) that was near "0" across almost all snow depths and minimum daily temperature (°C) ranges (Figure 1.6, Figure 1.11). Canada geese selected riverine and deep-water habitats more often during nocturnal than diurnal periods (Figure 1.4, Figure 1.7, and Figure 1.12). As minimum daily temperature (°C) decreased, the RSF *w*(x) increased for riverine and deep-water habitats. Industrial urban habitats had an increase in RSF *w*(x) as temperature decreased, but then selection peaked and started to decrease towards "1" at -5 °C (Figure 1.13). Green space use declined as temperature decreased and approached *w*(x) = 1 near -20 °C indicating that use was almost by chance (Figure 1.5).

Winter survival was 100% for Canada geese using the GCMA (*n* = 35) and 48% (95% CI range = 16% to 82%; *n* = 6) for geese that emigrated from the GCMA. Weekly survival for emigrating Canada geese was 95% (95% CI range = 86% to 98%). Time period affected survival for Canada geese that left the GCMA with an estimated weekly survival of 100% for early winter, 85% (95% CI range = 62% to 95%) during the mid winter, and 100% for late winter. I documented three direct mortalities, all from hunting during the mid-winter time period. Mortalities occurred 8 days (range 2–16) after the Canada geese emigrated from the GCMA. Hunting mortalities occurred in northwest Indiana, southwest Illinois, and northwest Tennessee. BCI was related negatively to survival, but confidence intervals overlapped zero indicating no true effect. The top two models for survival analysis ($\sum w_i = 0.9$) included time period (Table 1.5). All Canada geese that migrated from the GCMA died during the mid winter time period, a time period that corresponds to the hunting season in the region.

The majority of Canada geese (85%) fitted with transmitters never migrated south from the GCMA. During 2014–2015, only 3 Canada geese left the GCMA. One Canada goose left on 30 November 2014 and 2 left on 4 January 2015. During 2015–2016, only 3 of the 31 Canada geese emigrated from the GCMA to more southern latitudes, 1 left on 30 December 2015 and 2 left on 13 January 2016.

In 2015, Canada geese (*n* = 7) initiated spring migration on 11 March through 16 March 2015, while 2 geese remained in the GCMA for the breeding season. Spring migration initiated earlier in 2016 when Canada geese (*n* = 15) started northward from 20 February through 1 April 2016. Fourteen Canada geese remained within the GCMA during the breeding portion of the annual cycle in 2016. Canada geese showed high site fidelity to the GCMA. All Canada geese with active transmitters from 2014–2015 (*n* = 7) were present within the GCMA during the autumn of 2015. Return flights to the GCMA ranged from May through November in 2015.

1.5 DISCUSSION

Canada geese in the GCMA had relatively small core use areas (Rutledge et al. 2015), remained within urban areas and did not make flights to agricultural fields within or outside of the GCMA where they might have been subjected to hunting mortality, high survival and made use of novel habitats within highly urbanized areas such as rooftops, rail yards, water treatment facilities, and warm-water discharges along rivers and the canal. Canada geese in the GCMA tended to have relatively small 50% core use areas, which predominately included green spaces, and 95% UD were similar to the home range estimate of 25 km^2 produced by Groepper et al. (2008). Although agricultural fields were present within and nearby the GCMA Canada geese did not make foraging flights and apparently did not require waste grain in agricultural fields for survival. Possibly Canada geese entered the winter at with abundant fat reserves to minimize the need for feeding flights and instead choose to minimized energy expenditure by remaining within the GCMA throughout winter. For example, male Canada geese were approximately 500 g heavier and females were 700 g heavier than geese captured during winter near Rochester, Minnesota (McLandress and Raveling 1981; Appendix Table A.1). Additionally, Canada geese in the GCMA were larger than wintering geese from southern Illinois and east-central Wisconsin

(Gates e al. 2001). Moreover, Canada geese increased use of these industrial urban habitats as snow depth increased and temperature decreased suggesting there may be thermal or survival benefits from selecting these areas. While I know of no other published accounts of Canada geese extensively using rooftops and rail yards in winter, I expect they are taking advantage of the relative safety of the urban landscape.

Canada geese used a mix of habitats in the GCMA, including many areas not previously reported as primary habitats (e.g., rooftops, rail yards, wastewater treatment facilities). Large green spaces were selected across all time periods, even when temperatures were below the LCT for Canada geese, and likely provide necessary food and water resources needed by geese even during winter. Although the LCT may have been affected by a complex interplay of physiological and behavioral mechanisms resulting in variation between individuals and habitats, I believe the LCT I selected represented an approximate temperature threshold which could have influenced thermoregulatory costs of Canada geese in the GCMA during winter. During winter weather events when snow depth increased and temperatures decreased, Canada geese reduced their use of green spaces and increased use of industrial urban habitats (i.e., rooftops, rail yards, and the canal; Figures 1.4–1.13). This change may be in response to availability of roost areas and forage within green spaces becoming limited due to ice coverage and increased snow depth. Canada geese may change to novel urban habitats for thermal benefits, sanctuary, food resources (see Chapter 2). For example during these cold periods, spilled grain may have been available in rail yards. Industrial rooftops may have provided thermoregulatory benefits and sanctuary from disturbances and predators, and deep-water habitat may have provided open water for roost locations. Once temperature increased and snow depth decreased, Canada geese increased proportional use of green spaces. The difference in use of green space between the 2 years may be due to the weather extremes. The winter during 2014–2015 was 2 °C colder and had 32 cm more snow accumulation than an average winter for the GCMA compared to 2015–2016 that was 3 °C warmer with 30 cm less snow than average (NOAA 2015*b*, 2016). Harsh winter conditions during 2014–2015 may have affected the ability of Canada geese to roost on water sources in green spaces and reduced the availability of grass for foraging making geese utilize novel urban habitats at a higher frequency.

High survival of Canada geese in the GCMA relative to other published estimates during autumn and winter suggests that urban habitats provide sanctuary and other resources needed for survival north of historic wintering ranges (Balkcom 2010). Typically, survival rates for Canada geese are lower during winter months at more northern latitudes than I observed within the GCMA (72–98%; Hestbeck and Malecki 1989). Unlike Groepper et al. (2008), a study conducted in another urban landscape, Canada geese that wintered in the GCMA never occupied locations that permitted hunting and all geese had their entire 95% UD within city limits.

The majority of transmittered Canada geese (85%) never migrated south of the GCMA during winter and no geese made daily feeding flights to agricultural fields unlike results reported by Groepper et al. (2008). Canada geese could be shifting their foraging efforts and exploiting different types of available food resources within urban areas, similar in shifts seen by Atlantic brant (*Branta bernicla hrota*; Ladin et al. 2011). The most compelling reason for Canada geese not leaving the GCMA may be the lack of predation risk. Similarly, Balkcom (2010) indicated high seasonal survival (95.8%) in urban areas of Georgia, USA. I suspect that Canada geese are continually adapting to changing climate and landscapes in North America by shifting wintering ranges northward and utilizing nontraditional habitats within urban areas, which provide sanctuary conditions.

Autumn migration of Canada geese returning to the GCMA occurred earlier than other studies in the Midwest (Wege and Raveling 1983). Approximately 50% of Canada geese returned to the GCMA prior to open hunting seasons. Arriving during times when hunting pressure is limited allowed Canada geese to reach urban areas and remain within the city limits during autumn and winter when hunting seasons were open. Canada geese that did migrate from the GCMA during the winter did so during portions of the year when Canada goose hunting seasons were open in Illinois and surrounding states making geese susceptible to predation via hunting, ultimately lowering their survival estimates. Increased hunting pressure outside of urban environments likely creates a strong selection pressure for Canada geese to remain in urban environments, especially when novel urban habitat types may provide necessary resources for survival (Lima and Dill 1990).

1.6 MANAGEMENT IMPLICATIONS

Management of Canada geese in urban areas should focus on harassment during extreme winter weather conditions to reduce the risk of goose-aircraft collisions. Canada geese can mitigate the extreme weather events by taking advantage of novel urban habitats at the northern edge of their wintering range and increase survival. I suspect that Canada geese wintering in northern locations, such as the GCMA, are pushing their thermoregulatory limits, especially during harsh winter conditions. While no transmittered Canada geese died during the study within the GCMA, I found several goose carcasses on rooftops after extreme weather conditions. Harassment of Canada geese at these nontraditional habitats during cold periods may "push" geese to the point where they have to choose to either migrate out of the area, to locations where hunting is permissible, or potentially risk death due to increased energy demands and exposure to the elements. Currently much of the harassment and management of Canada geese within the

GCMA is focused on the breeding season (Smith et al. 1999, Scribner et al. 2003), and I suggest there is an opportunity to effectively manage geese in urban areas in winter. Additional research is needed to better understand response of Canada geese to harassment in urban areas and understand thermoregulatory balance in these areas.

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1.8 TABLES AND FIGURES

Table 1.1. Dates and number of Canada geese (*Branta canadensis*) captured and transmittered during autumn and winter 2014–2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

	2014–2015				2015–2016			
Location	November 13–31	December 1–15	January 15–31	February 15–28	November 14–31	December 1–15	January 1–15	February 15–29
Marquette Park			1		2	1		
McKinley Park	1					3	5	
Museum of Science and Industry	1				1		1	1*
Resurrection Cemetery		1	1		1	3	1	
Sherman Park	1	1			1	2		
Stickney Water Reclamation Plant			2	1*	1		3	1*
Washington Park					1	1	2	
Total	3	2	4	1	7	10	12	2

*Transmitters recovered from hunters and then redeployed

Table 1.2. Percentage of available habitat compared to all GPS locations in each habitat type used by Canada geese (*Branta canadensis*) and the percentage of habitat use when temperature was below the lower critical temperature (LCT; -6 °C) for Canada geese in the Greater Chicago Metropolitan Area, Illinois, USA, during 2014–2016.

Location	Total Area (km^2)	Surface Water (km^2)	Description
Marquette Park	1.25	0.16	Contains sports fields, 9-hole golf course, trees and shrubs, lagoon
McKinley Park	0.28	0.03	Contains sports fields, trees and shrubs, and pond with islands
Museum of Science and Industry	1.95	0.33	Contains sports fields, 18-hole golf course, trees and shrubs, a lagoon and harbors, bordered to the east by Lake Michigan
Resurrection Cemetery	1.18	0.02	Contains ponds, large buildings, headstones, trees and shrubs
Sherman Park	0.25	0.05	Contains sports fields, trees and shrubs, and a lagoon

Table 1.3. Percentage of available habitat compared to all GPS locations in each habitat type used by Canada geese (*Branta canadensis*) and the percentage of habitat use when temperature was below the lower critical temperature (LCT; -6 ºC) for Canada geese in the Greater Chicago Metropolitan Area, Illinois, USA, during 2014–2016.

		2014–2015		2015–2016		Total	
Habitat	Available	All Locations	Below LCT	All Locations	Below LCT	All Locations	Below LCT
Green Space	14.0%	30.1%[a]	18.4%[a]	62.7%[a]	40.8%[a]	59.8%[a]	36.0%[a]
Riverine	2.2%	14.1%[a]	15.6%[a]	7.6%[a]	12.0%[a]	8.1%[a]	12.8%[a]
Deep Water	1.0%	20.9%[a]	29.6%[a]	14.6%[a]	40.1%[a]	15.2%[a]	37.8%[a]
Industrial Urban	8.0%	30.6%[a]	32.3%[a]	9.4%	4.4%[a]	11.3%[a]	10.4%
Residential	74.8%	4.3%[a]	4.1%[a]	5.7%[a]	2.7%[a]	5.6%[a]	3.0%[a]
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[a] Designates proportional habitat use that was determined to significantly ($P \leq 0.05$) differ from proportion of habitat available based on Chi-squared tests.

Table 1.4. Percentage of available habitat compared to percentage of GPS locations in each habitat type used by Canada geese (*Branta canadensis*) for all locations and when temperature was below the lower critical temperature (LCT; -6 °C) for Canada geese during the 3 time periods in the Greater Chicago Metropolitan Area, Illinois, USA, during 2014–2016.

		Early Winter		Mid Winter		Late Winter	
Habitat	Available	All Locations	Below LCT	All Locations	Below LCT	All Locations	Below LCT
Green Space	14.0%	80.4% [a]	84.7% [a]	52.2% [a]	38.7% [a]	52.8% [a]	30.6% [a]
Riverine	2.2%	3.5%	7.3% [a]	11.4% [a]	11.8% [a]	8.4% [a]	14.0% [a]
Deep Water	1.0%	1.9%	0.7%	21.8% [a]	41.7% [a]	18.2% [a]	37.5% [a]
Industrial Urban	8.0%	6.8%	0.3% [a]	11.3% [a]	6.2%	14.2% [a]	14.2% [a]
Residential	74.8%	7.4% [a]	7.0% [a]	3.3% [a]	1.6% [a]	6.4% [a]	3.7% [a]
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

[a] Designates proportional habitat use that was determined to significantly ($P \leq 0.05$) differ from proportion of habitat available based on Chi-squared tests.

Table 1.5. Results of linear models evaluating the effects of period (early winter, mid winter, late winter), group (stayed or emigrated from the Greater Chicago Metropolitan Area), and body condition index (BCI) on survival (S) of Canada geese (*Branta canadensis*) captured and transmittered during autumn and winter 2014–2016 in the Greater Chicago Metropolitan Area, Illinois, USA with Akaike's Information Criterion adjusted for sample size AIC_c with number of parameters (k), difference in AIC_c with top model (ΔAIC_c), model weight (w_i), and deviance.

Model	k	AICc	ΔAICc	w_i	Deviance
S(Period) +(Group)+(BCI)	4	22.5	0.0	0.5	14.4
S(Period)	3	23.0	0.5	0.4	16.9
S(Group)	2	28.2	5.7	0.0	24.1
S(Constant)	1	37.0	14.5	0.0	35.0
S(BCI)	2	37.7	15.3	0.0	33.7

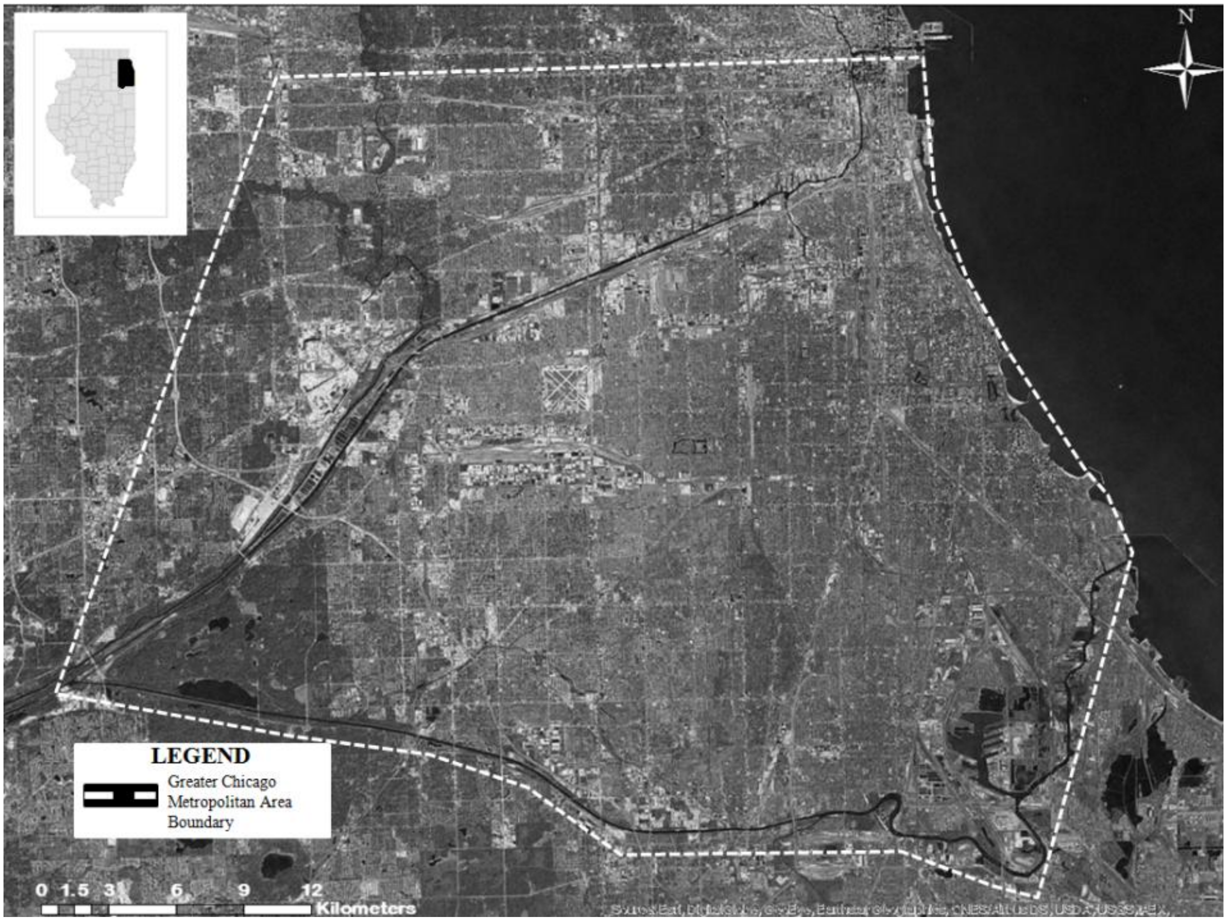

Figure 1.1. The Greater Chicago Metropolitan Area located in northeast Illinois, USA.

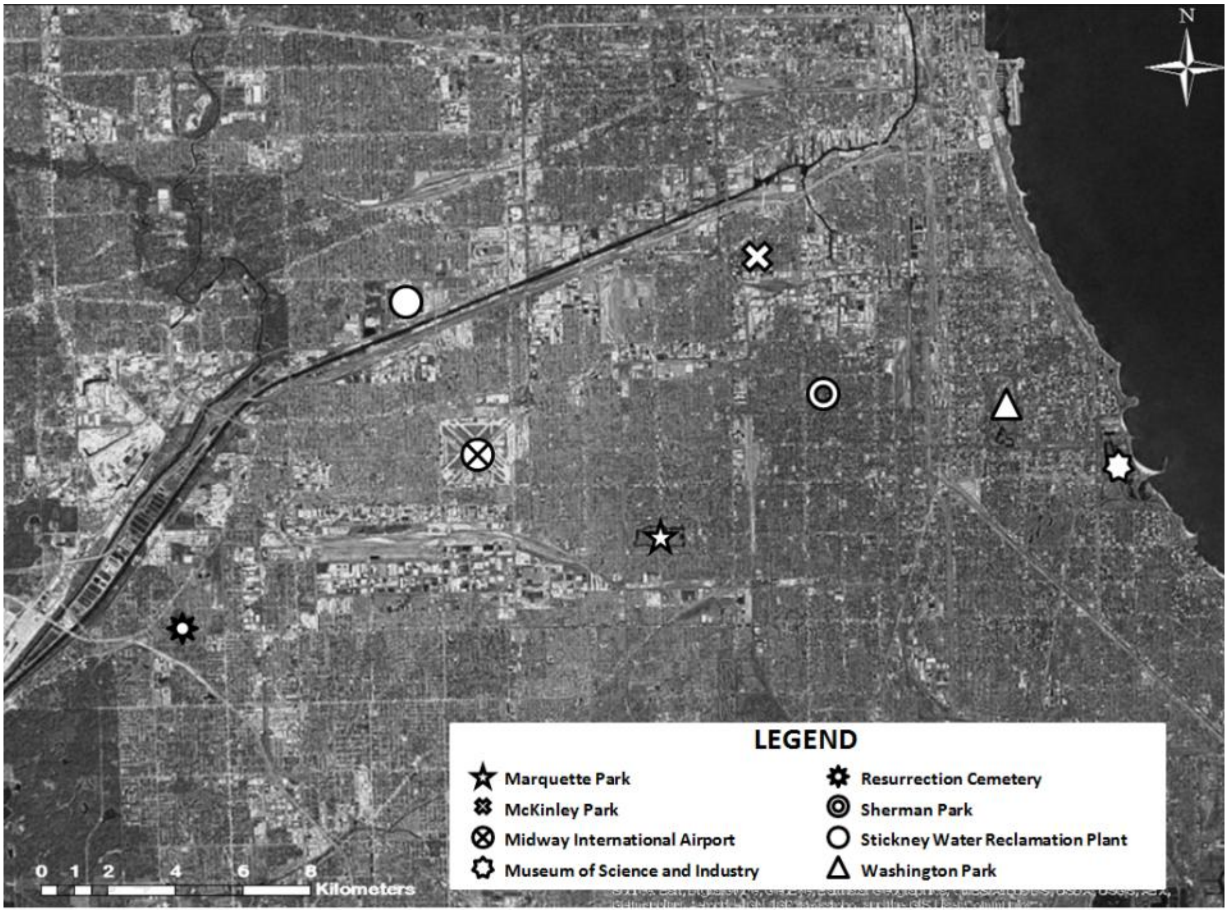

Figure 1.2. Main capture locations (*n* = 7) for Canada geese (*Branta canadensis*) in relation to Midway International Airport in the Greater Chicago Metropolitan Area, Illinois, USA.

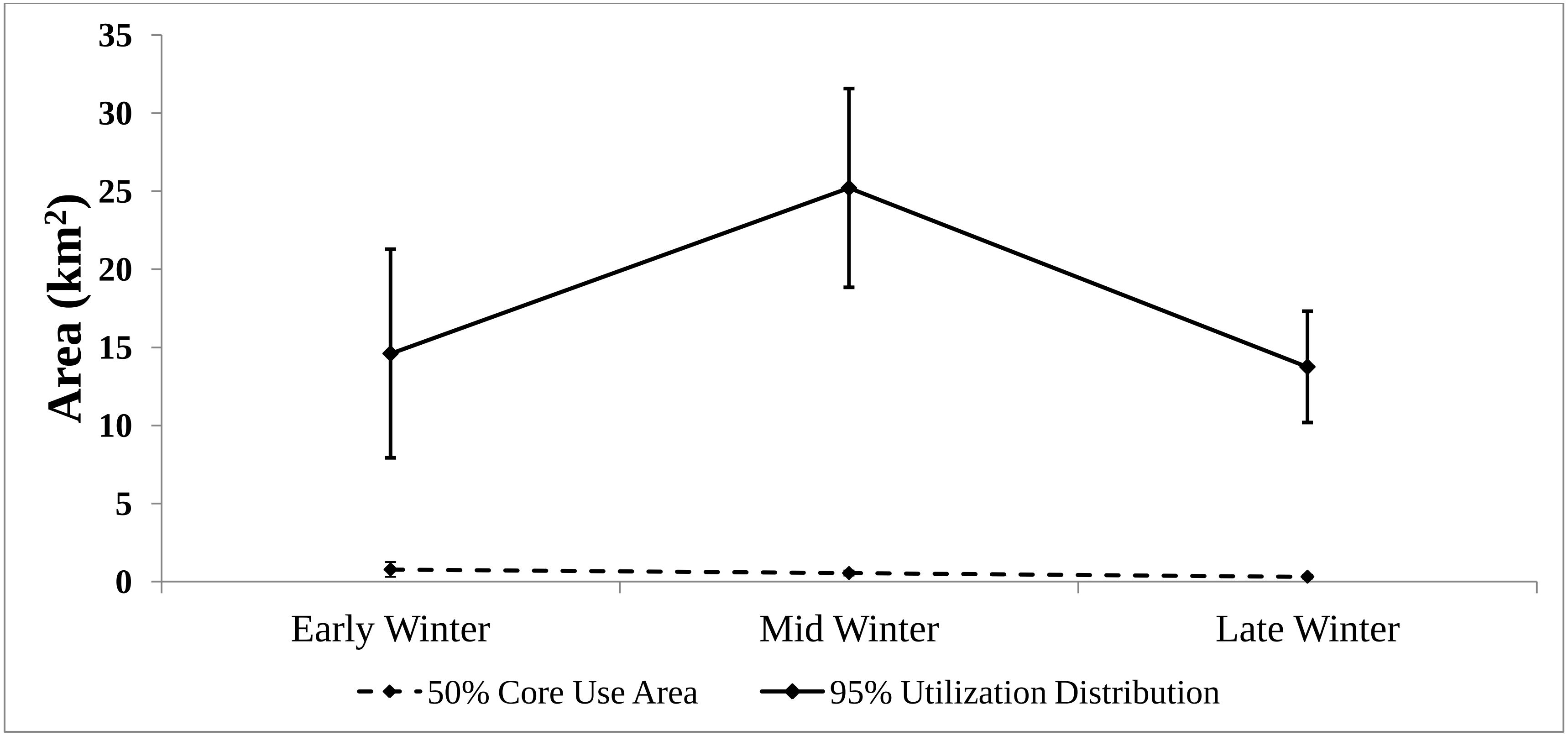

Figure 1.3. Change in 50% core use areas and 95% utilization distribution estimates with standard error bars across 3 time periods for Canada geese during autumn and winter 2014–2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

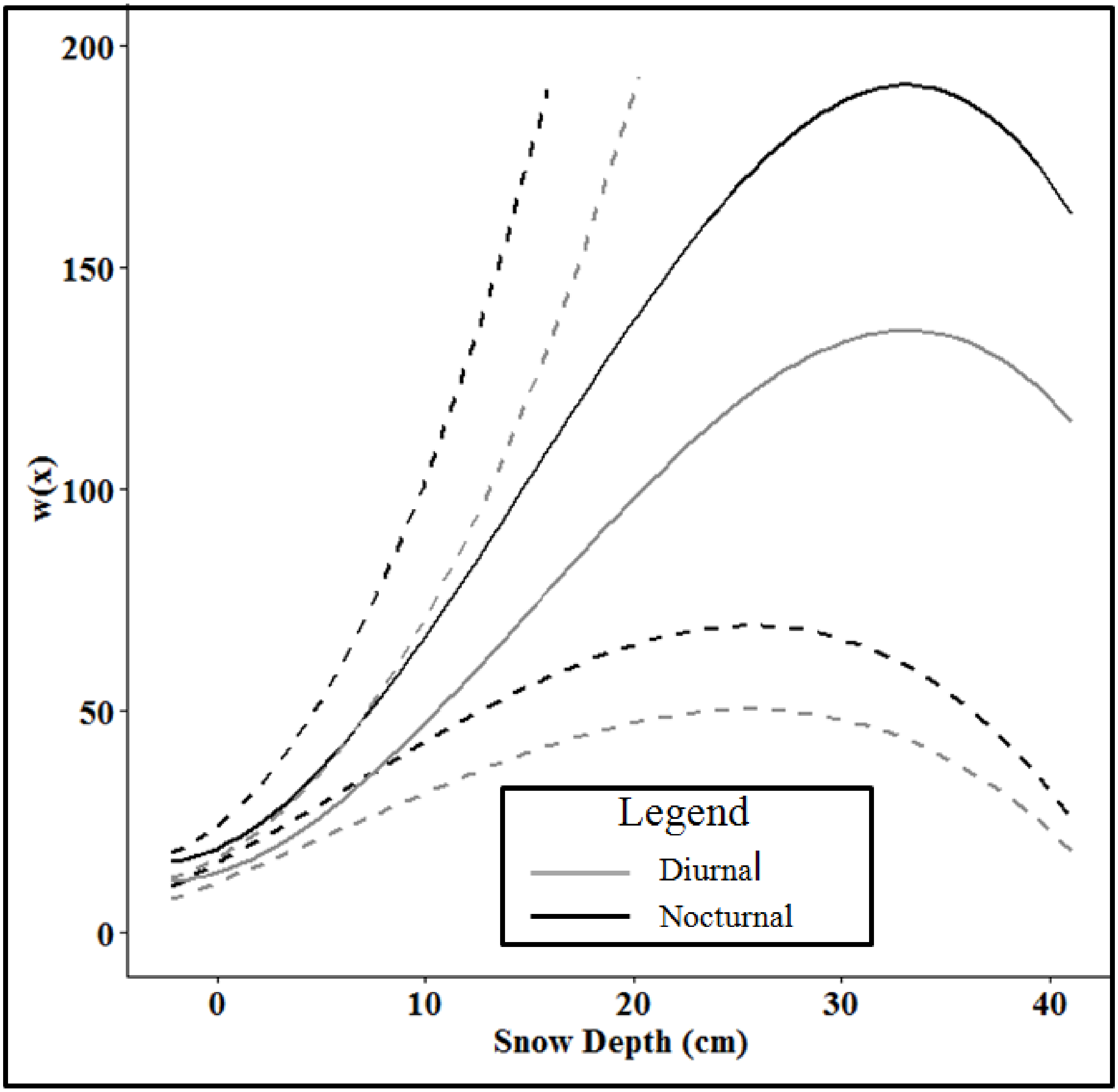

Figure 1.4. Estimated resource selection function *w*(*x*) for deep-water habitat used by Canada geese (*Branta canadensis*) at varying levels of snow depth (cm) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

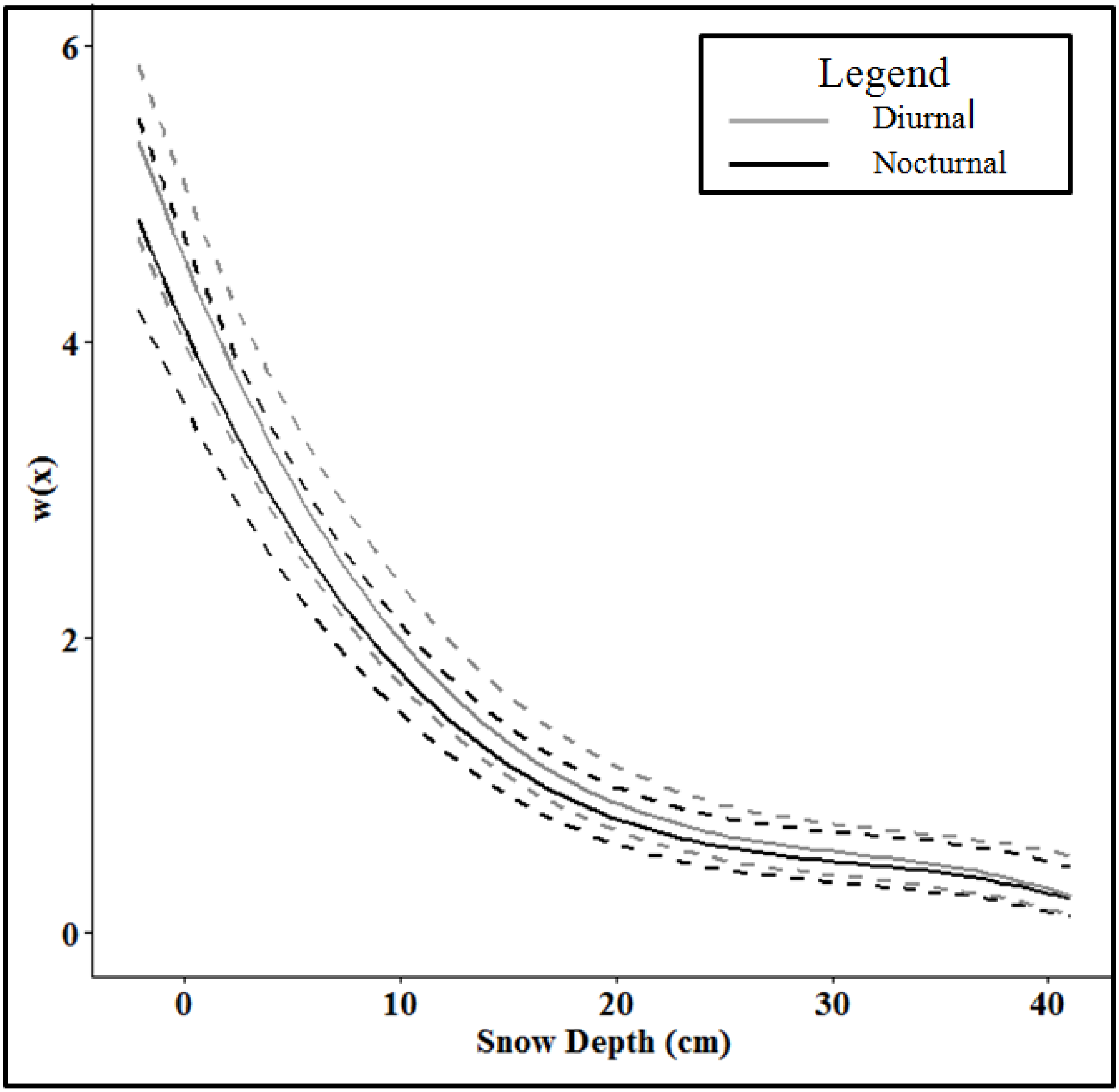

Figure 1.5. Estimated resource selection function *w*(*x*) for green space habitat used by Canada geese (*Branta canadensis*) at varying levels of snow depth (cm) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

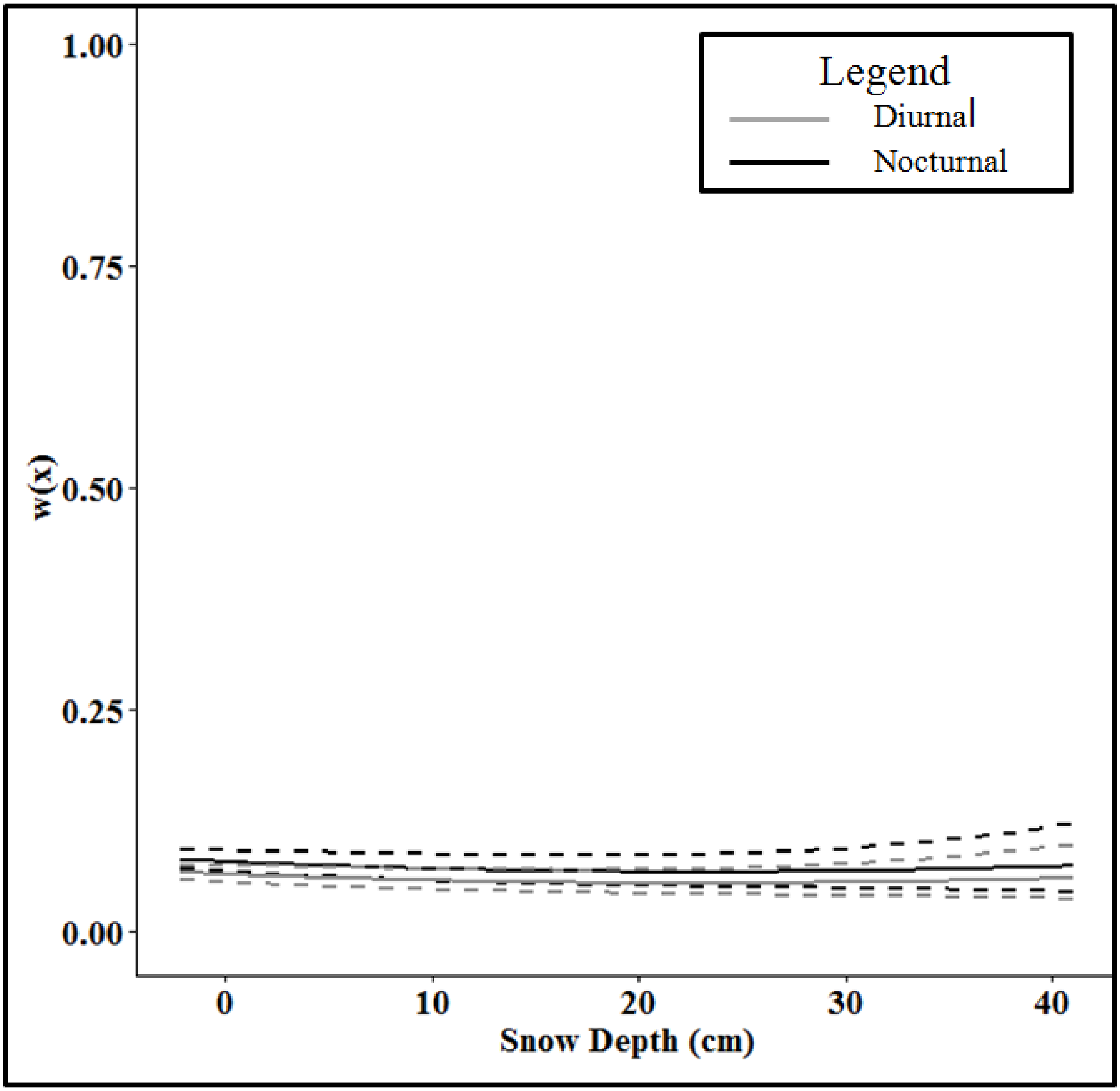

Figure 1.6. Estimated resource selection function *w*(*x*) for residential habitat used by Canada geese (*Branta canadensis*) at varying levels of snow depth (cm) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

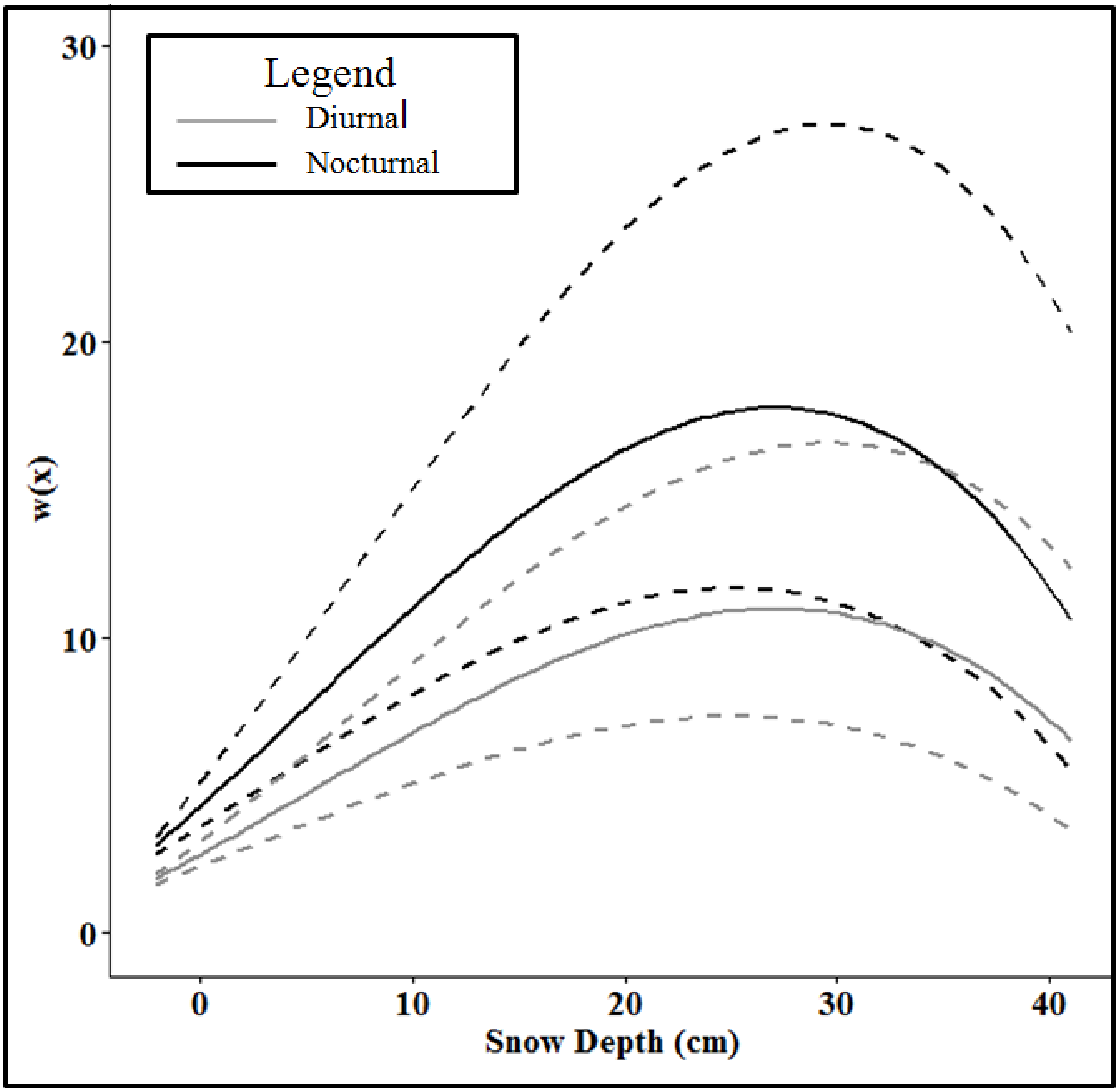

Figure 1.7. Estimated resource selection function *w*(*x*) for riverine habitat used by Canada geese (*Branta canadensis*) at varying levels of snow depth (cm) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

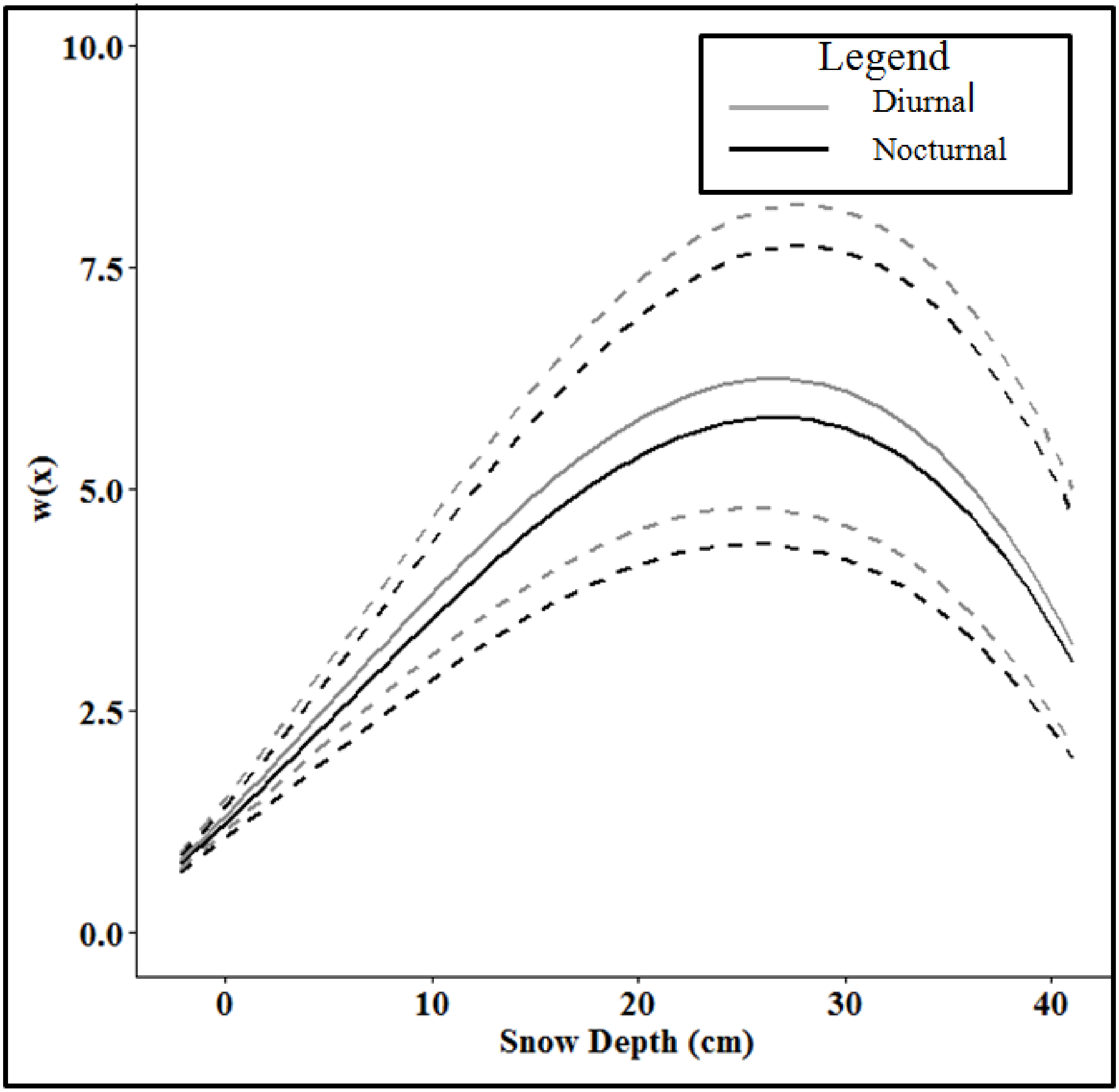

Figure 1.8. Estimated resource selection function *w*(*x*) for industrial urban habitat used by Canada geese (*Branta canadensis*) at varying levels of snow depth (cm) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

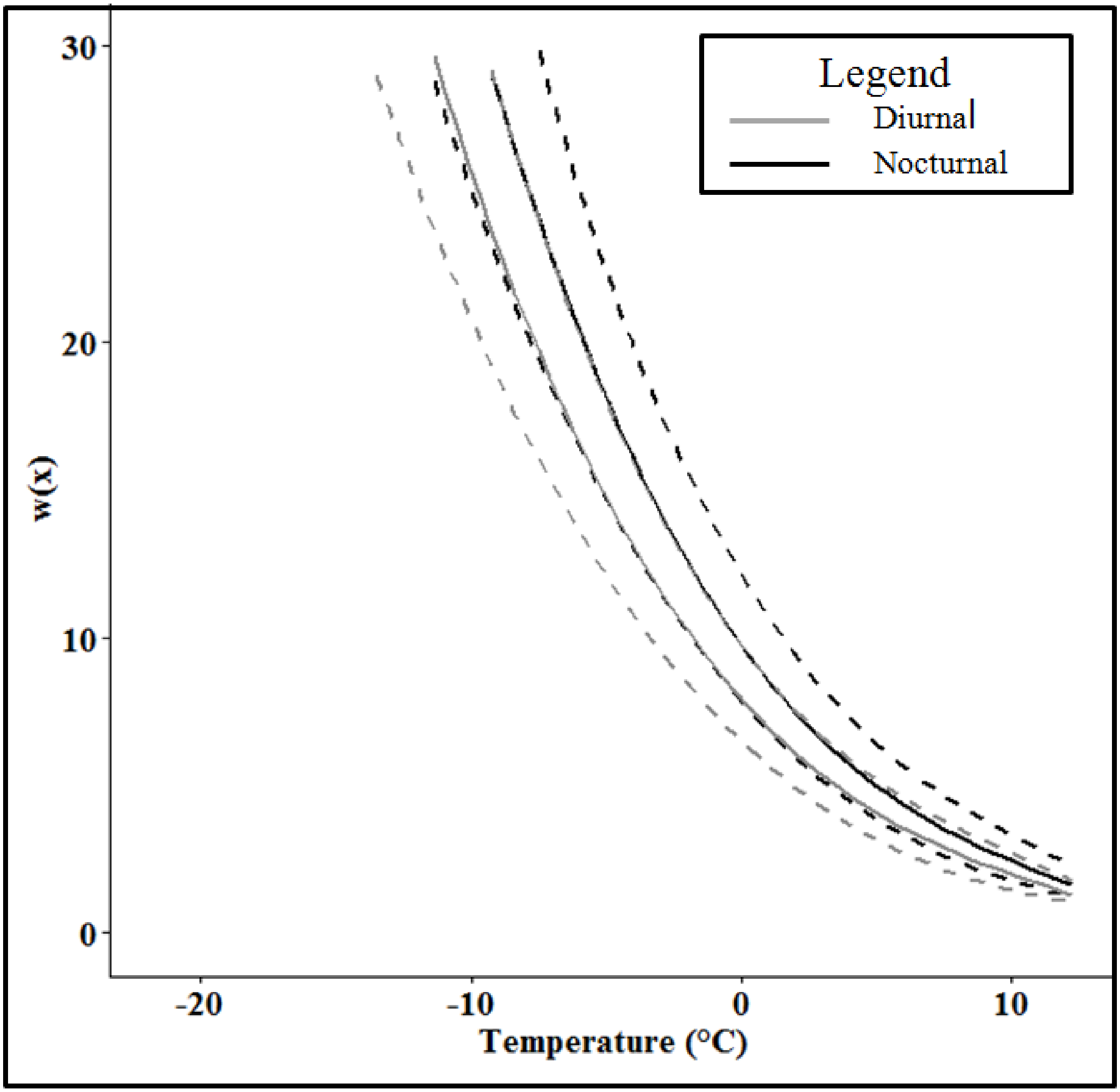

Figure 1.9. Estimated resource selection function *w*(*x*) for deep-water habitat used by Canada geese (*Branta canadensis*) at varying levels of minimum daily temperatures (°C) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

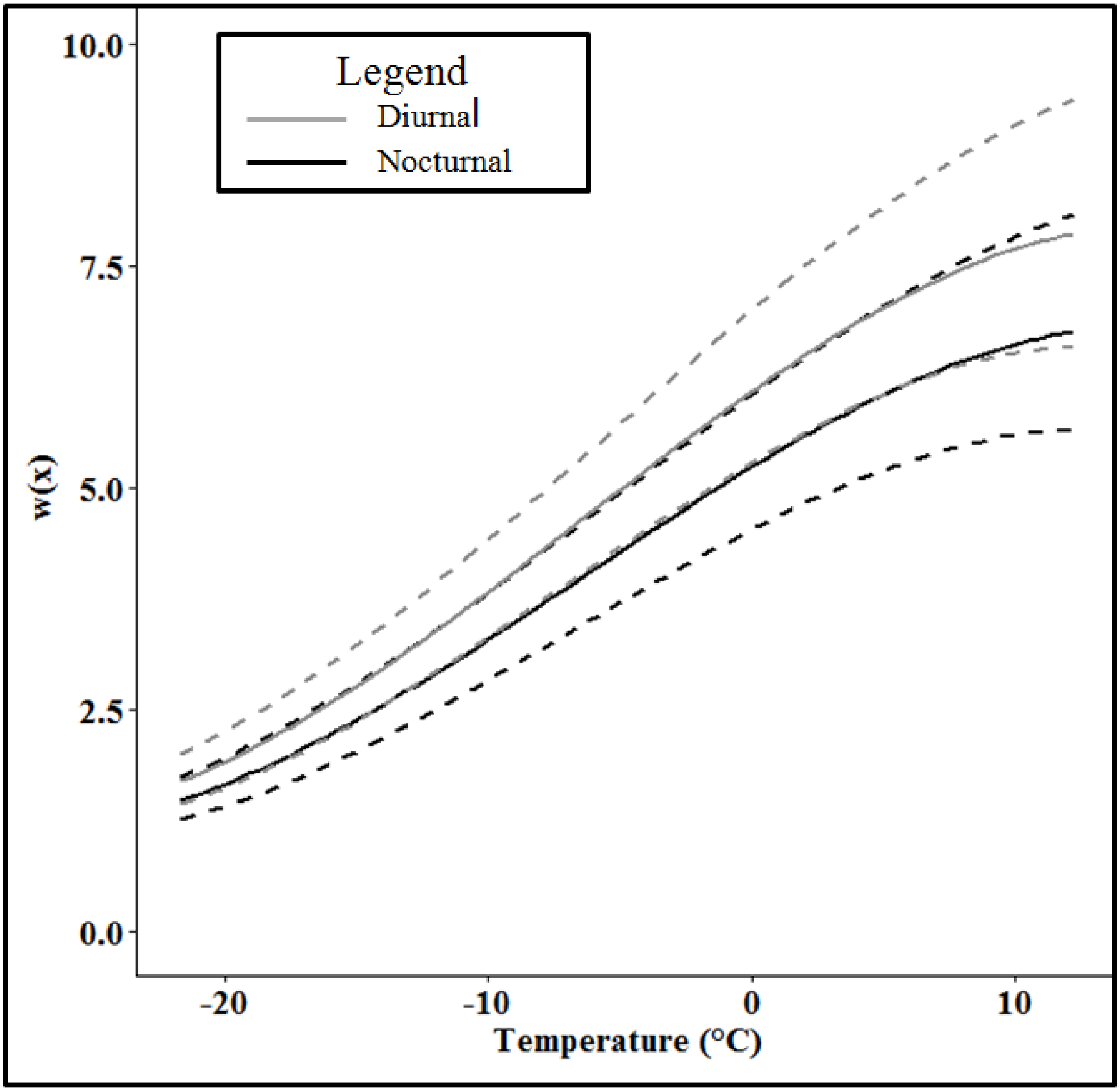

Figure 1.10. Estimated resource selection function *w*(*x*) for green space habitat used by Canada geese (*Branta canadensis*) at varying levels of minimum daily temperatures (°C) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

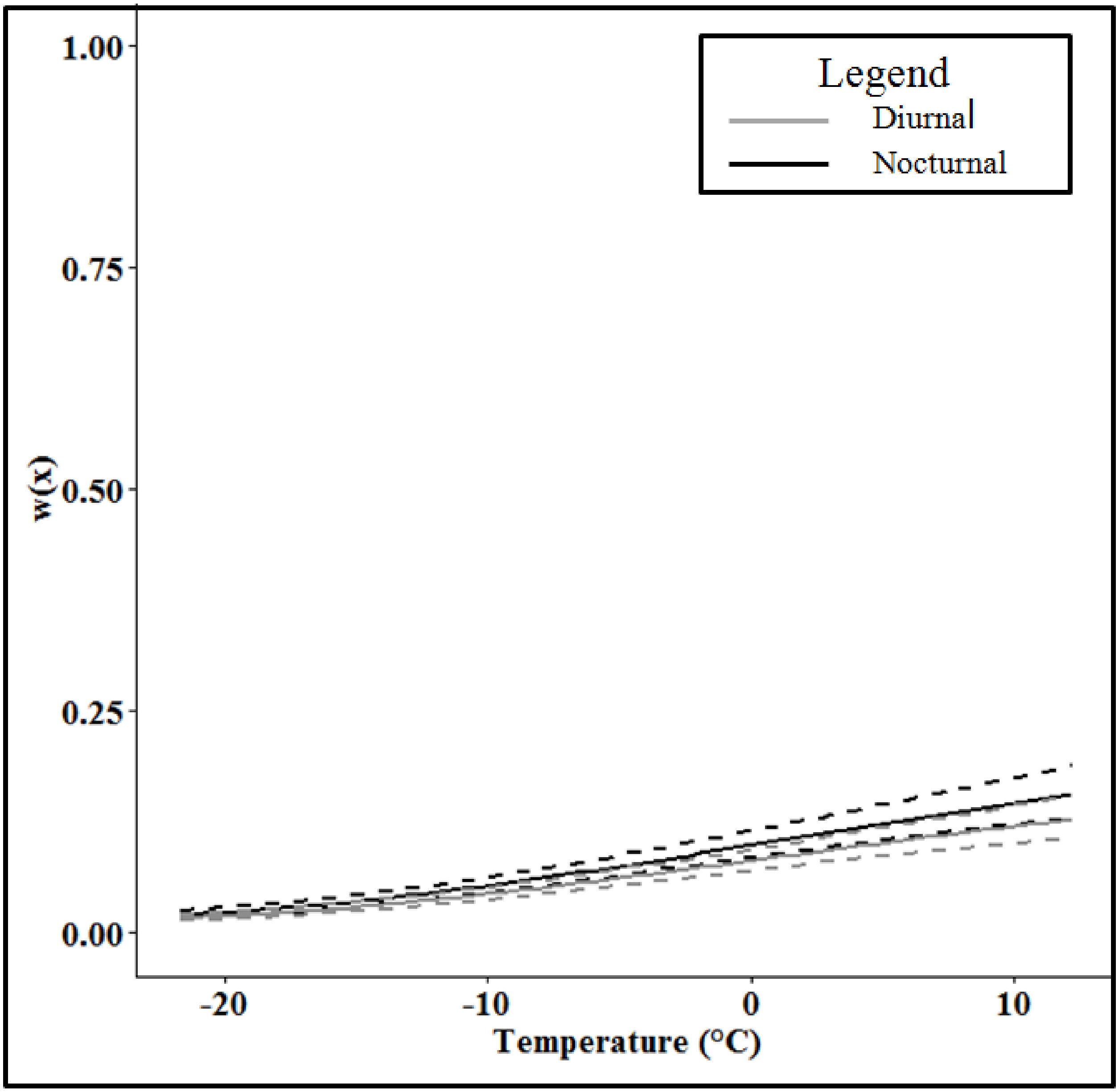

Figure 1.11. Estimated resource selection function *w*(*x*) for residential habitat used by Canada geese (*Branta canadensis*) at varying levels of minimum daily temperatures (°C) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

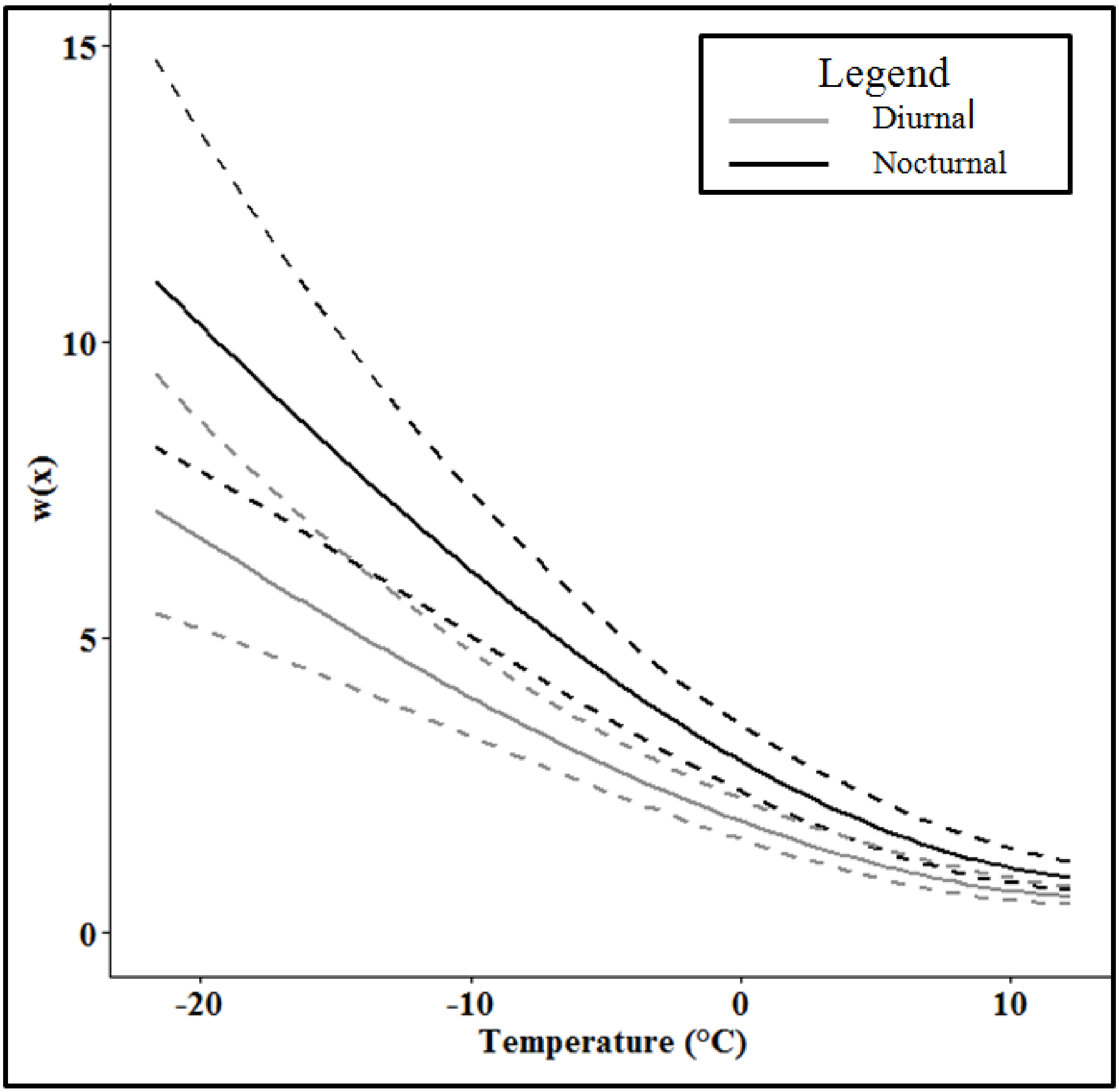

Figure 1.12. Estimated resource selection function *w*(*x*) for riverine habitat used by Canada geese (*Branta canadensis*) at varying levels of minimum daily temperatures (°C) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

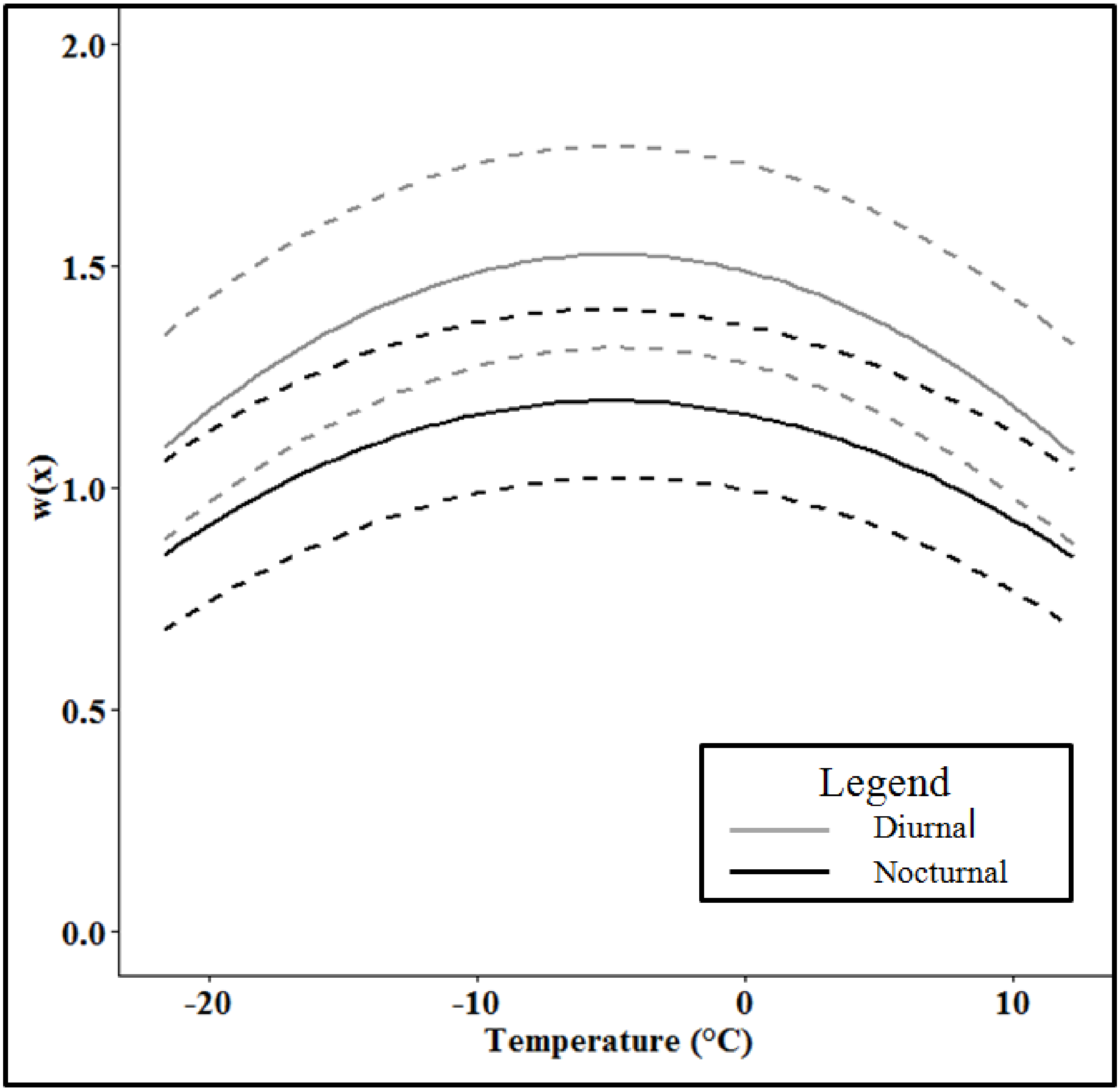

Figure 1.13. Estimated resource selection function *w*(*x*) for industrial urban habitat used by Canada geese (*Branta canadensis*) at varying levels of minimum daily temperatures (°C) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

CHAPTER 2: HOW DO CANADA GEESE ALTER THEIR BEHAVIOUR TO ALLOW FOR SURVIVAL NORTH OF HISTORIC WINTERING GROUNDS?

2.1 ABSTRACT

The winter distribution of birds is typically correlated with minimum temperature isotherms, but some individuals can overcome thermoregulatory limits though behavioral adaptations and utilization of urban areas. I investigated factors affecting habitat use and movements, as well as thermal benefits of habitats selected by Canada geese (*Branta canadensis*) during late autumn and winter in the Greater Chicago Metropolitan Area (GCMA) in northeastern, Illinois, USA. I captured Canada geese during November–February 2014–2016 and fitted 41 geese with solar-powered GPS transmitters that were affixed to neck collars. Transmitters operated on the cellular phone network and were programmed to collect hourly locations (n = 35,896). I investigated the movement of Canada geese both within and between six habitats (i.e., green space, rail yards, residential, riverine, rooftops, and deep-water). Although I found that rooftops and deep-water habitats had greater maximum daily temperatures, there was no difference in the minimum daily temperatures, providing limited support for their selection as thermal refugia in the winter. When temperatures were warmer than the lower critical temperature (LCT; -6 °C) Canada geese typically moved between green spaces and rooftops; however, when temperatures were below the LCT, geese moved from green spaces to deep-water habitats. Canada geese appear to be using multiple urban habitats to mitigate the effects of wintering at northern latitudes where thermoregulatory costs may be high. First, Canada geese used habitats that had slightly warmer maximum daily temperatures; second, geese used habitats where disturbance was likely minimal such as deep-water and rooftop habitats. Finally, Canada geese used novel habitats such as rail yards where they likely forage on spilled

agricultural grain from railcars and use of these nontraditional habitats in urban areas allows Canada geese to winter in more northerly areas than historically.

2.2 INTRODUCTION

The winter distributions of most birds appear to be driven by effects of multiple and interacting environmental factors (Brown 1984, Brown et al. 1995, Canterbury 2002). Typically, the northern boundaries of birds in winter correlate with average minimum temperature isotherms (Root 1988*a*, *b*). Winter weather increases energy demands at the same time that available resources become limited for most species (Charles and Harold 1966, Rising and Hudson 1974, Baldassarre and Bolen 2006). Distributions of winter ranges of birds can be affected by changes in available food or thermal refugia (Cotton 2003, Pearson and Dawson 2003). However, waste grain in agricultural fields can increase food availability during late autumn and winter and urban areas may provide thermal refugia that allows birds to maintain energy balances in more northerly areas than they have used historically (Jokimäki et al. 1996, Baldassarre and Bolen 2006, La Sorte and Thompson 2007).

A number of behavioral mechanisms may allow species to overcome factors limiting their northern distributions and expand their wintering ranges. For example, nine-banded armadillos (*Dasypus novemcinctus*) expanded their range north during over the past several decades through selection of thermally beneficial den sites and behavioral adaptations to forage during periods more thermally beneficial and remain sedentary during periods of colder temperatures (Bond et al. 2000, Eichler and Gaudin 2011). Adaptations of birds to supplementary food resources (i.e., bird feeders) have been found to expand avian winter ranges northward (Siriwardena et al. 2007, Zuckerberg et al. 2011). Grey-headed flying-fox (*Pteropus poliocephalus*) have expanded their winter range by utilizing urban areas that provide warmer winter conditions than rural areas (Parris and Hazell 2005). Behavioral adaptations through the use of additional food resources (e.g., bird feeders, agricultural waste), use of thermal refugia (e.g., warm-water discharges), and a reduction in energy expenditure (e.g., limited movements during times when not thermally beneficial) have facilitated northward expansion of many species to areas where they would not have been able to survive previously (Calder and King 1974, Prince and Zuckerberg 2015, Williams et al. 2015).

The Eastern Prairie Population of Canada geese (*Branta canadensis interior*), which nests in Manitoba along Hudson Bay, historically wintered in Texas, Louisiana, and Arkansas, but has shifted their wintering range northward to include Missouri and southern Illinois (Sheaffer et al. 2004). Similarly, the Mississippi Valley Population of sub-arctic breeding Canada geese (*B. c. interior*) have shifted their wintering range northward from Mississippi and Arkansas to southern Illinois and northwest Kentucky and then again to northern Illinois and southern Wisconsin (Reeves at al. 1968, Craven et al. 1986, Gates et al. 2001). Lefebvre and Raveling (1967) estimated maximum thermal stress for temperate-breeding Canada geese (*B. c. maxima*) and determined the northern limit during winter to be Rochester, Minnesota, USA. Currently, temperate-breeding Canada geese have expanded their range and now include year-round residency in portions of southern Ontario and Manitoba (Baldassarre 2014). Canada geese are wintering north of their historic winter distribution, but it is unclear how geese are able to negotiate the extreme winter conditions and why northward shifts are beneficial.

I studied Canada geese in northeast Illinois, USA to understand the factors that may influence habitat selection and movements at northern latitudes during winter. Specifically, my objectives were to determine: (1) if urban habitats provided a thermal refugia for Canada geese, (2) how weather affected movement distances within different urban habitats, and (3) transitions between particular habitats when temperatures were above and below the lower critical temperature. I further discuss the behaviors that may have allowed Canada geese to winter north of their traditional wintering grounds and the benefits of wintering in an urban landscape.

2.3 METHODS AND MATERIALS

Study Area

Canada geese were captured in the Greater Chicago Metropolitan Area (GCMA; 915 km^2) located in northeastern Illinois, USA (Fig 2.1) during late autumn and winter. The GCMA is located in portions of three counties (Cook, Du Page, and Will) and is a heavily urbanized landscape with little agriculture present (United States Department of Agriculture 2015). The GCMA averages 43 days annually below freezing, with 7 days below -18 °C. November has an average high of 9 °C and a low of 0 °C, December has an average high temperature is 2 °C with a low of -6 °C, January has an average is a high of 0 °C and a low of -9 °C, and February has an average high of 2 °C and low of -7 °C (NOAA 2015). Chicago averages approximately 93 cm of snowfall annually (NOAA 2015).

Field Methods

During 13 November 2014 through 28 February 2015 and14 November 2015 through 29 February 2016, I captured and transmittered 41 Canada geese within the GCMA. I focused my capture efforts at large parks, cemeteries, and the Stickney Water Reclamation Plant because of their available habitat and concentrations of Canada geese (Fig 2.2). Standard waterfowl capture techniques (e.g., rocket nets and cannon nets) could not be used at most sites due to the dense urban area so cast nets and small animal net guns (Wildlife Capture Services, Flagstaff, Arizona, USA) were used for most capture attempts.

Transmitters (*n* = 10 in 2014–2015 and *n* = 31 in 2015–2016) were deployed during four time periods each year (i.e., mid November, early December and mid December, and early January) to account for temporal variation and across seven different capture locations to account for spatial variation (Table 2.1). Transmitters recovered from hunters (*n* = 3) were redeployed during the latter part of the field seasons (Table 2.1). Transmitters included solar-powered GPS units from Cellular Tracking Technologies in Somerset, Pennsylvania, USA, and operated on the Global System for Mobile communications network and were configured to acquire a GPS location once per hour. Generation 2 models were used during 2014–2015 ($\bar{x}$ = 69.7 grams, SE = 0.2) and Generation 3 transmitters were used during 2015–2016 ($\bar{x}$ = 62.2 grams, SE = 0.2). Transmitters were < 2% of the body mass of Canada geese ($\bar{x}$ = 4,713 grams, SE =10.6) and all Canada geese were captured and handled using the approved methods detailed by the University of Illinois Institutional Animal Care and Use Committee (Protocol # 14155).

Using transmitter locations from 2014–2015, I identified 10 sites that were used throughout all portions of the autumn and winter by Canada geese. During 2015–2016, I used these sites to record ambient temperature and wind speed to understand thermal benefits of used sites. I deployed iButton temperature loggers (model DS1921G-F5#; Maxim Integrated, San Jose, CA) in green spaces (*n* = 7), rooftops (*n* = 2), and deep-water habitat (Stickney Water Reclamation Plant) to record ambient temperatures (ºC) (Hubbart et al. 2005). Restricted access prohibited the deployment of iButtons at rail yards. I deployed anemometers (model PCE-WL 1; PCE Americas Inc, Jupiter, FL) at green spaces (*n* = 2), rooftops (*n* = 3), and deep-water habitat approximately 15 cm off the ground or rooftop to record wind speeds. iButtons and anemometers were programmed to obtain hourly recordings and were deployed in specific locations used by Canada geese from 18 November 2015 through 29 February 2016.

Data Analysis

I removed locations from the day of capture from analysis to minimize potential influences on movements and habitat use. Transmitters required a once-weekly cellular connection to program their duty cycle to the standardized rate of 1 location/hour for the entire day and upload locations to an accessible database. Depending on deployment, some transmitters did not link properly so data from transmitters with less than 10 days of data collection were removed from analysis (4 in 2015–2016) because data were not collected in the same scale as other transmitters. Locations with only one satellite fix or with a horizontal dilution of precision value above 5 were removed because GPS coordinates were either not obtained or they had extremely low accuracy (CTT 2015). All analyses were performed using R Version 3.1.3 (www.R-project.org, accessed 15 July 2016). Statistical significance for all analyses was set at $P \leq 0.05$.

I defined a movement as the distance (m) between subsequent hourly GPS locations. Transmitters used for movement analysis were Generation 3 models that operated with high efficiency (n =27 transmitters, $\bar{x}$ = 20.8 locations/transmitter/day, SE = 0.4, range 15.4–23.3) and obtained locations on average close to the hourly setting ($\bar{x}$ = 70.1 min, SE = 1.3). To analyze movements and classify habitat types, I plotted all locations of Canada geese (n = 35,896) on Google Earth Pro and measured distance moved between hourly locations using the rgdall and adehabitatLT packages (Calenge 2006, Bivand 2015).

Habitats were classified as green space, rail yards, residential, riverine, rooftops, and deep-water using available aerial imagery and ancillary information. Green spaces were typically large parks, cemeteries, and other large grass areas that contained a mixture of ponds, trees and shrubs, large sports fields, and golf courses within their boundaries (Table 2.2). I also included small grass lawns and areas between buildings in the green space habitat. Rail yard habitat was composed of large complex series of railroad tracks where railcars were loaded, unloaded, and stored. Residential habitats were typically houses and developments, parking lots, streets, and miscellaneous other land uses occurring in residential areas. Riverine habitat consisted of the Des Plaines and Calumet rivers. Rooftop habitats were typically large flat industrial warehouse facilities or retail stores. Deep-water habitats were defined as the Chicago Sanitary and Ship Canal, which had steep concrete walls and warm water discharges along the canal corridor, and the Stickney Water Reclamation Plant, which was a mixture of gravel embankments and grass near deep-water settling ponds ($n = 96$). Deep-water habitat stayed open throughout the entire winter due to constant moving water within the settling ponds and warm-water discharge and barge traffic within the canal.

I removed distance measurements that were not from subsequent hourly locations (i.e., more than two hours between locations). Transitional movements ($n = 3,264$) between habitat types were also removed to provide data consisting of only movements within habitats for analysis. I conducted a Fisher's exact test to determine if transitional movements were greater between habitat types, both above and below the lower critical temperature (LCT), than by random chance. The LCT is estimated using the resting metabolic rate and is the point where the ambient temperature is below the thermoneutral zone and heat is required to maintain body temperature, typically through metabolizing endogenous reserves. I used the theoretical LCT of -6 ^{o}C for Canada geese, but I acknowledge that this is not a discrete threshold and that the LCT varies by individual through a complex interplay of physiological and behavioral adaptations (Batt et al. 1992). I calculated maximum daily movement distance (m) as the longest distance between subsequent hourly GPS locations for each day. I used a generalized linear model to test for the effects of snow depth, minimum daily temperature, and their interactions on maximum daily movement distance using the glm function in the nlme package (Pinheiro et al. 2016). In a separate generalized linear model, I modeled movement distances as a function of independent variables habitat, snow depth (cm), time of day (i.e., diurnal or nocturnal), LCT (i.e., above or below the LCT), and their interaction. Transformations ($\log_{10}$ [x+1]) were used to normalize movement distance parameters. The diurnal time period was set at 0500–1900 to account for crepuscular movements and the nocturnal time period was 1901–0459. Covariates of daily snow depth and daily minimum temperature were used because of their correlation with Canada goose activity patterns (Raveling et al. 1972). I analyzed movements within habitats and transitional movements to understand possible energy expenditure since increased movements distances require increased energy expenditure (Bowlin et al. 2005, Couturier et al. 2010, Jachowski and Singh 2015). Mean movements above and below the LCT were plotted by hour for visual representation of variation across the day. The non-significant predictor variables and interactions were removed from models by using partial sums of squares until only significant associations remained (Crawley 2005).

To compare daily temperatures among habitat types I used a general linear model with the lme function in package nlme package (Pinheiro et al. 2016) with mean daily temperature (^{o}C) as my dependent variable and habitat type as an independent variable and ID (data logger) as a random effect. I conducted similar linear mixed effects models for minimum and maximum daily temperature. I used a similar linear model to determine if mean and maximum wind speed (km/h) varied by habitat type with ID (data logger) as a random effect. I removed one location from my wind analysis due to constantly being knocked over and blown off the rooftop (last recorded wind speed that day was 78.9 km/h), which resulted in large gaps (i.e., months) of missing entries in the dataset. I conducted a post hoc Tukey's HSD test for significant results ($\alpha = 0.05$) to simultaneously test for differences in the means (Zar 2010).

2.4 RESULTS

Habitats did not differ in daily minimum temperature ($F_{6, 927} = 0.11$, $P = 0.90$), but they did have different daily maximum temperature ($F_{6, 927} = 5.9$, $P = 0.04$). The maximum daily temperatures were 3.15 °C (SE = 1.1; $P = 0.01$) and 3.54 °C (SE = 1.4, $P = 0.04$) warmer at rooftops and deep-water locations respectively than green space. Both rooftop and deep-water habitats had higher maximum daily temperatures for every month when compared to green space, although the difference was greater later in the winter (Figure 2.3). Both mean daily wind speeds ($F_{2, 515} = 79.7$, $P = 0.01$) and maximum daily wind speeds ($F_{2, 515} = 66.7$, $P = 0.01$) varied by habitat (Figure 2.4). The mean daily wind speeds were 13.6 km/h (SE = 1.1, $P < 0.01$) greater on rooftops than green space and deep-water habitat had mean wind speeds 6.5 km/h (SE = 1.3, $P < 0.01$) greater than green space. Rooftops had mean daily wind speeds of 7.1 km/h (SE = 1.3, $P < 0.01$) greater than deep-water habitats. Maximum daily wind speeds were 22.9 km/h (SE = 2.0, $P < 0.01$) greater at rooftops than green space habitats and deep-water habitats had maximum wind speeds 12.1 km/h (SE = 2.4, $P < 0.01$) greater than green space. The wind speeds on rooftops were 10.7 km/h (SE = 2.4, $P < 0.01$) greater than at deep-water habitats.

Movement distance differed by habitat type ($F_{4, 32,172} = 168.1$, $P < 0.01$), temperature ($F_{1, 32,175} = 603.2$, $P < 0.01$), snow depth ($F_{1, 32,175} = 203.9$, $P < 0.01$), and time of day ($F_{1, 32,175} = 3{,}690$, $P < 0.01$; Figure 2.5). Movement distances for Canada geese were shorter when temperature was below the LCT, as snow depth increased geese made shorter movements, and geese made shorter movements during the nocturnal period. Movements by Canada geese within rail yard ($\bar{x} = 224.0$ m, SE = 13.0) and green space habitats ($\bar{x} = 145.6$ m, SE = 3.4) were the longest for any habitat type, while movements by geese in deep-water habitats ($\bar{x}$ = 85.7 m, SE = 3) and rooftop habitats ($\bar{x}$ = 52.9 m, SE = 5.5) were the shortest (Table 2.3). In general, Canada geese moved 2 to 4 times farther in rail yards and green space than in deep-water and rooftop habitats (Table 2.3).

Canada geese were more likely to move between certain habitats and these habitats changed when temperatures were above and below the LCT. When the temperature was below the LCT, the only habitat transition that occurred more often than random was to green spaces from deep-water and vice versa (G^{adj} = 23.39, $P < 0.01$; Table 2.4). When the temperature was above the LCT, there were more movements between green space and rail yards than would be expected by chance (G^{adj} = 6.86, $P < 0.01$; Table 2.4). The mean movements for all transition flights between habitats was 1554.4 m (SE = 30.4).

The proportion of locations in green space was highest during diurnal hours (i.e., 0500–1900) and overall Canada geese used green space most (Figure 2.6). Both deep-water and riverine habitats had a spike in proportional use during early morning, but use decreased throughout the day. Proportional use of rail yards increased during early afternoon while use of residential habitat was consistent throughout the day (Figure 2.6). There were two peaks in movement distances during crepuscular periods (i.e., early morning and late evening), and the timing of these movements also varied depending if the temperature was above or below the LCT (Figure 2.7). The mean maximum daily movement of individuals across all habitats was 2,009.3 m (SE = 74.6) with the longest movement within the GCMA being 19,998 m.

2.5 DISCUSSION

Wintering ranges of Canada geese in the Mississippi Flyway have shifted northward and use of urban areas in northern latitudes appears to be a strategy for increasing survival. There might be a strong selection pressure on migratory Canada geese to winter at more northerly latitudes to minimize spring migration flight distances resulting in minimized energy expenditure and arrival to nesting grounds at a more opportune time to secure preferred nest sites (Alerstam and Lindstrom 1990). Canada geese appear to be utilizing a new strategy to winter at these northern clines through the use of nontraditional habitats occurring within urban areas (Chapter 1). During the autumn and winter 2014–2016, 66.7% of transmittered geese used novel urban habitats (rooftops and rail yards) and the ability of Canada geese to use these nontraditional habitats in urban areas likely allows them to maintain a positive energy balance and may even increase survival (Chapter 1). The ability of Canada geese to survive in these urban landscapes appears due to the ability to find potentially warmer habitats where costs of thermoregulation are within tolerable ranges, locate food sources (e.g., grass in green spaces, spilled grain in rail yards), and use disturbance free areas for loafing (e.g., rooftops).

There appear to be limited thermal benefits for selected habitats; I found no difference in daily low temperatures between habitats used by Canada geese, but data are limited to only sites that are being used by Canada geese. The maximum daily temperature was greater on rooftops and at deep-water habitats, but these habitats also had the greatest amount of wind. Green space had the lowest wind speed for all habitat types due to trees and buildings acting as wind blocks. Canada geese moved to deep-water habitats when temperatures were below the LCT, but given how the low temperatures in the green spaces were nearly the same as the deep-water habitats the thermal benefits of rooftops and deep-water habitats is likely limited. Shifts in habitat use may also be link to decreased open water in green spaces as ice coverage forces Canada geese to find alternative roost locations. The warmer temperatures on rooftops are likely the result of solar radiation as nearly all the rooftops used by Canada geese were black. Black rooftops and deep-water habitats absorbing solar radiation during the day would account for the warmer maximum temperatures, but no difference in the low temperatures at night (Figure 2.8).

Canada geese exhibited the greatest within-habitat movement distances in rail yards and green space. I commonly observed Canada geese in these habitats actively foraging. The rail yards contained spilled agricultural grains and the Canada geese were typically observed moving around the rail yards foraging for spilled corn or other items (Figure 2.9). The shortest movement distances were found in deep-water and rooftop habitats suggesting that these habitats are used primarily for roosting. Reduced movements in deep-water and rooftop habitats minimize energy expenditure. I observed Canada geese typically loafing or sleeping in these habitats (Figure 2.10). Deep-water and rooftops likely provided a safe location in the urban landscape for Canada geese to conserve energy. While one would expect Canada geese to use deep-water habitat, the rooftop is a novel habitat for waterfowl that provide a safe, disturbance-free location to conserve energy compared to green space and residential habitats that contain many disturbances such as walking humans, dogs, cats, cars and coyotes (Brown 2007).

Other studies of Canada geese have found that weather events impact the movement behavior of geese. Raveling et al. (1972) noticed significant declines in movements and activity of Canada geese when temperatures were below -6 °C. Similarly, I observed limited transitional flights between habitats and reduced movement distances within habitat types used by geese within the GCMA below the same temperature. Flight is the most energetically demanding activity for birds during the non-breeding portion of the year and studies of a closely related species brant (*Branta bernicla*) in Great Britain found that when disturbances occurred the average time of flight increased sevenfold (Alerstam 1991, Korschgen and Dahlgren 1992). I speculate that Canada geese wintering in the GCMA limit their movements as a strategy to limit energy expenditure and associated nutrient intake requirements.

Snow cover also has a large impact on behavior as it can limit food and habitat availability (Jorde et al. 1983, Schummer et al. 2010). I found that as snow accumulation increased there were shorter movements (Appendix; Figure A.2). However, in the second year of the study when the movement data were collected, snow accumulation was below average (National Oceanic and Atmospheric Administration 2016). During the initial year of the study, anecdotal observations supported the finding in year 2 that increases in snow depth were associated with reduced activity. Further research in years with average snow fall could help determine if other novel habitats are used in times of deep snow accumulation.

Canada geese in the urban landscape appear to require several different habitats and their use of habitats differs with temperature. In general, green space is the most used habitat regardless of temperature, but when temperatures are above the LCT, Canada geese most often moved between rail yards and green space. When temperatures are below the LCT, Canada geese move between deep-water and green spaces. Approximately 31% of all transitional movements when the temperature is below the LCT were to at deep-water habitats. My data suggest that Canada geese foraged in green spaces and rail yards and then moved to deep-water habitats to loaf and potentially take advantage thermal benefits.

During winter in the GCMA Canada geese have adapted a strategy of using nontraditional urban habitats with thermal benefits and that provide sanctuary from predation to maximize survival. Although food resources in urban areas may be limited or of low value, Canada geese are apparently minimizing movements and energy expenditure by remaining within small areas of the GCMA. Canada geese may have adopted a strategy of building fat reserves during autumn for use during winter, which allows Canada geese to modify their behavior and select habitat with minimal disturbance, instead of areas with high-energy forage or make flights to agricultural fields containing forage. Hunting seasons in the autumn and winter in North America are a significant source of mortality for Canada geese and the ability to use habitats in urban areas where generally there are regulations against hunting may allow geese to locate a safe refuge. The fact that urban areas are generally free of hunting pressure and appear to have the various habitats need by Canada geese suggests that geese will continue to use and potentially expand their use of urban landscapes in winter.

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2.7 TABLES AND FIGURES

Table 2.1. Dates and number of Canada geese (*Branta canadensis*) captured and transmittered during autumn and winter 2014–2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

	2014–2015				2015–2016			
Location	November 13–31	December 1–15	January 15–31	February 15–28	November 14–31	December 1–15	January 1–15	February 15–29
Marquette Park			1		2	1		
McKinley Park	1					3	5	
Museum of Science and Industry	1				1		1	1*
Resurrection Cemetery		1	1		1	3	1	
Sherman Park	1	1			1	2		
Stickney Water Reclamation Plant			2	1*	1		3	1*
Washington Park					1	1	2	
Total	3	2	4	1	7	10	12	2

*Transmitters recovered from hunters and then redeployed

Table 2.2. Percentage of available habitat compared to all GPS locations in each habitat type used by Canada geese (*Branta canadensis*) and the percentage of habitat use when temperature was below the lower critical temperature (LCT; -6 ºC) for Canada geese in the Greater Chicago Metropolitan Area, Illinois, USA, during 2014–2016.

Location	Total Area (km^2)	Surface Water (km^2)	Description
Marquette Park	1.25	0.16	Contains sports fields, 9-hole golf course, trees and shrubs, lagoon
McKinley Park	0.28	0.03	Contains sports fields, trees and shrubs, and pond with islands
Museum of Science and Industry	1.95	0.33	Contains sports fields, 18-hole golf course, trees and shrubs, a lagoon and harbors, bordered to the east by Lake Michigan
Resurrection Cemetery	1.18	0.02	Contains ponds, large buildings, headstones, trees and shrubs
Sherman Park	0.25	0.05	Contains sports fields, trees and shrubs, and a lagoon

Table 2.3. Mean movement distance (m) between hourly GPS locations with standard error (SE) within each habitat type when temperature is below the lower critical temperature (LCT; -6 °C), for the entire temperature range, and when above the LCT for Canada geese (*Branta canadensis*) in the Greater Chicago Metropolitan Area, Illinois, USA, from 15 November 2015 through 28 February 2016.

	Below LCT		All Temperatures		Above LCT	
Location	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Deep Water	69.8	3.7	85.7	3.0	101.6	4.8
Green Space	103.6	8.6	145.6	3.4	151.0	3.7
Rail Yards	152.1	28.6	224.0	13.0	230.9	14.0
Residential	62.4	23.1	117.9	11.8	121.1	12.4
Riverine	70.0	8.1	95.1	7.9	105.3	10.6
Rooftops	69.3	18.3	52.9	5.5	51.6	5.8

Table 2.4. Percent of transitional movements between habitat types when temperatures were below the Lower Critical Temperature (LCT; -6 °C) for Canada geese (*Branta canadensis*) wintering in the Greater Chicago Metropolitan Area, Illinois, USA, from 15 November 2015 through 28 February 2016. The departure habitats are on the vertical axis and destination habits are on the horizontal axis (n = 636 transitions).

		Destination					
		Deep Water	Green Space	Rail Yards	Residential	Riverine	Rooftops
Starting Location	Deep Water		22.6%[a]	2.4%	6.3%	0.6%	0.9%
	Green Space	18.4%[a]		3.8%	2.7%	5.7%	1.3%
	Rail Yards	2.7%	2.7%		0.5%	0.5%	1.3%
	Residential	7.5%	3.1%	0.8%		0.9%	0.2%
	Riverine	0.9%	6.4%	0.3%	1.4%		0.2%
	Rooftops	1.6%	2.7%	1.6%	0.2%	0.0%	

[a] Designates proportion of transitional flights that occur more often than by chance based on Fisher's exact test ($P \leq 0.05$).

Table 2.5. Percent of transitional movements between habitat types when temperatures were <u>above</u> the lower critical temperature (LCT; -6 °C) for Canada geese (*Branta canadensis*) while in the Greater Chicago Metropolitan Area, Illinois, USA, from 15 November 2015 through 28 February 2016. The departure habitats are on the vertical axis and destination habits are on the horizontal axis (*n* = 2,628 transitions).

		Destination					
		Deep Water	Green Space	Rail Yards	Residential	Riverine	Rooftops
Starting Location	Deep Water		8.6%	1.1%	2.1%	0.2%	1.1%
	Green Space	8.3%		10.4%[a]	7.5%	4.9%	4.9%
	Rail Yards	2.1%	8.6%		2.1%	0.2%	3.7%
	Residential	2.2%	7.0%	2.2%		2.4%	1.5%
	Riverine	0.2%	5.6%	0.3%	1.3%		0.2%
	Rooftops	1.0%	7.0%	1.7%	1.2%	0.5%	

[a] Designates proportion of transitional flights that occur more often than by chance based on Fisher's exact test ($P \leq 0.05$).

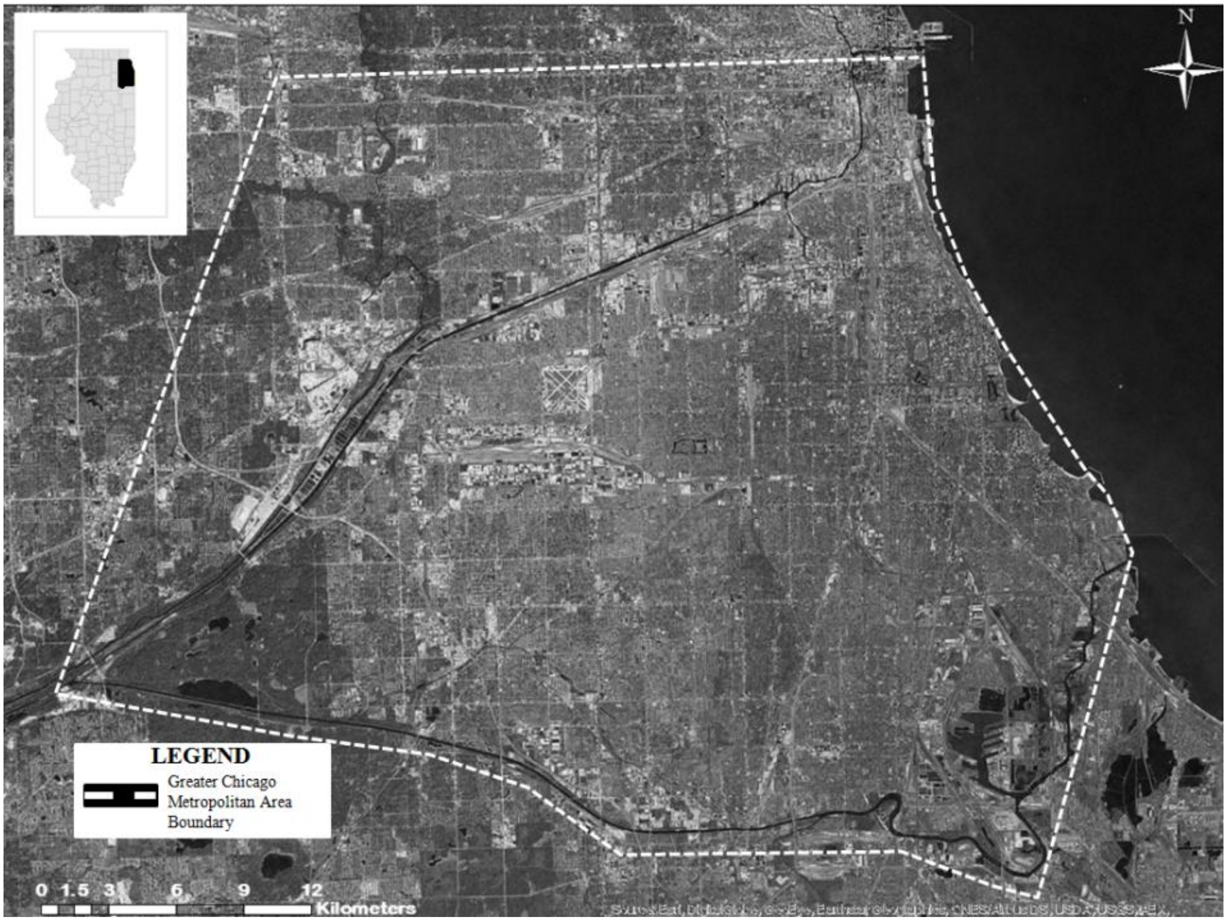

Figure 2.1. The Greater Chicago Metropolitan Area located in northeast Illinois, USA.

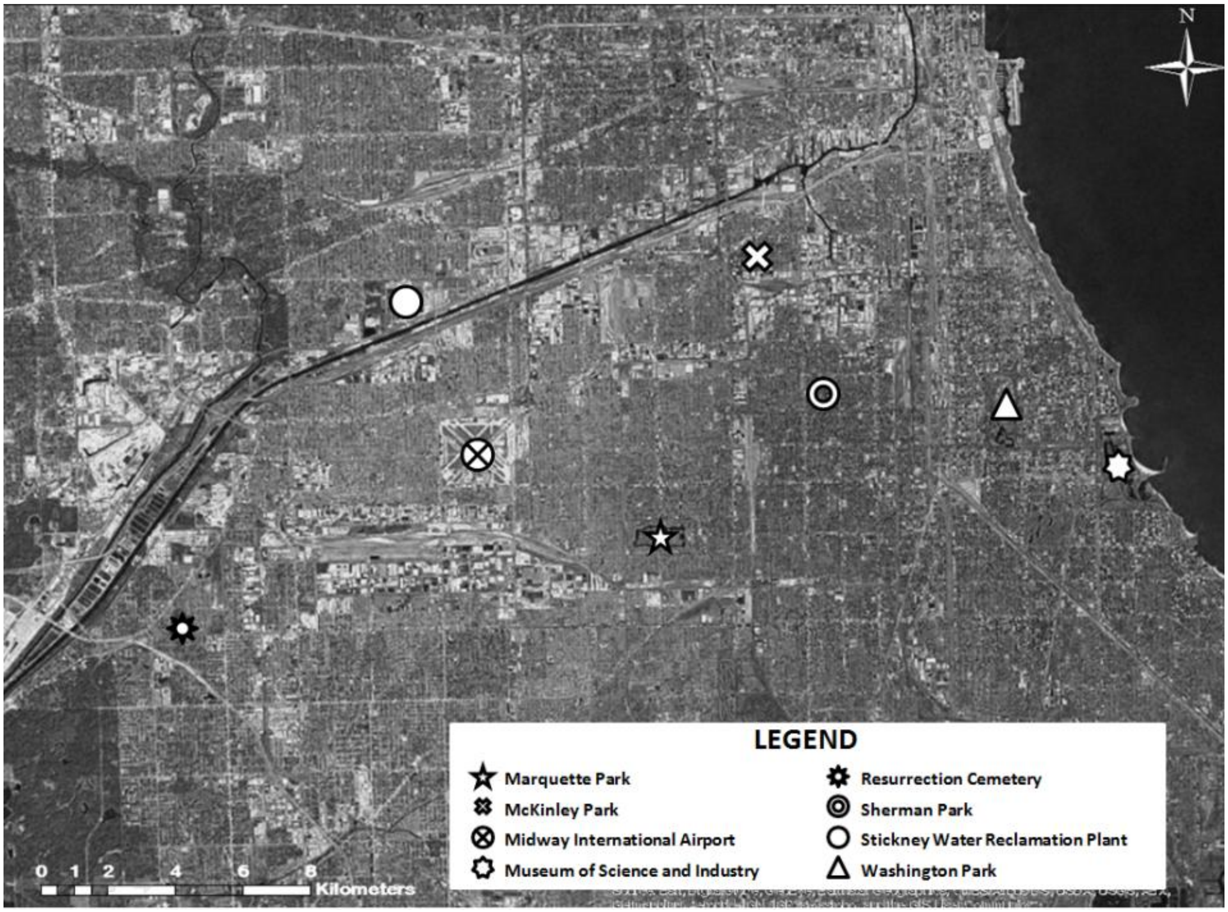

Figure 2.2. Main capture locations (*n* = 7) for Canada geese (*Branta canadensis*) in relation to Midway International Airport in the Greater Chicago Metropolitan Area, Illinois, USA.

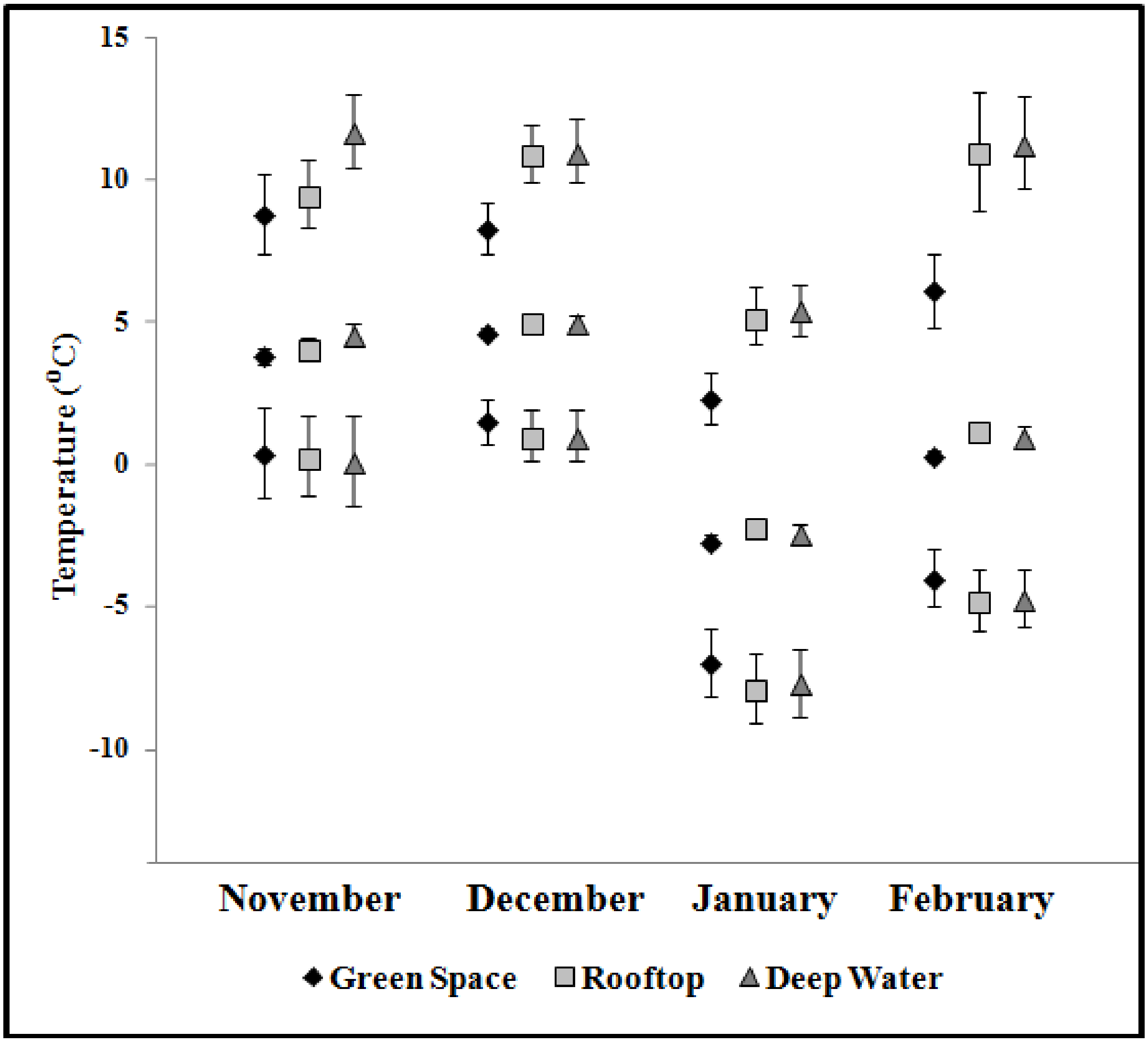

Figure 2.3. Comparison of daily high (top point), mean monthly (middle point), and daily low (bottom point) temperatures and standard errors for green space, rooftop, and deep-water habitats used by Canada geese (*Branta canadensis*) while in the Greater Chicago metropolitan Area, Illinois, USA from 18 November 2015 through 29 February 2016.

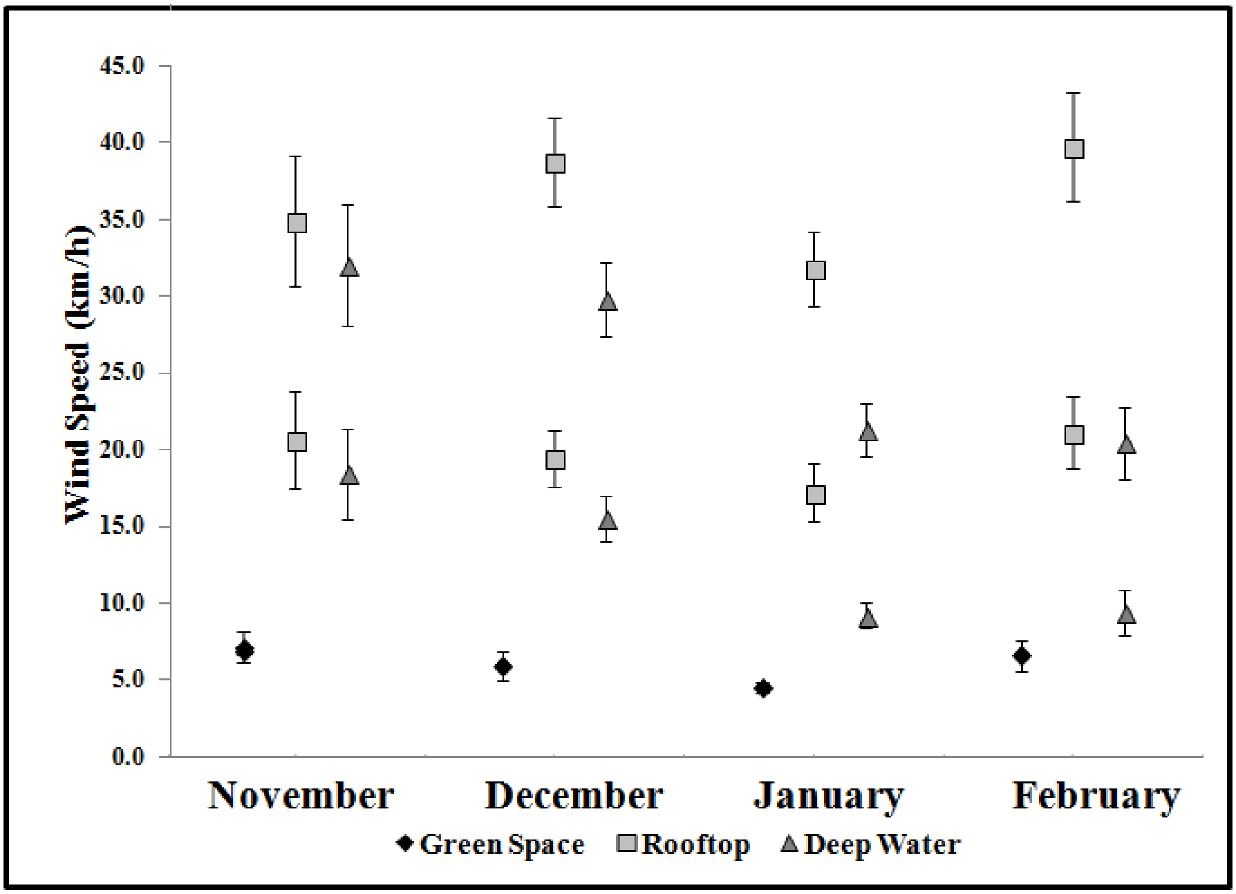

Figure 2.4. Comparison of mean monthly (bottom point) and mean maximum daily (top point) wind speeds (km/h) with standard errors for green space, rooftop, and deep-water habitats used by Canada geese (*Branta canadensis*) while in the Greater Chicago metropolitan Area, Illinois, USA from 18 November 2015 through 29 February 2016.

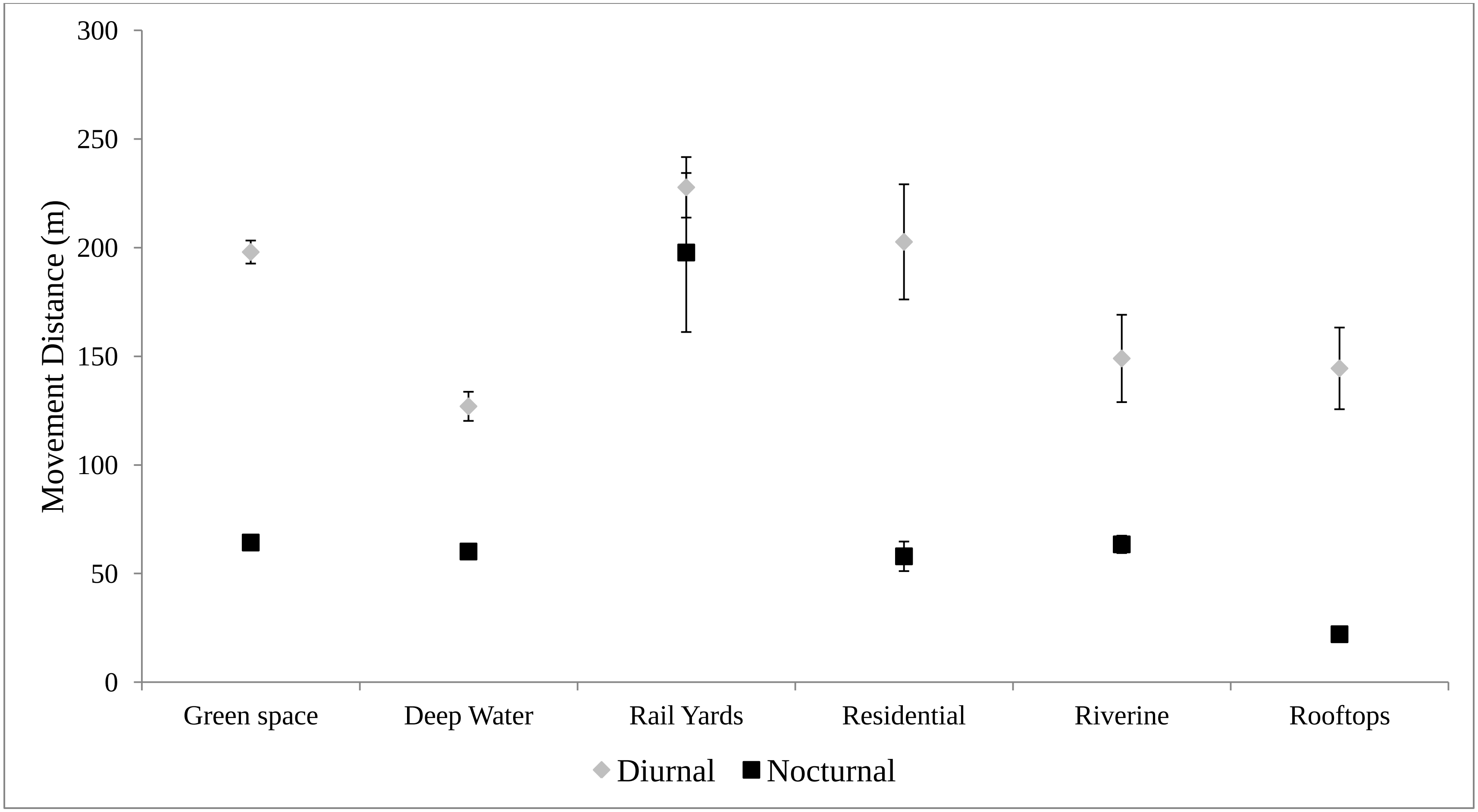

Figure 2.5. Mean movement distance (m) with standard error bars between hourly GPS locations within all habitats used during diurnal and nocturnal time periods for Canada geese (*Branta canadensis*) in the Greater Chicago Metropolitan Area, Illinois, USA from November 2015 through February 2016.

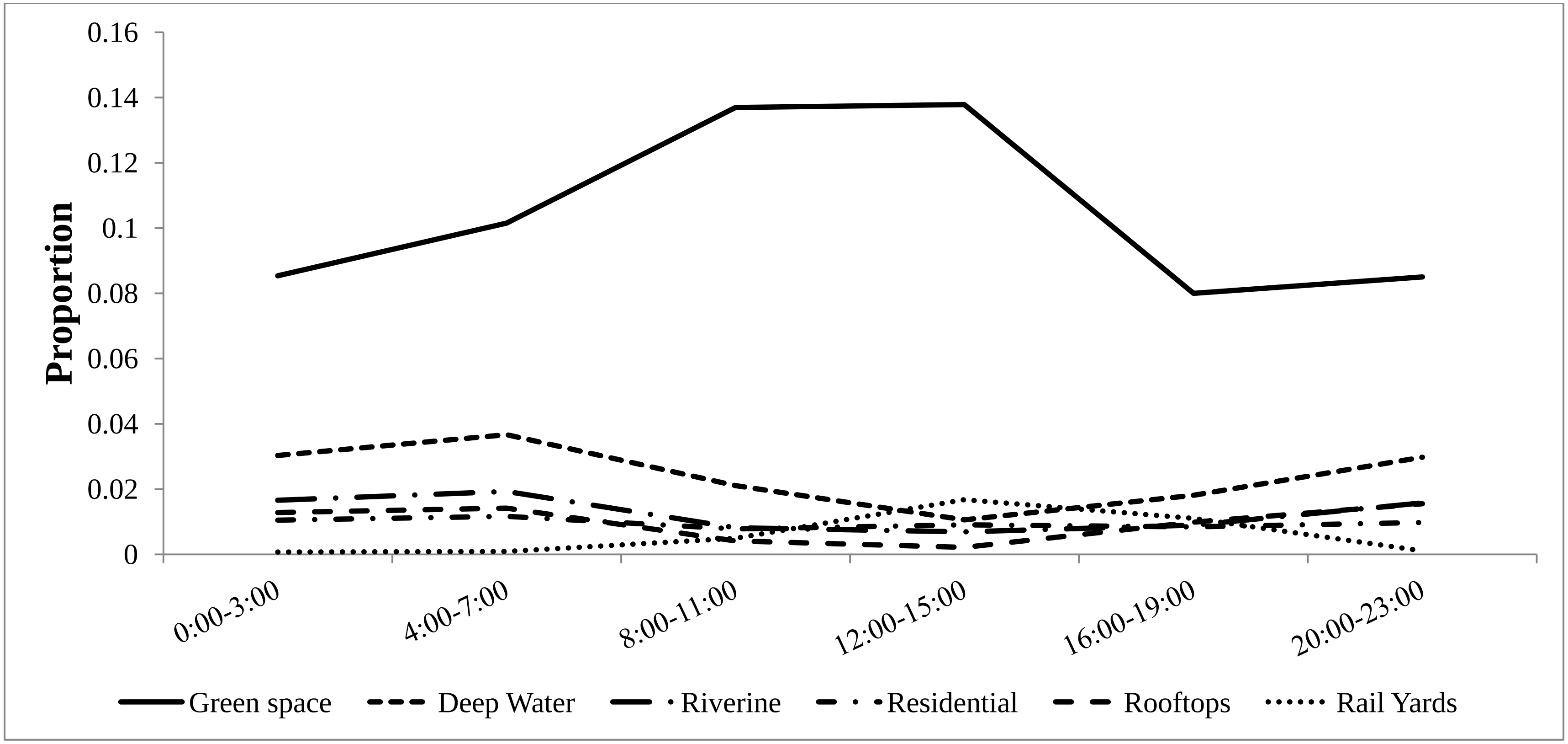

Figure 2.6. Proportion of locations within habitat types used by Canada geese (*Branta canadensis*) diurnally while in the Greater Chicago Metropolitan Area, Illinois, USA during autumn and winter 2015–2016.

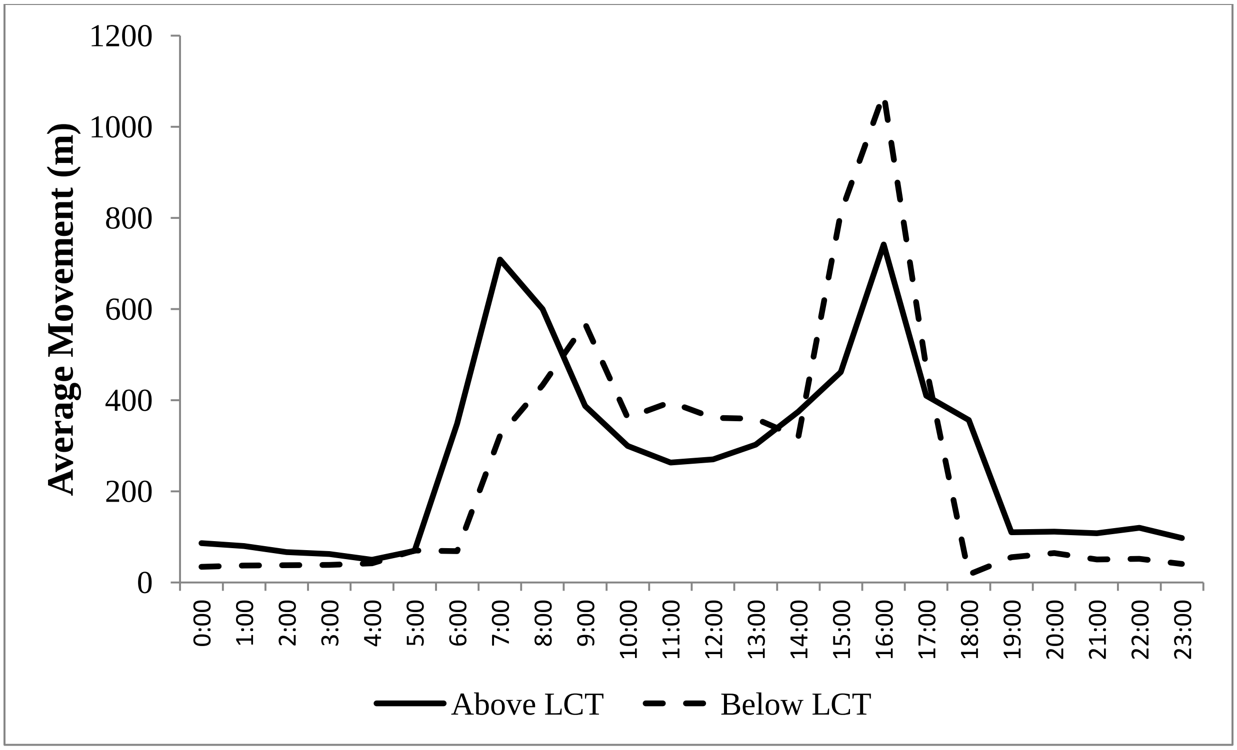

Figure 2.7. Mean movement distance (m) diurnally for Canada geese (*Branta canadensis*) when temperatures were above and below the lower critical temperature (LCT; -6 ^{o}C) in the Greater Chicago Metropolitan Area, Illinois, USA during autumn and winter 2015–2016.

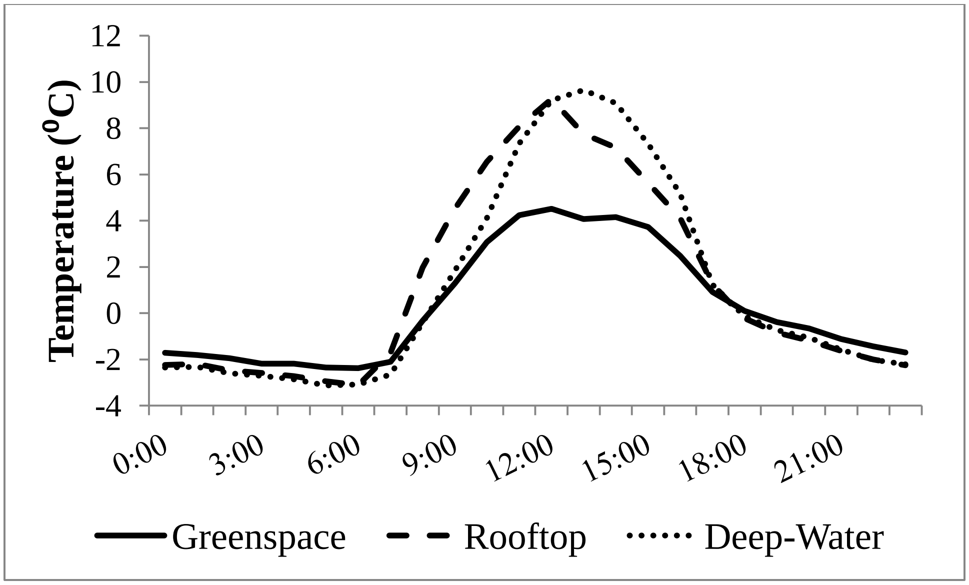

Figure 2.8. Fluctuation in daily temperatures recorded in habitats used by Canada geese (*Branta canadensis*) in the Greater Chicago Metropolitan Area, Illinois, USA during autumn and winter 2015–2016.

Figure 2.9. Canada geese foraging on agricultural waste at a rail yard in the Greater Chicago Metropolitan Area, Illinois, USA during the winter of 2014–2015.

Figure 2.10. Canada geese loafing on a rooftop in the Greater Chicago Metropolitan Area, Illinois, USA during the winter of 2014–2015.

CHAPTER 3: SUMMARY

The winter distributions of most birds are affected by multiple and interacting environmental factors (Brown 1984, Brown et al. 1995, Canterbury 2002). Typically, the northern boundaries of winter ranges correlated with average minimum temperature isotherms (Root 1988*a, b*). In particular, waterfowl select habitats during non-breeding periods (e.g., migration, winter) that provide the resources required to maintain a favorable energy balance and maximize survival (Baldassarre and Bolen 2006). Urban areas provide the necessary resources for survival, but they often require waterfowl to use nontraditional habitats and adopt behaviors different than individuals using traditional habitats (Marzluff 2001, Zuckerberg et al. 2011). Urban areas at the northern extent of wintering ranges may provide food resources, sanctuary from hunting and other predators, and reduced energy expenditure associated with reduced migration distances (Conover and Chasko 1985, Guthery et al. 2005, Anderies et al. 2007, Zuckerberg et al. 2011). Use of urban areas by Canada geese has been shown to increase clutch size, nest success, and annual survival compared to rural areas (Raveling 1981, Paine et al. 2003, Balkcom 2010). Thus, there may be fitness incentives for Canada geese using urban areas during nonbreeding periods at northern extents of their wintering range.

Climate change and landscape modifications, especially large-scale expansion of agriculture, have altered wintering ranges of waterfowl. For example, subarctic-breeding Canada geese have shifted their winter range northward (Gates et al. 2001, Scribner et al. 2003). Specifically, the Mississippi Valley Population of subarctic-breeding Canada geese (*B.c. interior*) have shifted their wintering range northward from southern Illinois and northwest Kentucky to northern Illinois and southern Wisconsin (Craven et al. 1986, Gates et al. 2001, AGJV 2013). Migrating Canada geese may join with geese in urban areas creating large concentrations, which can create conflicts with humans (Conover and Chasko 1985, Smith et al. 1999).

Large populations or dense concentrations of Canada geese can pose threats to humans, including contamination of water sources (Allan et al, 1995), aggressive behavior towards humans (Smith et al. 1999), disease transmission (Smith et al. 1999, Kullas et al, 2002), and strikes with aircraft (Dolbeer et al. 2000). Local regulations in urban areas that limit hunting, public perception, and mixing of different Canada goose populations with different management objectives can create management challenges (Coluccy et al. 2001, Unites States Fish and Wildlife Service 2015). However, hunting is not permitted in many urban areas and limited data are available to determine susceptibility of geese using urban areas during winter to hunting mortality when geese migrate south following cold-weather events, make foraging flights to agricultural fields, or are displaced by already abundant numbers of geese using a limited number of available habitats.

I captured Canada geese during November–February 2014–2016 in the Greater Chicago Metropolitan Area (GCMA) located in northeastern Illinois, USA and fitted 41 geese with solar-powered GPS transmitters. Transmitters were mounted on neck collars and operated on the cellular phone network to collect hourly locations (n = 39,392). Canada geese used urban areas exclusively throughout autumn and winter and did not make foraging flights to agricultural fields within or outside the GCMA. Canada geese in the GCMA tended to have relatively small 50% core use areas ($\bar{x}$ = 0.7 km^2, SE = 0.3), which were predominantly in green spaces, and had 95% UD ($\bar{x}$ = 24.5 km^2, SE = 5.2) similar to those reported in other urban areas (Groepper et al. 2008). Canada geese selected green spaces (59.8%) in greater proportion than availability (14%), but they were also documented using novel urban habitats such as rooftops and rail yards

(11.3%). Habitat use shifted away from green spaces (36%) to industrial urban areas (10.4%), riverine (12.8%), and deep-water habitats (37.8%) as temperatures decreased below the Lower Critical Temperature (LCT; -6 °C) for Canada geese. During periods when temperature decreased and snow depth increased geese increasingly used industrial urban areas (i.e. rooftops and rail yards), which may increase risk for collisions with aircraft nearby Midway International Airport. While I know of no other published accounts of Canada geese using rooftops in winter, we expect they are taking advantage of the relative safety of the urban landscape and may be behaving similarly in other urban areas.

Both snow depth and minimum daily temperatures decreased movement distances. Movements by Canada geese within green space habitat ($\bar{x}$ = 145.6 m, SE = 3.4) were the longest for any habitat type, while movements by geese in deep-water habitats were the shortest ($\bar{x}$ = 85.7 m, SE = 3). Proportion of use of green space habitat increased during diurnal hours. Both deep-water and riverine habitats had higher proportional use during earlier morning hours and the opposite was shown in industrial urban habitat where proportional use increased during midday to early evening. Deep-water and industrial urban habitat (i.e., rooftops) consistently had warmer daily high temperatures than green space by 3.5 °C and 3.2 °C, respectively, but there was no difference in daily minimum temperatures among all habitat types. Green space habitat was more sheltered from the wind while deep-water habitat and industrial urban habitat exceeded green space maximum wind speeds by 12.1 km/h and 22.9 km/h, respectively. The majority of transmittered Canada geese (85%) wintering in the GCMA never migrated south and no geese made foraging flights outside of the urban areas to agricultural fields. Winter survival was 100% for Canada geese remaining in the GCMA and is the greater than published estimates for Canada geese (Balkcom 2010). Survival was 48% for geese that left the GCMA, with all mortality due to hunting. Since Canada geese remaining within the GCMA did not make foraging flights to agricultural fields, hunting may not be a viable option to reduce urban populations or change movements patterns during winter. Targeted harassment at urban habitats apparently used for sanctuary may force geese to leave urban areas and subsequently allow the population to be more effectively managed via hunting.

During periods when temperature decreased and snow depth increased geese increasingly used industrial urban areas (i.e., rooftops and rail yards), which may be due to water within green spaces freezing and availability to forage on grasses decreasing with snow depth. Shifts in habitat use during these weather events may increase risk for collisions with aircraft nearby Midway International Airport. Most nontraditional habitats were located within a close proximity to Midway International Airport, within 4 km or less, and may be areas to concentrate harassment efforts when winter weather becomes extreme to mitigate use of these locations from geese to prevent possible goose-airplane collisions (Appendix Figure A.3). Industrial urban habitats appeared to reach a threshold for both snow depth (26 cm) and minimum daily temperature (-5 °C) where the selection for this habitat started to decrease. This may provide certain weather scenarios when harassment efforts should focus on this habitat and then potential shift to other habitats such as deep-water or riverine.

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APPENDIX

Table A.1. Morphological measurements (mean and standard error) of Canada geese (*Branta canadensis*; *n* = 41) captured and fitted with transmitters in the Greater Chicago Metropolitan, Illinois, USA, during autumn and winter 2014–2016.

	Males			Females		
Measurement	*n*	$\bar{x}$	*SE*	*n*	$\bar{x}$	*SE*
Mass (kg)	21	5.0	0.1	20	4.4	0.1
Skull (mm)	21	131.2	1.4	20	123.8	1.4
Culmen (mm)	21	58.6	1.1	20	55	1.0
Tarsus (mm)	21	114.7	1.4	20	108.4	1.4

Table A.2. Morphological measurements and subspecies classification using culmen length classification method provided by Moser et al. (1991) of Canada geese (*Branta canadensis; n* = 41) captured and fitted with transmitters in the Greater Chicago Metropolitan, Illinois, USA, during autumn and winter 2014–2016. Female *B.c. interior* culmen < 53 mm, Female *B.c. maxima* culmen < 56.8 mm, male *B.c. interior* > 53 mm, male *B.c. maxima* > 56.8 mm.

ID	Sex	Skull (mm)	Culmen(mm)	Tarsus(mm)	Mass (kg)	Classification
00D	M	136.0	61.5	112.1	6.0	*B.c. maxima*
01D	F	121.2	54.9	108.4	4.2	*B.c. maxima*
02D	F	121.2	50.7	98.7	4.0	*B.c. interior*
03D	M	130.0	57.4	110.8	4.5	*B.c. maxima*
57R	F	129.4	59.3	105.9	4.8	*B.c. maxima*
58R	M	135.2	57.7	125.9	5.9	*B.c. maxima*
59R	F	125.9	54.0	112.9	5.1	*B.c. maxima*
60R	M	125.8	53.2	120.9	5.1	*B.c. interior*
61R	F	130.2	57.7	117.8	4.3	*B.c. maxima*
62R	F	119.8	53.4	103.9	3.3	*B.c. maxima*
63R	F	128.4	57.4	109.8	4.2	*B.c. maxima*
64R	F	126.0	56.6	110.7	4.2	*B.c. maxima*
65R	M	109.9	43.4	101.2	3.7	*B.c. interior*
66R	M	131.9	59.8	110.2	5.0	*B.c. maxima*
67R	F	125.3	55.5	108.8	3.9	*B.c. maxima*
68R	F	117.3	51.1	107.8	3.7	*B.c. interior*
69R	M	127.5	55.6	112.8	3.9	*B.c. interior*
70R	M	129.1	60.4	108.9	4.6	*B.c. maxima*
71R	M	136.9	65.2	122.2	5.1	*B.c. maxima*
72C	F	115.8	51.9	100.2	4.1	*B.c. interior*
72R	M	131.1	60.3	111.8	5.0	*B.c. maxima*
73C	M	130.9	58.1	110.5	5.3	*B.c. maxima*
73R	M	137.4	63	122.1	4.7	*B.c. maxima*
74C	F	121.5	55.5	106.8	4.3	*B.c. maxima*
76C	M	130.9	59.8	105.1	5.3	*B.c. maxima*
76R	F	134.2	64.4	120.8	5.7	*B.c. maxima*
78C	F	108.3	43.4	99.4	3.8	*B.c. interior*
83C	F	129.1	56.5	110.9	4.5	*B.c. maxima*
84C	M	127.2	54.6	107.8	5.0	*B.c. maxima*

Table A.2. Continued

ID	Sex	Skull (mm)	Culmen(mm)	Tarsus(mm)	Mass (kg)	Classification
85C	M	132.8	58.3	118.5	5.5	*B.c. maxima*
86C	M	139.5	66.2	120.8	5.1	*B.c. maxima*
87C	M	121.9	53.8	109.0	4.7	*B.c. interior*
88C	F	117.8	50.9	99.2	4.2	*B.c. interior*
89C	M	132.7	59.8	117.4	5.2	*B.c. maxima*
90C	M	135.0	63.8	121.1	5.0	*B.c. maxima*
91C	F	122.7	54.7	105.8	5.1	*B.c. maxima*
95C	M	133.7	57.2	118.8	5.5	*B.c. maxima*
96C	F	129.2	58.2	116.5	5.6	*B.c. maxima*
97C	F	122.0	54.7	106.0	4.2	*B.c. maxima*
98C	M	139.7	62.5	120.0	5.0	*B.c. maxima*
99C	F	131.5	59.9	117.1	5.0	*B.c. maxima*

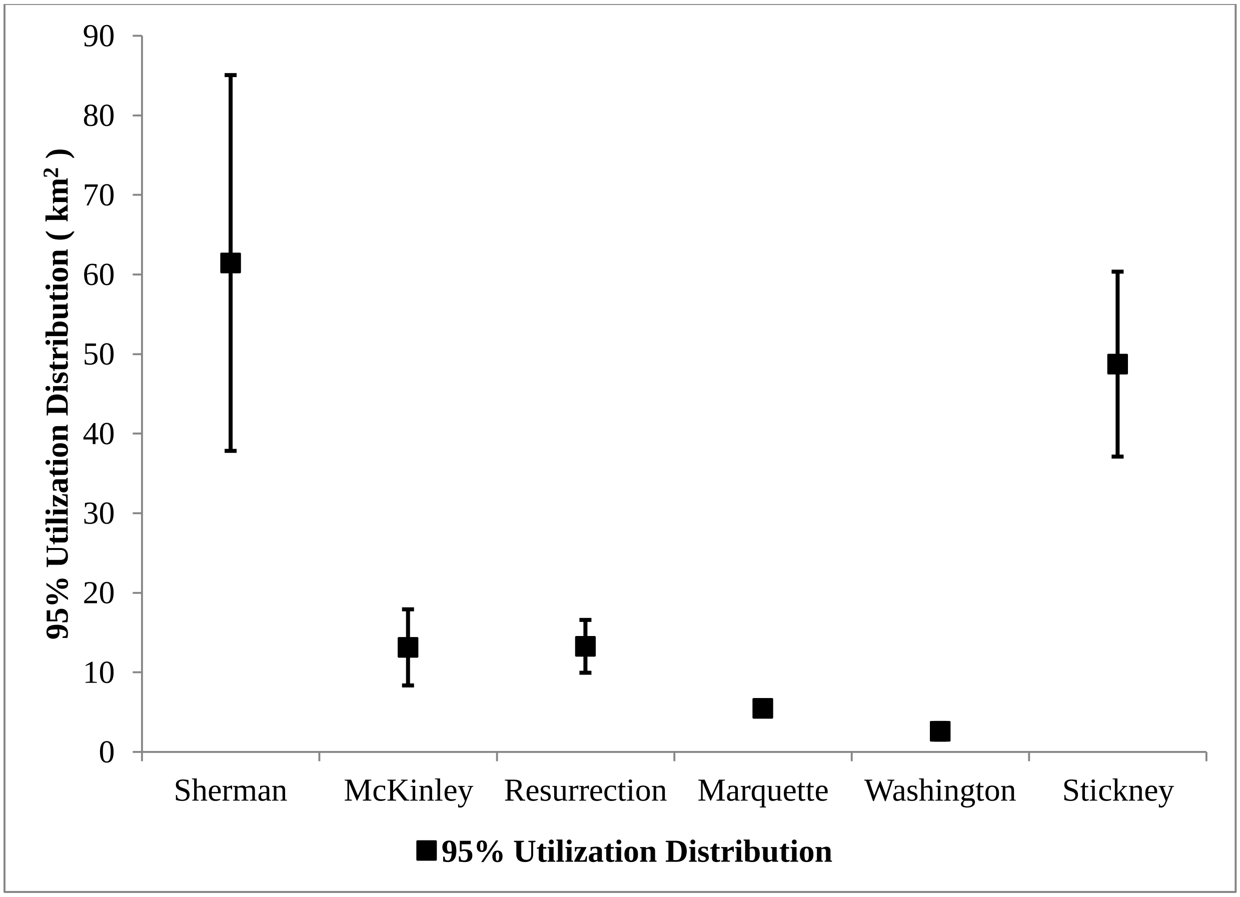

Figure A.1. Mean 95% Utilization Distribution with standard errors for Canada geese (*Branta canadensis*) by capture location (in order from smallest area km^2) in the Greater Chicago Metropolitan Area, Illinois, USA during autumn and winter 2014–2016. The Museum of Science and Industry was removed from analysis because of a low sample size (*n* = 2; Sherman Park = 0.25 km^2, McKinley Park = 0.28 km^2, Resurrection Cemetery = 1.18 km^2, Marquette Park = 1.25 km^2, Washington Park = 1.42 km^2, and Stickney Water Reclamation Plant = 1.97 km^2). Resources may have become limited at Sherman Park and lead to increased 95% utilization distribution. Stickney Water Reclamation Plant was a site where Canada geese were commonly harassed by USDA Wildlife Services in early morning hours to prevent goose-aircraft collisions and may have led to an increased 95% utilization distribution.

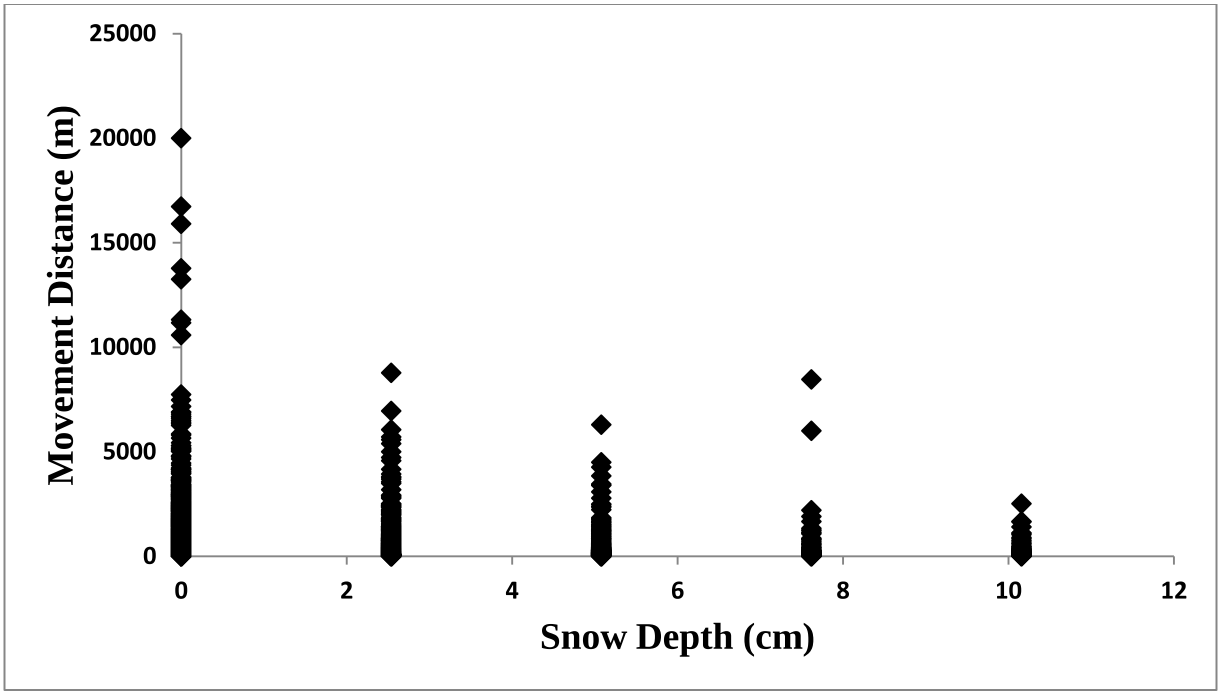

Figure A.2. Movement distances by Canada geese across snow depths from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

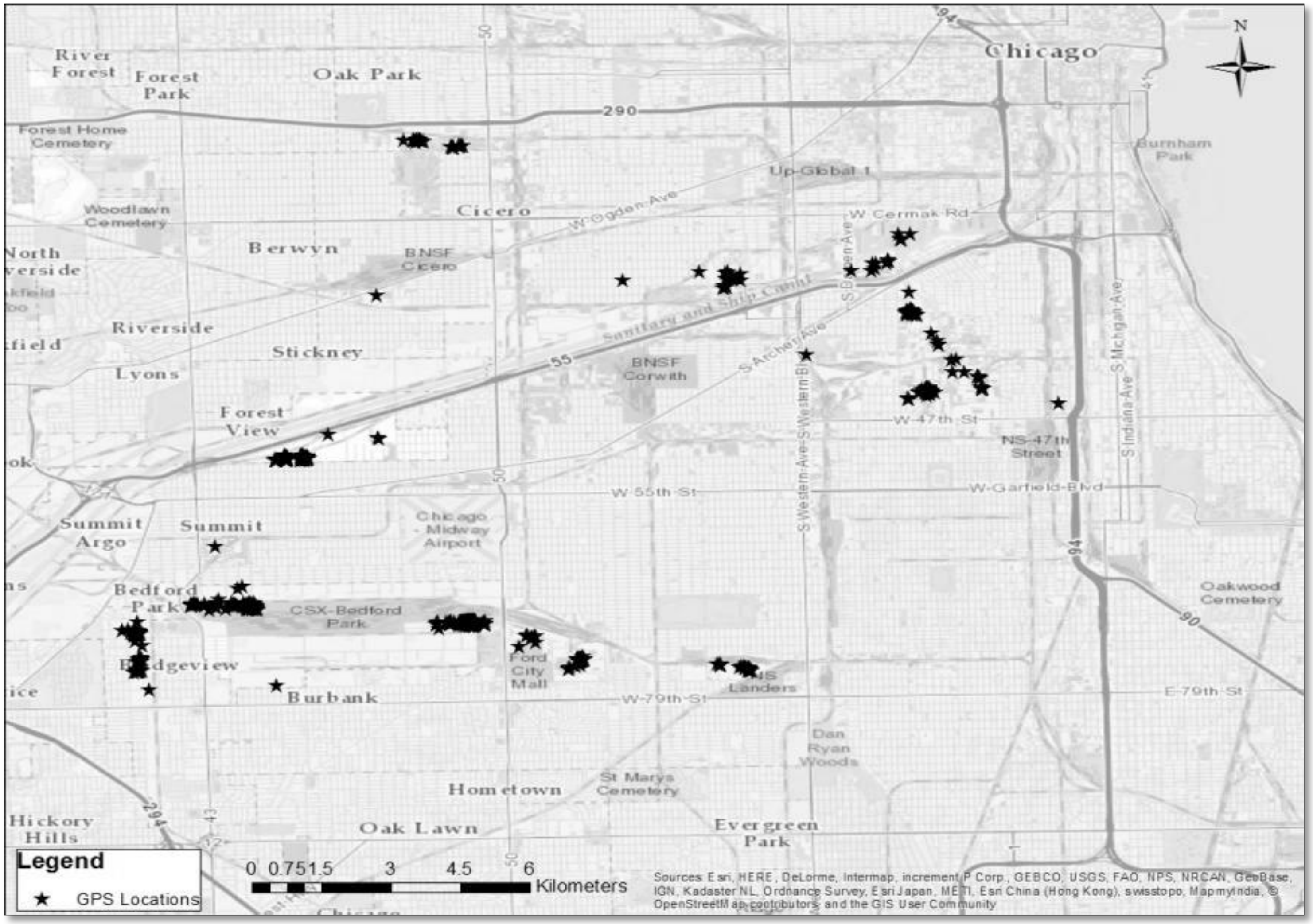

Figure A.3. GPS locations from transmittered Canada geese (*Branta canadensis*) while geese utilized rooftops during late autumn and winter 2014–2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

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RESEARCH ARTICLE

Survival and habitat selection of Canada Geese during autumn and winter in metropolitan Chicago, USA

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ABSTRACT

Winter distribution and resource use of animals is driven by myriad interacting biotic and abiotic factors. Urban areas provide sanctuaries from hunting for game animals and may have thermal benefits during winter through reduced thermoregulatory costs. We deployed cellular GPS transmitters affixed to neck collars of 41 Canada Geese (*Branta canadensis*) in the Greater Chicago Metropolitan Area (GCMA) of northeastern Illinois, USA, to determine habitat selection and survival during autumn and winter. Canada Geese selected green spaces (59.8%) in greater proportion than available (14%), but they also regularly used industrial urban habitats such as rooftops and rail yards (11.3%), which has not been previously reported. Use of green spaces (–55.8%) decreased and use of industrial urban (+11.4%), riverine (+23.8%), and deep-water habitats (+140.7%) increased as temperatures dropped below the lower critical temperature for Canada Geese (i.e. the temperature at which increased thermoregulatory costs are incurred to maintain core body temperature). Most Canada Geese (85%) remained within the GCMA throughout winter, and none made foraging flights to agricultural fields within or outside of the urban area. Seasonal survival was considerably greater ($S = 1.0$) for geese that remained within the GCMA than those that left ($S = 0.48$) during winter. High survival, use of nontraditional habitats (e.g., green spaces, rooftops, and rail yards), and avoidance of agricultural fields suggests Canada Geese may be minimizing risk rather than maximizing energy intake by using urban areas during winter. Future research should focus on the thermoregulatory and movement strategies employed by geese to survive in urban areas where food resources may be limited. Further, researchers interested in discouraging geese should evaluate their response to harassment when temperatures are below the lower critical temperature.

Keywords: Canada Geese, habitat use and selection, home range, survival, transmitters, urban

Supervivencia y selección de hábitat de *Branta canadensis* durante otoño e invierno en el área metropolitana de Chicago, EEUU

RESUMEN

La distribución invernal y el uso de recursos de los animales están impulsados por un conjunto numeroso de factores bióticos y abióticos interactuantes. Las áreas urbanas brindan santuarios sin cacería para los animales de caza y pueden tener beneficios climáticos durante el invierno mediante la reducción de costos de termorregulación. Colocamos transmisores GPS de celular fijados en el cuello por medio de collares a 41 individuos de *Branta canadensis* en el Gran Área Metropolitana de Chicago (GAMC) del noroeste de Illinois, EEUU para determinar la selección de hábitat y la supervivencia durante otoño e invierno. La especie seleccionó espacios verdes (59.8%) en mayor proporción que los disponibles (14%), pero también usó regularmente hábitats urbanos industriales como techos y descampados del ferrocarril (11.3%), lo que no ha sido reportado con anterioridad. El uso de espacios verdes (-55.8%) disminuyó y el uso de hábitats industriales urbanos, (+11.4%), fluviales (+23.8%) y de aguas profundas (+140.7%) aumentó a medida que las temperaturas cayeron por debajo de la temperatura crítica inferior para *B. canadensis* (i.e. la temperatura a la cual se incurren en mayores costos de termorregulación para mantener la temperatura corporal central). La mayoría de los individuos de *B. canadensis* (85%) permaneció dentro del GAMC a lo largo del invierno y ninguno realizó vuelos de forrajeo a campos agrícolas dentro o fuera del área urbana. La supervivencia estacional fue considerablemente mayor ($S = 1.0$) para los individuos que permanecieron dentro del GAMC que paro los que se fueron ($S = 0.48$) durante el invierno. La alta supervivencia, el uso de hábitats no tradicionales (e.g., espacios verdes, techos y descampados del ferrocarril) y la elusión de los campos agrícolas sugiere que *B. canadensis* puede estar minimizando los riesgos más que maximizando el consumo de energía mediante el uso de áreas urbanas durante el invierno. Futuras investigaciones deberían enfocarse en las estrategias de termorregulación y de movimiento utilizadas por *B. canadensis* para sobrevivir en las áreas urbanas donde los recursos alimenticios pueden ser limitados. Más aún, los investigadores interesados en desalentar a los individuos de *B. canadensis* deberían evaluar sus respuestas al acoso cuando las temperaturas están por debajo de la temperatura crítica inferior.

Palabras clave: B. canadensis, rango de hogar, supervivencia, transmisores, urbano, uso y selección de hábitat

INTRODUCTION

The winter distribution of animals is driven by effects of multiple and interacting environmental factors (Brown 1984, Brown et al. 1995, Canterbury 2002), including average minimum temperature isotherms (Root 1988a,b). Decreasing temperatures may increase energy demands to boost metabolic rates concurrent with food resources becoming limited or unavailable for some migratory species during winter (Baldassarre and Bolen 2006). However, a number of adaptations may allow some species to overcome factors limiting their northern distributions and expand their wintering ranges. For example, nine-banded armadillos (*Dasypus novemcinctus*) expanded their range northward over the past several decades through selection of thermally beneficial den sites and behavioral adaptations to minimize heat loss (Bond et al. 2000, Eichler and Gaudin 2011). Gray-headed flying foxes (*Pteropus poliocephalus*) have expanded their winter range by utilizing urban areas that provide warmer winter conditions than rural areas (Parris and Hazell 2005). Exploitation of supplementary food resources related to human activities (e.g., bird feeders, agricultural waste grain) has allowed northward expansion of winter ranges of many bird species (Siriwardena et al. 2007, Zuckerberg et al. 2011). Further, an increasingly warming climate has shifted wintering ranges of many birds poleward, although variation among species and interacting factors affecting habitat suitability make predicting these shifts difficult (Princé and Zuckerberg 2015, Williams et al. 2015).

Some bird species have shifted their wintering range northward by taking advantage of conditions in urban areas (Zuckerberg et al. 2011). Urban areas at the northern edge of a migratory species' wintering range can provide habitat resources (e.g., food, living space, and water), sanctuary from predators, and reduced energy expenditure associated with reduced migration distance (Conover and Chasko 1985, Anderies et al. 2007, Zuckerberg et al. 2011). Urban areas may provide sanctuary from hunting for game species and may be warmer than the surrounding rural landscape (Oke 1973, Grimmond 2007). Such northward shifts in wintering ranges and adaptation to urban areas have been documented for several species of waterfowl, including Canada Geese (*Branta canadensis*; Gates et al. 2001, Baldassarre and Bolen 2006).

Use of urban areas by Canada Geese during the breeding period can be advantageous (e.g., increased clutch size, nest success, and annual survival compared to use of rural areas; Raveling 1981, Paine et al. 2003, Balkcom 2010), but few benefits have been documented outside of the breeding season. Waterfowl select habitats during nonbreeding periods that provide the resources required to maintain a favorable energy balance and maximize survival (Gates et al. 2001, Baldassarre and Bolen 2006). Waste grain in agricultural fields can increase food availability during late autumn and winter, and urban areas may provide thermal benefits allowing birds to maintain positive energy balances in more northerly areas (Jokimäki et al. 1996, La Sorte and Thompson 2007). Urban areas also attract migrating Canada Geese from subarctic-breeding populations (*B. c. interior*), which sometimes aggregate during autumn and winter with temperate-breeding geese (*B. c. maxima*) in urban areas, creating large concentrations and potential conflicts with humans (Conover and Chasko 1985, Smith et al. 1999). For Canada Geese, mixing of populations with different population management objectives is one of several challenges for managers in urban areas (Coluccy et al. 2001, Scribner et al. 2003, United States Fish and Wildlife Service 2015). Hunting is an important population management tool that can be used to reduce overabundant populations and wildlife–human conflicts (Conover 2001). However, regulations preventing hunting in urban areas can create sanctuaries, increasing potential wildlife–human conflicts and limiting management options.

We studied Canada Geese wintering in or migrating through a large urban area in the midwestern USA during late autumn and winter to better understand habitat use and selection, survival within and outside of the urban areas, and movements to agricultural fields where there was potential for mortality due to hunting. Specifically, our objectives were to (1) determine core use areas and overall home ranges during winter, (2) identify habitat use and selection, (3) estimate survival within and outside of urban areas and identify cause of mortality, and (4) describe migration phenology in relation to hunting. We predicted that Canada Geese would use large green spaces and deep-water areas for roosting and conduct daily flights to agricultural fields to obtain food and maintain energy reserves (Conover and Chasko 1985, Smith et al. 1999). We predicted that reduced risk of

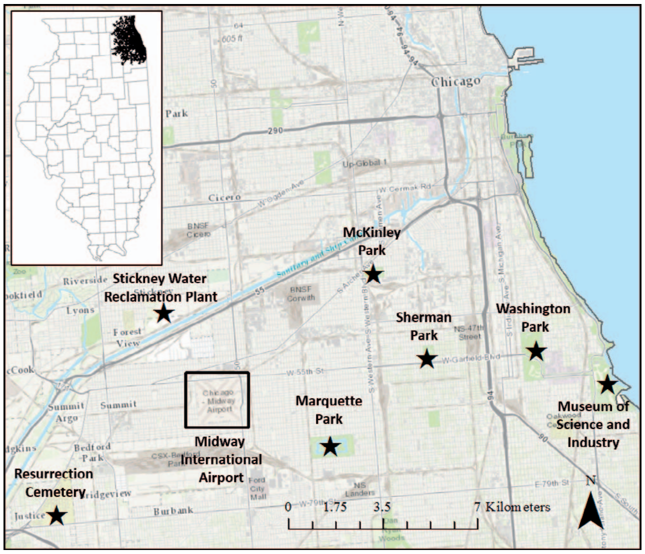

FIGURE 1. Main capture locations ($n = 7$) of Canada Geese (*Branta canadensis*) in relation to Midway International Airport within the Greater Chicago Metropolitan Area, Illinois, USA (inset).

mortality from hunting would increase survival of Canada Geese in urban areas compared to those that used rural areas (Balkcom 2010).

METHODS

Study Area

Canada Geese (hereafter, geese) were captured in the Greater Chicago Metropolitan Area (GCMA; ~915 km^2) in northeastern Illinois, USA, during late autumn and winter (Figure 1). The GCMA included portions of Cook, Du Page, and Will counties and was heavily urbanized with some agricultural fields present within and near city limits (United States Department of Agriculture 2015). Agricultural fields of primarily corn and soybeans were located within 10–30 km of capture and marking locations of geese. The GCMA averages 43 days annually with temperatures dropping below 0 °C and 7 days below –18 °C. November has an average high of 9 °C and a low of 0 °C, December has an average high temperature of 2 °C with a low of –6 °C, January has an average high of 0 °C and a low of –9 °C, and February has an average high of 2 °C and low of –7 °C (National Oceanic and Atmospheric Administration 2015a). Chicago averages 93 cm of snowfall annually (National Oceanic and Atmospheric Administration 2015a). The GCMA has an estimated temperate-breeding Canada Goose population exceeding 30,000 individuals (Paine et al. 2003) and a human population of 9.4 million in Chicago and surrounding suburbs (United States Census Bureau 2013; Figure 1).

Field Methods

During mid-November through late February 2014–2016, we captured and attached transmitters to 41 geese within the GCMA. Our research also involved goose–aircraft collision risk, so we focused capture efforts where geese concentrated in fall and winter near Midway International Airport (41°47′6.5"N, 87°45′6"W), including large parks, cemeteries, and the Stickney Water Reclamation Plant (Figure 1). We used rocket nets, cast nets, and small animal net guns (Wildlife Capture Services, Flagstaff, Arizona, USA) to capture geese. We determined sex and age using cloacal inversion and feather characteristics. We took standard morphological measurements (mass, skull length, culmen length, tarsus length) using a caliper (nearest 0.1 mm) and a digital scale (nearest 0.01 kg). To each goose, we attached an aluminum tarsal band and a GPS transmitter affixed to a white plastic waterfowl neck collar with black alphanumeric codes.

Transmitters ($n = 10$ in 2014–2015 and $n = 31$ in 2015–2016) were deployed during 4 time periods each year (mid-November, early December, mid-December, and early January) and at 7 different capture locations to account for temporal spatial variation in migration chronologies of geese. Transmitters recovered from hunters ($n = 3$) were redeployed during late February. Transmitters included solar-powered GPS units (Cellular Tracking Technologies, Somerset, Pennsylvania, USA), which operated on the global system for mobile communications network and were configured to acquire a GPS location once per hour. Generation 2 models were used during 2014–2015 ($\bar{x} =$ 69.7 grams, SE = 0.2) and Generation 3 models were used during 2015–2016 ($\bar{x} = 62.2$ grams, SE = 0.2). Transmitters were <2% of the body mass of captured geese ($\bar{x} = 4{,}713$ grams, SE = 10.6).

Data Analysis

We removed locations from the day of capture from analysis, except for survival analysis, to minimize potential influences of capture on movements and habitat use. Transmitters required a once-weekly cellular connection to program their duty cycle to the standardized rate of 1 location hr^{-1} for the entire day and upload locations to an accessible database. Data from transmitters with less than 10 days of data collection were removed from analysis ($n =$ 1 in 2014–2015 and $n = 4$ in 2015–2016). Locations with only one satellite fix or with a horizontal dilution of precision value above 5 were removed because GPS coordinates were either not obtained or they had extremely low accuracy (Cellular Tracking Technologies 2015). All analyses were performed using R Version 3.1.3 (R Core Team 2015).

Core use areas and overall home range analysis. To characterize spatial use of the GCMA, we estimated core use areas (50% utilization distribution [UD; km^2]) and overall home ranges (95% UD) using a dynamic Brownian bridge movement model (dBBMM) and the adehabitatHR, rgdall, and move packages in R (Calenge 2006, Bivand et al. 2015, Kranstauber and Smolla 2015). We estimated core use areas to target specific areas used by geese during winter where management actions may need to focus and overall home ranges to represent the majority of spatial use of geese during winter. A dBBMM is a more appropriate method to estimate spatial use than kernel density estimates because it incorporates the temporal structure of the locations to estimate potential trajectories of the segments between those locations using a maximum likelihood function (Horne et al. 2007, Kranstauber et al. 2012) and accounts for nonindependence of systematically collected data (Worton 1989, Fieberg et al. 2010). If a goose emigrated from the GCMA, all locations from migration date forward were removed from core use area and overall home range analysis. All locations obtained from November 15 through February 28 of both years were used to calculate core use areas and overall home range. We also divided autumn and winter into 3 distinct periods: early winter (November 15–December 31), mid-winter (January 1–January 31), and late winter (February 1–February 28; Raveling et al. 1972). We used mean imputation to fill in missing data for time period analysis due to temporal spacing of transmitter deployment and migration, which simultaneously retained important core use area and overall home range information (Zar 2010). Transmitters ($n = 6$) from 2014–2015 that were present in the GCMA during 2015–2016 were not used for analysis during the second year because of limited locations with poor temporal spacing (i.e. weeks between locations) and low accuracy. In separate linear mixed models (R; lme function in the nlme package; Pinheiro et al. 2016), we modeled the response variables of core use area size and overall home range size as functions of time period (i.e. early, mid-, and late winter) with location of capture and year as random effects. We inspected residuals to ensure a normal distribution and designated $\alpha = 0.05$.

Resource selection. To identify habitat use and selection, we plotted all locations of geese on Google Earth Pro using the rgdal and adehabitatLT packages in R (Calenge 2006, Bivand et al. 2015). We defined habitat as the resources and other conditions present at a transmitter location where geese were present that could influence occupancy and established 5 categories of habitat which we assumed were independent (Hall et al. 1997). Habitats were classified manually by visually assigning green space, riverine, deep-water, industrial urban, or residential identifiers to each use location or random point using available aerial imagery and ancillary information. Green spaces were typically parks, cemeteries, small grass lawns and areas between buildings, and other areas primarily in grass cover that contained a mixture of ponds, trees and shrubs, large sports fields, and golf courses within their boundaries (Dorak 2016). Riverine areas consisted of the open water, sand bars, mud flats, and other various vegetation and cover types within and immediately adjacent to the main river channel of the Des Plaines River and Calumet River systems. Deep-water areas included the Chicago Sanitary and Ship Canal, which had steep concrete walls and warm-water discharges along the canal corridor, and the Stickney Water Reclamation Plant. We classified the entire Stickney Water Reclamation Plant as deep-water because most anecdotal observations of geese there were in or immediately adjacent to settling ponds; however, this area contained developed areas, green spaces, and deep-water areas in a highly interspersed arrangement. Industrial urban habitat included flat rooftops, which were typically large flat industrial buildings and retail stores, and adjacent rail yards composed of large complex series of railroad tracks where railcars were loaded, unloaded, and stored. Residential areas were typically houses and developments, parking lots, and miscellaneous other land uses occurring in residential areas.

To determine habitat availability for comparison with use locations, we used a random number generator to create 500 locations within the study area and assigned each point to a habitat as described previously. We compared habitat use and availability across the entire autumn and winter period for both years and when the temperature dropped below the theoretical lower critical temperature (LCT) for Canada Geese (–6 °C; Calder and King 1974, Alisauskas and Ankney 1992). The LCT is the ambient temperature below which an animal must increase its metabolic rate and potentially increase its metabolization of endogenous resources to maintain body temperature; it is estimated using ratios of body mass to body temperature, and surface area and plumage (Alisauskas and Ankney 1992, Dawson and O'Connor 1996). We acknowledge that the LCT likely varies by individual and over time through a complex interplay of physiological, morphological, and behavioral characteristics that may also be related to individual habitats or physical characteristics of sites (McKinney and McWilliams 2005, Livolsi et al. 2015). Although we acknowledge the inherent variability among individuals, habitats, and conditions, we believe the selected LCT represented an approximate temperature threshold, which likely influenced thermoregulatory costs of geese in the GCMA during winter (Alisauskas and Ankney 1992, Gates et al. 2001). Additionally, we compared habitat use across the 3 time periods (early, mid-, and late winter). We determined the phenology of spring and autumn migration by noting when a marked individual emigrated from the GCMA and did not return for >30 days and when an individual

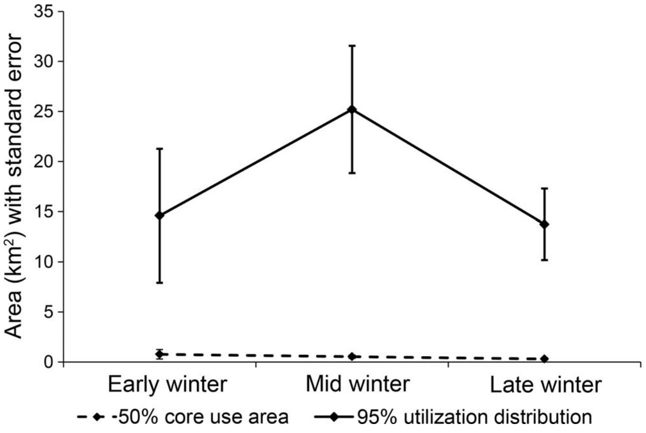

FIGURE 2. Change in 50% core use areas and 95% utilization distribution estimates with standard error bars across 3 time periods for Canada Geese (*Branta canadensis*) during autumn and winter 2014–2016 in the Greater Chicago Metropolitan Area, Illinois, USA.

immigrated into the GCMA after being gone for a period >30 days.

We used a resource selection function (RSF) with an exponential link to describe habitat selection ($w(x)$; McDonald 2013). A $w(x) > 1$ represented selection, $w(x) = 1$ represented habitat use in proportion to availability, and $w(x) < 1$ represented habitat avoidance. We analyzed the RSF as a function of habitat (i.e. green space, riverine, deep-water, industrial urban, and residential), time of day (i.e. diurnal or nocturnal), an interaction of habitat and time of day, and snow depth (cm). In a separate analysis, we analyzed RSF as a function of habitat, time of day, an interaction of habitat and time of day, and minimum daily temperature (°C; Manly et al. 2007, McDonald 2013). We set the diurnal time period to 0500–1900 to include crepuscular movements and the nocturnal time period 1901–0459 to exclude crepuscular movements. We used a quadratic term because we expected that there would be a threshold in both snow depth and minimum daily temperature where habitat use would cease. Weather data were obtained from the weather station at Midway International Airport (Weather Underground 2016). We plotted the parameter estimates to make predictions of RSF within the range of minimum daily temperatures and snow depth data (Neter et al. 1996) and used a smoothing factor to interpolate the predicted RSF between large gaps in snow depth data.

Survival. Winter survival (S) with 95% confidence intervals (CI) was calculated for the time period November 15 through February 28, 2014–2016, using the Known-Fate model in Program MARK because transmitters provided fine-scale data and status (i.e. alive or dead) of all geese was known (Cooch and White 2006). We assumed that all transmittered geese were independent and because of spatial variation in transmitter deployment, we used a staggered entry design. We divided time intervals into 3 periods (i.e. early, mid-, late winter) and calculated a body condition index (BCI) following Arsnoe et al. (2011; Devries et al. 2008). We conducted an ordinary least-squares regression of adjusted mass and an index of body size (principal component 1 of skull, culmen, and tarsus length) and then divided the residuals from the predicted mass to create a condition score for each bird. We created 6 models to evaluate the effects of BCI, group (remained in GCMA or emigrated from GCMA), and time period on survival and ranked models using Akaike's information criterion adjusted for a small sample size (AIC_c; Burnham and Anderson 2002). We summed model weights (w_i) of top models in which a variable appeared to determine relative variable importance.

RESULTS

Data collected from winter 2014–2015 were limited due to battery recharging issues with Generation 2 transmitters ($n = 9$ transmitters, $\bar{x} = 10.5$ locations per transmitter per day, SE = 2.9, range 2.0–26.4). Generation 3 transmitters deployed in winter 2015–2016 provided increased battery life and efficiency ($n = 27$ transmitters, $\bar{x} = 20.8$ locations per transmitter per day, SE = 0.4, range 15.4–23.3). Time between locations was greater for Generation 2 transmitters in 2014–2015 ($\bar{x}$ = 274.1 min, SE = 75.2) than Generation 3 transmitters in 2015–2016 ($\bar{x} = 70.1$ min, SE = 1.3). We obtained 3,496 usable locations in 2014–2015 and 35,896 usable locations in 2015–2016.

Neither core use areas ($\bar{x} = 0.7$ km^2, SE = 0.3; $F_{1,95} = 1.3$, $P = 0.26$) nor overall home ranges ($\bar{x} = 24.5$ km^2, SE = 5.2; $F_{1,95} = 0.37$, $P = 0.54$) of geese ($n = 36$) varied by time period (Figure 2). Geese selected green space (59.8%), deep-water (15.2%), industrial urban (11.3%), and riverine (8.1%) habitats in greater proportion than their availability ($P \leq 0.05$; Table 1). When temperatures dropped below LCT, geese increased use of deep-water (+140.7%) and riverine habitats (+23.8%) and decreased use of green space (–55.8%; Table 1). Green space was used more than any other habitat and selected across time periods, but proportional use declined from early winter (80.4%) to mid-winter (52.2%) and late winter time periods (52.8%; Table 2). Geese increased use of deep-water habitat from 1.9% in early winter to 21.8% during mid-winter and 18.2% in late winter (Table 2). Similarly, geese increased use of industrial urban habitats from early winter (6.8%) to mid-winter (11.3%) and late winter (14.2%; Table 2).

Snow depth ($F_{1,\ 78,728} = 119.2$, $P < 0.01$), minimum daily temperature ($F_{1,\ 78,728} = 183.6$, $P < 0.01$), time of day ($F_{1,\ 78,728} = 9.2$, $P < 0.01$), and all interactions ($P < 0.01$) affected habitat use. The resource selection function (RSF) was above 1 for every habitat except residential, indicating that geese selected green space, industrial urban, riverine, and deep-water habitats but avoided residential habitats

TABLE 1. Percentage of available habitat (Available), percentage of locations occurring in each habitat across all temperatures (All Locations), and percentage of locations occurring in each habitat use when temperature was above (Above LCT) and below (Below LCT) the lower critical temperature (LCT; –6 °C) for Canada Geese in the Greater Chicago Metropolitan Area, Illinois, USA, during autumn and winter 2014–2016.

		2014–2015			2015–2016			Total		
Habitat	Available	All locations	Above LCT	Below LCT	All locations	Above LCT	Below LCT	All locations	Above LCT	Below LCT
Green space	14.0%	30.1%	41.6%	18.4%	62.7%	67.4%	40.8%	59.8%	66.0%	36.0%
Riverine	2.2%	14.1%	12.6%	15.6%	7.6%	6.6%	12.0%	8.1%	6.9%	12.8%
Deep water	1.0%	20.9%	12.3%	29.6%	14.6%	9.1%	40.1%	15.2%	9.3%	37.8%
Industrial urban	8.0%	30.6%	29.0%	32.3%	9.4%	10.5%	4.4%	11.3%	11.5%	10.4%
Residential	74.8%	4.3%	4.5%	4.1%	5.7%	6.4%	2.7%	5.6%	6.3%	3.0%

(Figures 3 and 4). As snow depth increased, selection increased for industrial urban, riverine, and deep-water habitats, while selection for green space decreased (Figure 4). Geese tended to avoid residential habitat across almost all snow depths and minimum daily temperature ranges (Figures 3 and 4). Geese selected riverine and deep-water habitats more often during nocturnal than diurnal periods (Figures 3 and 4). As minimum daily temperature decreased, selection of riverine and deep-water habitats increased. Selection of industrial urban habitats increased as temperature decreased until approximately –5 °C (Figure 3). Use of green space declined as temperature decreased until –20 °C (Figure 3). Notably, we recorded no use of agricultural fields within or outside of the GCMA by geese that remained within the GCMA during winter.

Winter survival was 100% for geese using the GCMA ($n = 35$) and 48% (95% CI range = 16–82%; $n = 6$) for geese that emigrated from the GCMA. Although BCI was related negatively to survival, confidence intervals overlapped zero indicating a weak effect. Weekly survival for emigrating geese was 95% (95% CI range = 86–98%) across the entire winter period. The top two models explaining survival ($\sum w_i = 0.9$) included time period (Table 3). Weekly survival was 100% during early winter, 85% (95% CI range = 62–95%) during mid-winter, and 100% during late winter. We documented 3 direct mortalities from hunting during the mid-winter time period. Mortalities occurred an average of 8 days (range 2–16) after the geese left the GCMA. Hunting mortalities occurred in northwest Indiana, southwest Illinois, and northwest Tennessee. The majority of geese (85%) fitted with transmitters never migrated south from the GCMA. During 2014–2015, 3 of 10 geese left the GCMA. One goose left on November 30, 2014, and 2 left on January 4, 2015. During 2015–2016, 3 of the 31 geese emigrated south from the GCMA between December 30, 2015, and January 13, 2016.

In 2015, most geese ($n = 7$) initiated spring migration during March 11–16 while 2 geese remained in the GCMA for the breeding season. During 2016, most geese ($n = 15$) initiated spring migration during February 20 through April 1, although a larger percentage (48%; $n = 14$) remained within the GCMA during spring and summer 2016 than in 2015. Geese showed high fidelity to the GCMA across seasons and years. All geese with active transmitters from winter 2014–2015 ($n = 7$) returned to or remained within the GCMA during the autumn of 2015 and 17 of 21 geese with active transmitters from winter 2015–2016 remained in or returned to the GCMA during the autumn of 2016. Return flights to the GCMA ranged from August through November in 2015 and from August through October in 2016. All 6 geese with active transmitters that were marked during winter 2014–2015 returned to or stayed within the GCMA during the autumn of 2016. We were unable to assign breeding locations to geese that left the GCMA.

TABLE 2. Percentage of available habitat (Available), percentage of locations occurring in each habitat across all temperatures (All Locations), and percentage of locations occurring in each habitat use when temperature was below the lower critical temperature (Below LCT; –6 °C) for Canada Geese in the Greater Chicago Metropolitan Area, Illinois, USA, during 3 periods of the autumn and winter 2014–2016.

		Early winter		Mid-winter		Late winter	
Habitat	Available	All locations	Below LCT	All locations	Below LCT	All locations	Below LCT
Green space	14.0%	80.4%	84.7%	52.2%	38.7%	52.8%	30.6%
Riverine	2.2%	3.5%	7.3%	11.4%	11.8%	8.4%	14.0%
Deep water	1.0%	1.9%	0.7%	21.8%	41.7%	18.2%	37.5%
Industrial urban	8.0%	6.8%	0.3%	11.3%	6.2%	14.2%	14.2%
Residential	74.8%	7.4%	7.0%	3.3%	1.6%	6.4%	3.7%

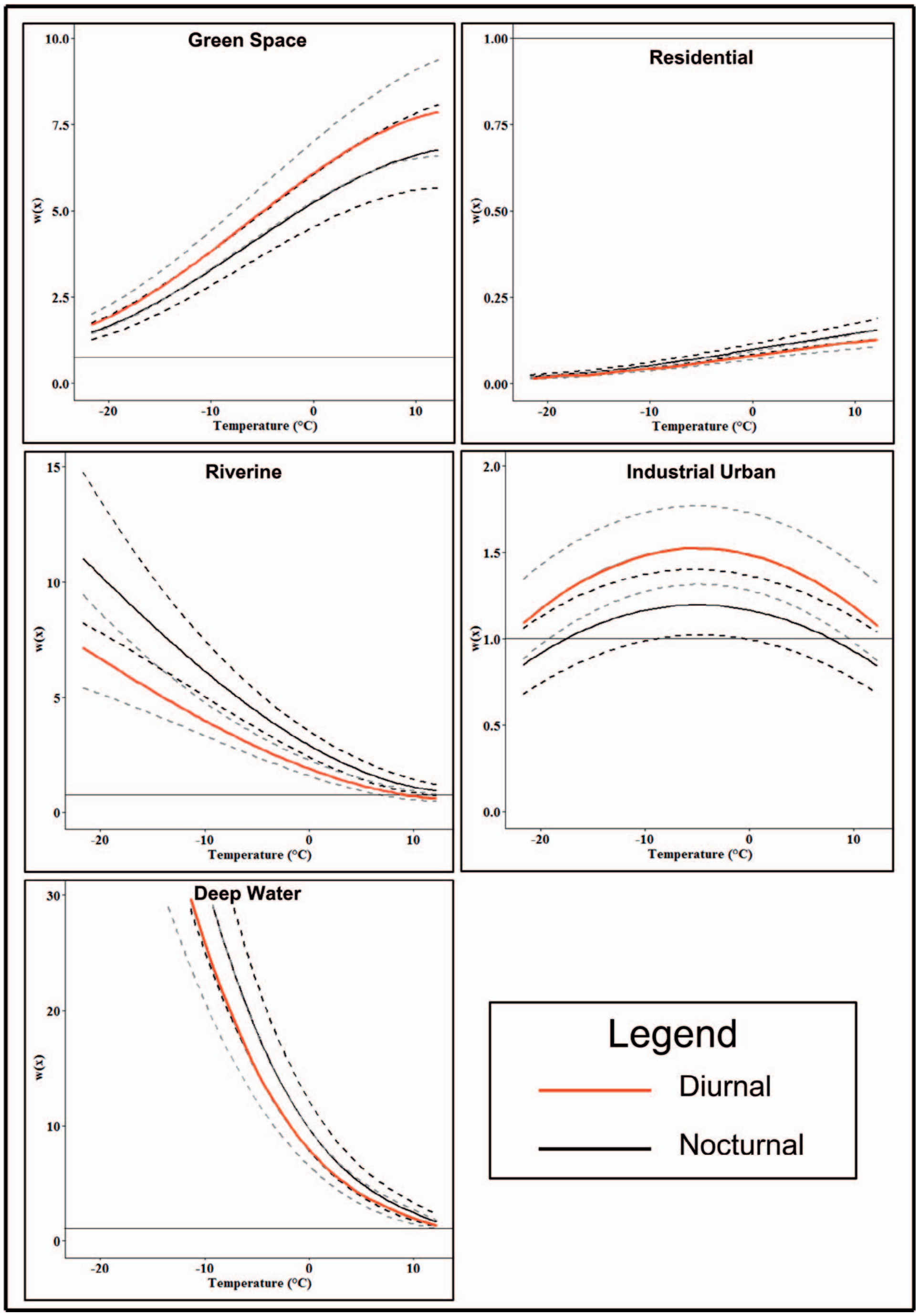

FIGURE 3. Resource selection function *w*(*x*) with 95% confidence intervals (broken lines) for habitats used by Canada Geese (*Branta canadensis*) relative to minimum daily temperatures (°C) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA. A value of 1 (designated by horizontal line) indicates no selection or avoidance.

DISCUSSION

Our results suggest that the GCMA has become a large sanctuary for Canada Geese, but the expansion of agriculture and availability of open water may not be the most important environmental factors behind the northerly shift in wintering ranges of geese (Baldassarre 2014, Dorak 2016). Canada Geese within the GCMA had relatively small core use areas and most did not leave the urban area during winter. Although agricultural fields were present within and near the GCMA (∼10 km from core study area), within reasonable daily flight distances, geese

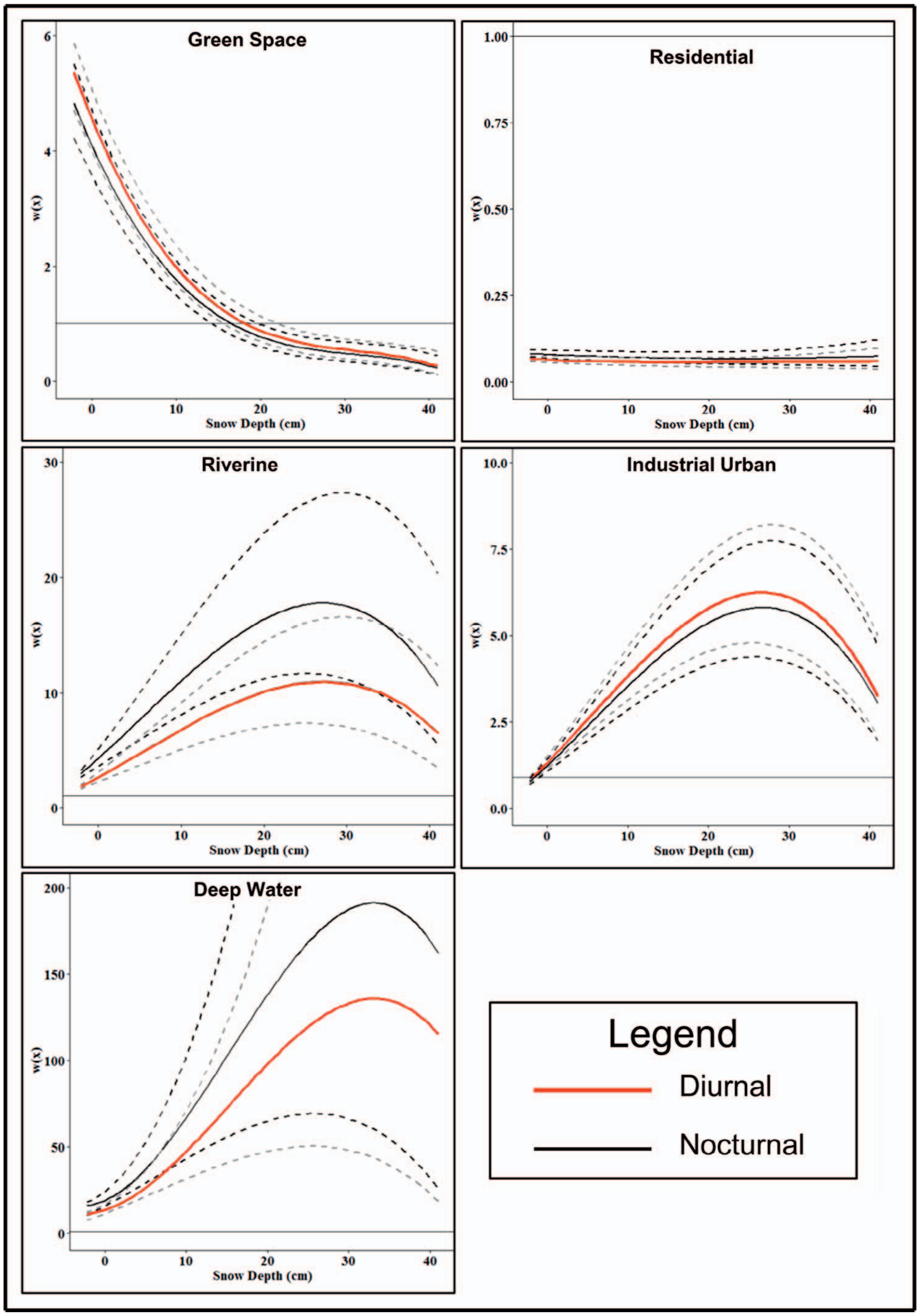

FIGURE 4. Estimated resource selection function $w(x)$ with 95% confidence intervals (broken lines) for habitats used by Canada Geese (*Branta canadensis*) relative to snow depth (cm) from November 2015 through February 2016 in the Greater Chicago Metropolitan Area, Illinois, USA. A value of 1 (designated by horizontal line) indicates no selection or avoidance.

did not make foraging flights to agricultural fields during winter. Accordingly, geese that remained within the GCMA during winter had high survival, but those that left the GCMA had high mortality. Survival rates were greater for geese that remained within the GCMA and much lower for geese that left the urban area than previously reported during open hunting seasons (Hestbeck and Malecki 1989, Groepper et al. 2008, Rutledge et al. 2015). Sanctuary may have been a more important selective pressure than high-quality forage during winter for geese in our study area (Luukkenon et al. 2008, Balkcom 2010, Pilotte et al. 2014).

TABLE 3. Results of linear models evaluating the effects of period (early winter, mid-winter, late winter), group (stayed or emigrated from the Greater Chicago Metropolitan Area), and body condition index (BCI) on survival (*S*) of Canada Geese (*Branta canadensis*) captured and transmittered during autumn and winter 2014–2016 in the Greater Chicago Metropolitan Area, Illinois, USA, with Akaike's Information Criterion adjusted for sample size AIC_c, number of parameters (*k*), difference in AIC_c with top model (ΔAIC_c), model weight (w_i), and deviance. Lowest AIC_c value was 22.5.

Model	*k*	ΔAIC_c	w_i	Deviance
S(Period)+(Group)+(BCI)	4	0.0	0.5	14.4
S(Period)	3	0.5	0.4	16.9
S(Group)	2	5.7	0.0	24.1
S(Constant)	1	14.5	0.0	35.0
S(BCI)	2	15.3	0.0	33.7

Geese used a mix of habitats in the GCMA, including many that were nontraditional (e.g., water treatment facilities, deep-water areas within shipping canals) and had not been previously documented (e.g., rooftops, rail yards). Geese selected green space, riverine, and deep-water habitats and avoided residential habitats across both years of our study. Despite extensive use of these novel industrial urban habitats, use was nearly equivocal with availability across years. Large green spaces were selected across all time periods and years, had the greatest proportional use among habitats, and likely provided necessary food, water, and sanctuary needed by geese across most temperature ranges. However, when snow depth increased and temperatures decreased, geese reduced their use of green spaces and increased use of industrial urban, deep-water, and riverine habitats. This change may have been in response to the reduced availability of interspersed open water and/or forage within green spaces when covered by ice and snow. There were likely physiological benefits of geese using industrial urban and deep-water habitats during cold weather associated with energy conservation strategies (Gates et al. 2001).

Industrial urban, deep-water, and riverine habitats perhaps provided thermal benefits, reduced disturbance, and even food resources needed during harsh weather conditions. Rooftops may have provided thermoregulatory benefits associated with warmer ambient temperatures or sanctuary from disturbances and predators, which may have reduced energy expenditures. Although most anecdotal observations of geese foraging occurred in green spaces, we observed geese foraging in rail yards and speculate that spilled grain from rail cars or other foods may have been available. Deep-water and riverine habitat may have provided open water for safe roosting locations, which enhanced energy conservation. The ability of Canada Geese to use these novel habitats in urban areas illustrates a remarkable behavioral adaptability to improve survival during winter (Gates et al. 2001).

Patterns of habitat use differed across years of our study in response to different weather conditions. The winter of 2014–2015 was 2 °C colder and had 32 cm more snow accumulation than an average winter, compared to 2015–2016, which was 3 °C warmer with 30 cm less snow than average (National Oceanic and Atmospheric Administration 2015b, 2016). Harsh winter conditions during 2014–2015 appear to have resulted in geese reducing their use of green spaces and increasing the use of industrial urban habitats relative to the milder winter of 2015–2016. Use of deep-water and riverine habitat had a larger proportional increase when temperatures were below the LCT in the milder winter of 2015–2016 than in the colder winter of 2014–2015. Use of industrial urban habitats was substantially greater during the colder winter of 2014–2015, regardless of the LCT. Changing patterns of habitat use in urban areas in response to winter severity may indicate that energetic strategies were influenced by behavioral adaptations to maximize survival rather than driven solely by endogenous physiological rhythms (Gates et al. 2001).

We found further evidence of plasticity in the life-history strategies employed by geese in our study (Ankney 1996). During spring and summer following transmitter attachment, a portion of marked geese remained within the GCMA and other temperate areas, but others migrated to subarctic areas during breeding or molting periods (Dorak 2016). Migration timing and wintering locations of subarctic-breeding Canada Geese have changed concurrent with land use patterns, hunting regimes, and abundance of temperate-breeding geese (Gates et al. 2001, Scribner et al. 2003). For example, the Mississippi Valley population of subarctic-breeding Canada Geese (*B. c. interior*) shifted their wintering range northward from Mississippi and Arkansas to southern Illinois and northwest Kentucky in the mid-twentieth century. During 1980–2000, this population further shifted its wintering range northward to northern Illinois and southern Wisconsin (Craven et al. 1986, Gates et al. 2001, Arctic Goose Joint Venture 2013). Wintering at more northerly latitudes minimizes spring migration distances, allowing geese to arrive at breeding grounds earlier but has energetic tradeoffs (Alerstam and Lindstrom 1990).

Geese wintering in northern areas with cold temperatures must forage daily or arrive with sufficiently large energy reserves to ensure adequate body condition is maintained. Geese captured in the GCMA were 11–13% heavier than geese captured near Rochester, Minnesota (McLandress and Raveling 1981), and 18–20% larger than those wintering in southern Illinois and east-central Wisconsin (Gates et al. 2001). While diet information for geese in the GCMA is not available, we observed geese primarily foraging on dead grass during winter, which was likely a low-quality forage compared to agricultural grains (Kaminski et al. 2003), and we suspect that geese arrive in the GCMA during fall with large energy reserves to offset poor foraging conditions during winter. Geese that left the GCMA during winter may have been nutritionally stressed and the risk from hunting may have been outweighed by the risk of staying within the GCMA and facing continued declines in body condition. Additionally, geese may have exploited different types of food resources to offset reduced availability of waste grain within urban areas, similar to the behavioral plasticity exhibited by Atlantic Brant (*Branta bernicla hrota*) on the Atlantic Coast (Ladin et al. 2011). Historically, geese have met increased energy requirements by feeding on waste grain in agricultural areas, but hunting pressure and increasing urbanization have created vast sanctuaries where both temperate- and subarctic-breeding geese congregate in winter to maximize survival (Gates et al. 2001).

Interestingly, migration phenology of subarctic-breeding Canada Geese in our study also appears to be timed so that geese reach the GCMA before most hunting seasons open in the fall. Autumn migration of geese returning to the GCMA occurred earlier than other studies in the Midwest (Wege and Raveling 1983, Luukkenon et al. 2008). Approximately 70% of our transmittered geese returned to the GCMA prior to open hunting seasons. Moreover, 85% of the individuals marked in this study never left the GCMA during winter when hunting seasons were open. Increased hunting pressure outside of urban areas likely created a strong selection pressure for geese to remain in urban areas (Lima and Dill 1990). Given small home ranges and high survival rates in urban areas closed to hunting, management of goose populations in the GCMA using hunting may be challenging, as has been noted in other northern temperate areas (Luukkonen et al. 2008, Beaumont et al. 2013, Pilotte et al. 2014).

Dense concentrations of geese in urban areas can pose threats to humans, including contamination of water sources (Allan et al. 1995), aggressive behavior toward humans (Smith et al. 1999), disease transmission (Smith et al. 1999, Kullas et al. 2002), and strikes with aircraft (Dolbeer et al. 2000). Geese are the largest bird commonly struck by aircraft in North America and were responsible for 1,403 recorded bird strikes to civil aircraft from 1990 to 2012 (Dolbeer and Eschenfelder 2003, Dolbeer et al. 2014). Noteworthy goose–aircraft strikes include the destruction of a $190 million U.S. Air Force aircraft, which resulted in 24 human deaths (Dolbeer et al. 2000, Richardson and West 2000) and U.S. Airways Flight 1549 that crash-landed in the Hudson River in New York after striking multiple subarctic-breeding Canada Geese (Marra et al. 2009). Thus, geese can pose risks to human health and safety in urban areas, especially during winter when large flocks congregate around limited resources and there is a strong disincentive (i.e. lower survival probability) for emigration outside of the city.

Given the strategy possibly employed by geese in the GCMA to maximize energy conservation and minimize foraging in risky areas, we suggest that managers consider harassment during cold winter weather conditions when geese are below their LCT and energetic costs of moving following disturbances could affect survival. Harassment of geese during cold periods may "push" geese to the point where they have to choose to either move out of the area to find additional food or potentially risk death due to increased energy demands. However, we acknowledge the logistical and social challenges related to harassment of geese in urban areas; population management outside of winter may be necessary to reduce human–wildlife conflicts. Future research should focus on the thermoregulatory and movement strategies employed by geese in urban areas where food resources are likely limited.

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