



Stopover Duration of Fall-Migrating Dabbling Ducks

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ABSTRACT The amount of time migrating birds spend at stopover sites, or stopover duration, partially determines an individual's access to resources, the environmental conditions encountered, and the exposure to predation, which in turn affect survival and fecundity. As such, migratory behaviors such as stopover duration can have a considerable effect on populations of migrants and plans for their conservation. This is especially true for migrant waterfowl, which are explicitly conserved through Joint Venture (JV) partnerships under the North American Waterfowl Management Plan. Although waterfowl are one of the most heavily studied taxa, little is known about their stopover behavior due to the scope of migration. Consequently, conservation plans of many mid-migration JVs either omit estimates of stopover duration or rely on antiquated data to estimate energetic requirements. We used weather surveillance radar to identify and enumerate ducks emigrating from an important stopover area in central Illinois. By using radar data in combination with data from weekly aerial inventories, we estimated an average stopover duration for fall-migrating dabbling ducks (tribe Anatini) of 28 days (SD = 12) over 8 years (1996, 1997, 2003, 2005–2009). Our estimate was similar to the historical estimate of 28 days (1940–1966), which serves as the primary reference for the Upper Mississippi River Great Lakes Region JV conservation plan. In addition to a corroborative mean, we also found considerable inter-annual variation in stopover duration. Estimated annual stopover duration was correlated positively with an index of annual foraging habitat quality (Spearman's rank correlation; $r_s = 0.83$), suggesting ducks may have assessed local conditions and adjusted the spatiotemporal course of fall migration. If the stopover behavior of fall-migrating ducks is flexible and forage-dependent, it is possible ducks allocate their time among sites in a somewhat ideal and optimal fashion, which could substantially affect the way resources are allocated within the spatial context of a JV region. © 2012 The Wildlife Society.

KEY WORDS ducks, Illinois, migration, stopover duration, waterfowl, weather surveillance radar.

Migration is a critical component of the annual cycle of many bird species (Hutto 2000, Berthold 2001, Sillett and Holmes 2002, Mehlman et al. 2005, Moore et al. 2005). Migrating birds typically alternate between periods of flight and periods of rest and refueling at stopover sites. The amount of time spent at these sites (stopover duration) and the rate of refueling define the overall migration strategy and determine the spatiotemporal course of the migration. This course can determine access to critical resources, environmental conditions encountered, and exposure to predation, all of which in turn affect survival and fecundity (Owen and Black 1991, Sherry and Holmes 1995, McNamara et al. 1998, Hutto 2000).

Because stopover duration indirectly affects fitness, it is important to the conservation and management of migrant populations. This may be especially true in the case of

migrant waterfowl, where stopover duration affects conservation at multiple spatial scales. At the continental scale, stopover duration affects how waterfowl distribute themselves latitudinally from year to year (Bellrose and Crompton 1970, Nichols et al. 1983). At regional scales, such as those under the jurisdiction of the Joint Ventures (JVs) of the North American Waterfowl Management Plan (NAWMP; Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986, Canadian Wildlife Service, U.S. Fish and Wildlife Service, and Secretaria de Medio Ambiente y Recursos Naturales 2004), stopover duration partly determines the energetic demands placed on a region by a target population (*sensu* Prince 1979, Reinecke et al. 1989, Soulliere et al. 2007). At finer scales, such as a wetland complex, stopover duration may influence the amount of use an area receives and the resulting magnitude of harvest (Bellrose et al. 1979, Stafford et al. 2010a).

Several studies have informed our understanding of stopover duration for migrating birds, but only 4 have focused on ducks, with 3 during fall (Bellrose and Crompton 1970, Bellrose et al. 1979, Kremetz et al. 2009) and 1 during spring (Miller et al. 2005). Bellrose and Crompton (1970)

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used proportional distribution of indirect leg-band recoveries (i.e., recovered outside of the banding year) of mallards (*Anas platyrhynchos*) across latitudes as an index of the amount of time spent at that latitude. The authors' approach of drawing temporal inferences from spatial data required several analytical assumptions. Nonetheless, their 28-day estimate of the average stopover duration of fall-migrating mallards during 1940–1966 is still used in conservation planning efforts, such as those of the Upper Mississippi River and Great Lakes Region Joint Venture (UMRGLRJV; Bellrose and Crompton 1970, UMRGLRJV Board 1998, Soulliere et al. 2007). Bellrose et al. (1979) used weekly abundance estimates to derive total duck use during fall (i.e., use-days), and divided this value by the peak abundance estimate. This technique provided a conservative estimate of the time ducks spent at the study area, but did not account for myriad sources of variability. More recently, satellite telemetry has been used to track individual ducks during migration and document actual stopover durations (Miller et al. 2005, Kremenz et al. 2009). However, transmitters have the potential to physically burden marked avifauna and alter behavior related to migration and stopover (Wilson and McMahon 2006, Barron et al. 2010). Furthermore, the cost of satellite telemetry typically limits researchers to small samples, which may fail to capture variation among individuals, or differences associated with sex, age, or study year (e.g., weather, habitat, population density; Cox and Afton 2000, Petrie and Wilcox 2003, Lee et al. 2007, Kremenz et al. 2009).

Inter-annual variation in stopover behavior has been well-documented in shorebirds and passerines (Butler et al. 1987, Moore and Simons 1992, Schaub and Jenni 2001, Ydenberg et al. 2004), but only anecdotally in ducks (Bellrose and Crompton 1970, Bellrose et al. 1979). Further, some studies of passerines have documented significant links between stopover duration and resource availability, but no such investigation for waterfowl has had the temporal resolution and replication to empirically examine this relationship. Because migrating ducks rely on foraging habitats that often vary in quality from year to year due to the influence of hydrology (Havera 1999, Bowyer et al. 2005), a behavioral capacity to respond to resource variability by adjusting stopover duration should be especially pronounced in this taxon (Newton 2008).

We examined recent patterns of stopover in fall-migrating ducks, compared our estimates of stopover duration with historical estimates, and explored mechanisms for inter-annual changes in stopover duration. Our specific objectives were to: 1) analyze weather surveillance radar (WSR) data to estimate the number of ducks emigrating from a major waterfowl stopover along the Illinois River over 8 falls (1996, 1997, 2003, 2005–2009); 2) use these data in combination with weekly duck abundance estimates from aerial surveys to calculate average annual stopover duration; 3) compare our estimates of stopover duration with a historical estimate (1940–1966) for the same study site (Bellrose and Crompton 1970); and 4) explore a potential mechanism for the regulation of stopover duration by investigating

the relationship between stopover duration and foraging habitat quality.

STUDY AREA

We estimated stopover duration at a 14,431-ha complex of wetlands and backwater lakes in the Illinois River valley (IRV) of central Illinois (Fig. 1). The larger entities in the complex were the Emiquon preserve, Chautauqua National Wildlife Refuge (NWR), Clear Lake, Rice Lake, Big Lake, Goose Lake, and Duck Creek Cooling Lake. Our study area contained several wetland types, including areas managed for growth of moist-soil plants (Fredrickson and Taylor 1982), large areas of open water with submerged aquatic vegetation, floodplain forests, and shallow-water lakes (Havera 1999). Over the last several decades Chautauqua NWR has been the most important waterfowl refuge in Illinois with respect to use, and has been designated a Globally Significant Bird Area (Bellrose 1980, Havera 1999). In 2006, The Nature Conservancy and the U.S. Fish and Wildlife Service restored an additional 4,000 ha in the region, substantially increasing the amount of habitat for migratory waterfowl within this complex. Dabbling ducks (tribe Anatini) account for the majority of waterfowl use during fall; for example, 2008 aerial inventories of waterfowl attributed 81% of use to dabbling ducks. This complex is 60 km west of a WSR unit (KILX) located in Lincoln, Illinois. The location of KILX relative to the direction of duck movements to and

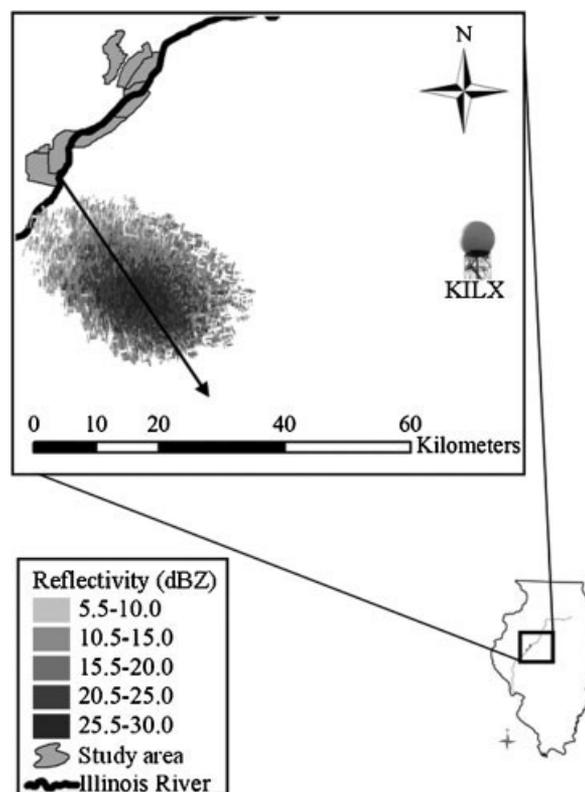


Figure 1. An estimated 20,485 ducks departing major wetland complex along the middle Illinois River, Illinois, USA, at 2340, 8 November 2008 (approx. 20 min after departure), as depicted on weather surveillance radar (KILX) 0.5° reflectivity scan (maximum reflectivity 30 dBZ; O'Neal et al. 2010). Black arrow indicates departure track (150°).

from the Illinois River allowed us to observe ducks as they departed our study area, but not when they arrived. During fall, ducks immigrating to the middle Illinois River from northerly directions descend upon our study area at a range of ≥ 70 km from KILX. Thus, if arriving ducks appeared on KILX at all, they likely only entered the bottom of the beam, which is >380 m above ground level (AGL) at >70 km range (Diehl and Larkin 2004). In contrast, ducks emigrating from our study area traveled SSE toward KILX, placing them within the radar's beam that extends from 125 m to 820 m AGL at 40-km range (O'Neal 2010).

METHODS

Classification of Targets

For many decades, WSR has been recognized as a tool for the study of bird movements (Nisbet 1963; Gauthreaux 1970, 1992; Gauthreaux and Belser 1998; Koistinen 2000; Larkin et al. 2002; Diehl et al. 2003). Recently, WSR has been validated as a quantitative technique for the study of waterfowl movements, which in some contexts can be related to specific locations (O'Neal et al. 2010).

Most WSR units generate 3 data fields: 1) reflectivity, which is a measure of the amount of energy returned to the radar by a target; 2) radial velocity, which is a measure of target motion toward or away from the radar, and; 3) spectral width, which is a measure of the variation in radial velocity during the radar's sampling period. Herein, we focus on reflectivity because it has the most consistent application to biological targets and their densities. Reflectivity is measured in units of Z (Crum et al. 1993) within sampled volumes of airspace (i.e., pulse volumes) with dimensions of 1 km in depth (slant range) by 0.95° in diameter for standard resolution (1995–2007) and 0.25 km in depth by 0.5° in diameter for the recently introduced super resolution (2008–2009). The linear width and height of pulse volumes increase with range and the resulting change in sampling volume must be taken into account when converting target density to estimates of target abundance. Because Z varies greatly depending on the size and number of targets, it is usually presented logarithmically as dBZ. Radar scans occur every 10 min when operating in the typical clear-air mode, often capturing airborne targets on multiple scans that may be viewed in sequence to create time-lapse depictions of movements.

Movements of aerofauna captured on WSR can be classified based on the natural history of organisms present in a region during the time period of interest (Russell and Wilson 1996, Larkin 2005). Specifically, emigrant ducks can be separated from insects, songbirds (*Passeriformes*), and other waterfowl based on the following criteria: 1) morphology relative to radar wavelength (e.g., mean radar cross-section is approx. 113 cm^2); 2) spatial distribution throughout the region and within a wetland complex (e.g., emanating from wetlands and often from the refuge areas within wetlands); 3) timing of movements at the daily and annual scale (e.g., 45-min post-sunset during traditional spring and fall migration periods; Bellrose 1980); 4) distance flown

(>40 km); 5) environmental conditions associated with movements (e.g., following wind; O'Neal 2010); 6) abundance at the source wetland relative to other species surveyed during weekly aerial inventories (i.e., Canada goose [*Branta canadensis*], greater white-fronted goose [*Anser albifrons*], snow goose [*Chen caerulescens*], American white pelican [*Pelecanus erythrorhynchos*], and American coot [*Fulica americana*]); and 7) temporally clustered departures that affect spatial distribution in flight (O'Neal et al. 2010). In a separate study during 2007 and 2008, we empirically validated these classification criteria for the same movements of ducks on KILX using portable radar and thermal infrared ground-truthing techniques (O'Neal et al. 2010).

Screening of WSR Data

We used the NEXRAD (NEXt generation RADar) data inventory hosted by the National Oceanic and Atmospheric Administration's (NOAA) National Climatic Data Center (NCDC; NOAA 2009a) to screen WSR data from KILX for missing data that would prevent us from examining all the emigrations in a given fall. Because a single movement could account for a substantial portion of all the relevant reflectivity emanating from the study area in a given fall (e.g., maximum movement in 1996 = 17% of total reflectivity for that fall), we excluded years that lacked data for even a single day within our study period. Of the 15 years for which KILX data were available (1995–2009), 9 (1996–1998, 2003, 2005–2009) lacked such gaps and had comprehensive datasets during fall (Oct–Dec). We downloaded level II KILX data for these years from the Hierarchical Data Storage System hosted by NOAA's National Environmental Satellite, Data, and Information Service (NOAA 2009b).

We used GRLevel2 software (Gibson Ridge Software, Suwanee, GA) to screen all scans from 1 October to 31 December (≥ 144 scans/day), flagged potential duck movements originating from our study sites, and identified cases in which weather systems obscured the radar domain to the extent that duck movements could have gone undetected (Gauthreaux and Belser 2005). We excluded fall 1998 due to weather obstruction, which left 8 years for final analysis. We analyzed all movements flagged in GRLevel2 using Integrated Data Viewer 2.6 (Unidata, Boulder, CO) to identify duck emigrations present in the radar data (O'Neal et al. 2010).

Quantification of Duck Departures on WSR

To quantify the number of ducks in a given departure event, we examined the time period following takeoff and ascent, prior to eventual dispersion or mixing with birds from other stopover areas (Diehl and Larkin 2004), identifying the single scan when total reflectivity first stabilized. We used Weather and Climate Toolkit 2.2 (NOAA, Washington, D.C.) to convert the individual scan from each movement to an ortho-rectified shapefile and then delineated the boundary of each emigrant group using ArcMap 9.3 (Environmental Systems Research Institute, Redlands, CA). We replicated the delineation process 3 times for all emigrations in 2008 ($n = 12$) and estimated error associated with our attempted

delineation using the mean coefficient of variation. Following Black and Donaldson (1999), we estimated the density of ducks for each pulse volume within a delineated emigrant mass using the equation:

$$\text{Number of ducks/km}^3 = \frac{Z \times 28}{\text{average S-band radar cross-section}}$$

where average S-band radar cross-section was 113 cm² (O'Neal et al. 2010). After calculating the density of ducks for each pulse volume within an emigrant mass, we estimated the size (km³) of each pulse volume based on the width of the beam (1996–2007: 0.95°; 2008–2009: 0.5°) and the median recorded range. We then multiplied the density of ducks in each pulse volume by the size of that pulse volume and summed the number of ducks among all pulse volumes to determine the magnitude of the entire movement. Lastly, we combined all movements in each year to estimate total number of emigrating ducks.

Quantification of Duck Use and Estimation of Average Stopover Duration

We required direct counts of dabbling ducks and other avifauna at our study site during fall of each study year to classify targets and estimate stopover duration. In 1995–2009, the Illinois Natural History Survey (INHS) conducted inventories of waterfowl abundance approximately weekly throughout our entire study area using a fixed-wing, single-engine aircraft at altitudes of 61–137 m and speeds of 161–241 km/h (Havera 1999). These aerial inventories did not employ concurrent ground counts. However, Stafford et al. (2007) reported that INHS aerial counts of waterfowl at an important stopover site on in our study area (Chautauqua NWR) were strongly correlated ($r = 0.78\text{--}0.85$) with abundance estimates from ground counts conducted during the same weeks during falls 2003–2005.

The mean start and end dates for these aerial surveys during the 8 years we analyzed were 14 October \pm 2 days (SD) and 20 December \pm 8 days (SD), respectively, and the mean interval between counts was 8.0 \pm 1.0 days (SD). Using weekly count data, we calculated total dabbling duck use for our study location during each fall, expressed as duck use-days (DUDs). We calculated total DUDs as the sum of the

moving average (Eberhardt and Thomas 1991, Williams et al. 2002) of dabbling ducks counted during fall inventories (Stafford et al. 2007). We estimated the average stopover duration (days) in a given year by dividing the annual estimate of DUDs during fall by the number of emigrating dabbling ducks estimated from WSR.

Analysis of Variation in Stopover Duration

Ducks that migrate through the IRV rely on wetland habitats that are dynamic due to highly variable hydrology, which causes unpredictable periods of drawdown and flooding. As such, production of plant foods for waterfowl in IRV wetlands can vary considerably from year to year (e.g., Havera 1999, Bowyer et al. 2005). To document this variation, INHS has estimated the quality of waterfowl plant foods (primarily moist-soil plants; Fredrickson and Taylor 1982) in IRV wetlands since the late 1970s using a simple, qualitative index (1–5; 1 = no or poor food production, 2 = fair, 3 = good, 4 = very good, 5 = excellent). Each August and September, observers assessed the extent and maturity of waterfowl plant foods aerially and from the ground at several backwater wetlands in the IRV and ranked overall food production in the region according to the index. For example, years where growing-season floods prevented or impaired moist-soil plant growth would receive index values of 1 or 2, respectively. Alternatively, years where hydrologic conditions allowed for considerable or extensive growth and plant maturity through September would receive index scores of 4 or 5, respectively. These unpublished values have been primarily used for internal reporting or presentation to the Mississippi Flyway Council Technical Section in annual habitat reports (i.e., index presented nominally). Techniques based on similar indices of habitat quality have predicted moist-soil plant seed production well (Naylor et al. 2005). We examined the relationship between our estimates of average stopover duration and the index of foraging habitat quality using Spearman's rank correlation to explore the possibility that ducks adjusted their migratory behavior according to local resource availability (PROC CORR, SAS v9.2; SAS Institute 2008).

RESULTS

On average, a quarter of nights showed emigration each year (Table 1). The magnitude of emigrations varied considerably

Table 1. Number of aerial surveys per year (n surveys), average aerial estimate of duck abundance per year and standard error (SE), estimated dabbling duck use for each fall based on aerial inventory data (UDs), radar-derived estimates of total emigrants (ducks; Total emigrants), number of emigrations (n emigrations), proportion of nights duck emigration occurred (Proportion), and estimated annual stopover duration (days) during falls 1996, 1997, 2003, and 2005–2009 at a major wetland complex in the middle Illinois River valley. We also provide study-period averages (Overall).

Year	n Surveys	Abundance		Total UD's	Total emigrants	n Emigrations	Proportion	Stopover duration
		\bar{x}	SE					
1996	9	60,778	8,690	3,401,475	177,883	15	0.27	19
1997	10	138,605	25,158	7,010,698	146,714	16	0.25	48
2003	10	57,168	8,997	3,477,913	91,300	18	0.29	38
2005	10	42,785	11,729	3,655,468	109,936	18	0.25	33
2006	10	49,344	7,693	3,574,975	165,105	17	0.25	22
2007	9	26,437	3,717	2,094,240	189,023	22	0.29	11
2008	10	35,941	6,972	2,658,003	84,952	12	0.16	31
2009	8	39,199	7,573	2,769,490	125,874	17	0.27	22
Overall	10	56,282	5,550	3,580,283	136,348	17	0.25	28

(Table 1). Error associated with our estimated delineation of a group of migrants on a given night was minimal, with a mean coefficient of variation of 1.3% across all departures in a 1-year subsample (2008). Aerial estimates of duck abundance varied considerably within and among years, but consistently increased through October and November until a peak in the last week of November or first week of December, followed by a steady decrease. Average stopover duration was 28 days (SD = 12) during our study period. Annual average estimates of stopover duration varied considerably among years, ranging from 11 days to 48 days (Table 1). Average annual stopover duration correlated positively ($r_s = 0.83$, $P = 0.011$) with the index of annual foraging habitat quality (Fig. 2).

DISCUSSION

Our direct estimation of the magnitude of migrant turnover at a discrete stopover location is an important advancement in the study of avian migration (Thompson 1993). The techniques we developed provide unique data for investigating many biological processes, including population trends (Routledge et al. 1999, Frederiksen et al. 2001, Farmer et al. 2007). Our results demonstrate how these data may be used to study a quantitative characteristic of migration that is critical to the biology and conservation of transitory populations.

By integrating radar data with aerial counts of migratory ducks, we were able to provide the first estimate of stopover duration for the typical suite of dabbling duck species that migrate through the mid-continent. Our 8-year dataset yielded an estimate that captured important variation due to factors that included fluctuations in environmental conditions and breeding population levels. These data improve our understanding of the stopover behavior of ducks and inform related conservation planning.

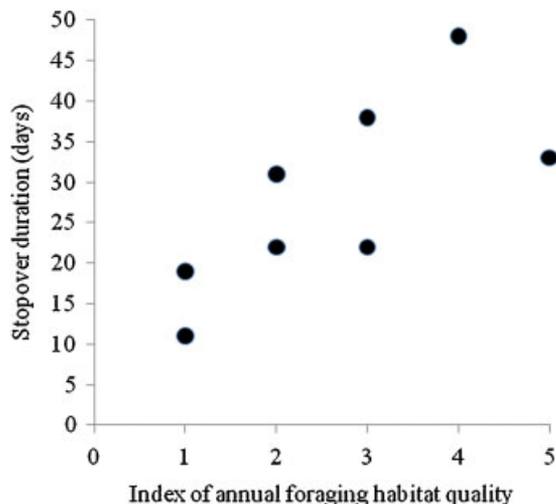


Figure 2. Scatterplot of radar-derived estimates of mean annual stopover duration (days) for dabbling ducks and an annual index of foraging habitat quality (1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent) in the Illinois River valley during falls 1996, 1997, 2003, and 2005–2009.

Conservation plans and energetic models for ducks in some North American ecoregions have relied on taxonomic extrapolations of single-species estimates from mallards (Bellrose and Crompton 1970, UMRGLRJV Board 1998, Soulliere et al. 2007). However, considerable variation in timing of migration exists among dabbling ducks due to variation associated with species, sex, age, and individuals (Bellrose 1980). We contend that our estimate of stopover duration for multiple Anatini species captured such variation and represents a robust estimate for use in conservation planning of migratory habitat used by multiple species (Mehlman et al. 2005).

Our 28-day estimate of mean stopover duration during fall migration is similar to Bellrose and Crompton's (1970) 28-day estimate for mallards and the 21-day estimate of Bellrose et al. (1979) for all dabbling duck species. Using an independent method, we have provided some of the first replication and corroboration of the original estimates of stopover duration, which are critical to conservation planning. Radio-tracking of mallards in the IRV during 2009 also yielded a similar average stopover duration estimate (29 ± 3 days; A. P. Yetter, INHS, unpublished data). Our mean estimate was considerably greater than the median estimate of stopover duration reported by Kremenz et al. (2009; 5 days) for mid-continent mallards during fall. However, their estimate was based on the stopovers of 40 individually marked birds (10/yr; 2004–2007). Because individual birds vary considerably in their stopover behavior (Yong and Moore 1993, Miller et al. 2005, Lee et al. 2007, Petersen 2009), the sample from the Kremenz et al. (2009) study may not be representative of the entire mallard population in that region. Moreover, the vast majority of the stopovers studied by these authors occurred at higher latitudes where we would expect more rapid fall turnover rates than central Illinois (Bellrose and Crompton 1970).

We acknowledge that error associated with aerial estimates and local duck harvests could have influenced our stopover duration estimates. If significant visibility bias existed in aerial survey estimates then corresponding estimates of stopover duration would be biased low. However, the surveyed habitats in our study area were typically more open than forested habitats often described as limiting visibility in other reports of aerial surveys (Reinecke et al. 1992, Pearse et al. 2008). Our estimates of stopover duration could also have been affected by the local harvest of immigrant ducks. However, harvest data collected during our study period indicated that less than 10% of the transient population passing through our study area (as estimated by radar) was harvested within the same area (P. Willms and C. Wieda, Illinois Department of Natural Resources, unpublished data; S. McClure, The Nature Conservancy, unpublished data). Therefore, it is unlikely that removal of these birds substantially biased our stopover duration estimates.

Our estimate of average annual stopover duration provided useful corroboration of an important parameter for conservation planning, but the variation among annual estimates may also be important. Indeed, our estimates of stopover duration varied >300% from year to year and our previous

validation of the methodology (O'Neal et al. 2010) revealed that this variation was partly or mostly biologically based, rather than attributable to measurement error. Based on the ability of WSR to detect a single duck at ranges exceeding those of ducks in this study (O'Neal 2010) and the spatially and temporally concentrated nature of typical emigrations from our study area, it is unlikely that any emigrations went undetected. In addition, we eliminated the potential bias caused by the reflectivity of weather events by omitting all years in which precipitation potentially obscured avian movements (i.e., 1998).

Based on the significant relationship between average annual stopover duration and our index of foraging habitat quality, we hypothesize that ducks adjusted the amount of time they spent at our study area according to the availability of food. This behavioral response to resources has been observed in other migratory birds. Western sandpipers (*Calidris mauri*) altered their stopover duration when an increase in the predator population indirectly affected access to forage, resulting in a 68% decrease in length of stopover over 9 years (Ydenberg et al. 2004).

If abundance of available food predicts rate of energy gain (Graber and Graber 1983, Baker et al. 2001), then the positive linear relationship between stopover duration and rate of energy gain observed in our study superficially contradicts the expected negative relationship based on optimal migration models (Bairlein 1985, Biebach 1985, Biebach et al. 1986, Alerstam and Lindström 1990, Yong and Moore 1997). However, actual migration strategies often deviate from optimality models according to species and contextual conditions. For example, when faced with a geographic barrier to migration, such as the Sahara Desert, passerines that accumulated fuel stores at medium rates stayed the longest (Schaub et al. 2008). Similarly, migrating shorebirds that experienced either low or high fattening rates stayed the shortest periods, and those with moderate fattening rates stayed the longest (Piersma 1987). Additionally, many of the optimal migration models have been derived from spring migration, when birds are generally more time-constrained (Cherry 1982, Izhaki and Maitav 1998, Yong et al. 1998). Those models that did consider outward migration have been based on neo-tropical birds, which are long-distance, obligate migrants that seem to be under selective pressure to minimize time spent migrating (Ellegren 1991, Lindström and Alerstam 1992, Klaassen and Lindström 1996, Fransson 1998).

We propose five possible reasons for the positive correlation we found between our index of foraging habitat quality and stopover duration. First, dabbling ducks are a combination of obligate and facultative migrants that migrate relatively shorter distances than neo-tropical migrants, and may therefore be less time-constrained (Schaub et al. 2008). Second, dabbling ducks may linger in Illinois in fall seasons with high-quality foraging habitat as long as weather remains tolerable, avoiding or postponing migration to lower latitudes further away from breeding grounds (Pienkowski and Evans 1985). Third, less foraging habitat (Bellrose et al. 1979) might concentrate birds, increase density-dependent

competition for resources (Bellrose and Crompton 1970), and thus motivate birds to depart. Fourth, the quality of aquatic habitat in Illinois is increasingly varied across space, with more aquatic features void of food than there were in the past (Bellrose et al. 1979, Stafford et al. 2010b). Ducks may respond to this situation by staying longer whenever they find high-quality habitat to reduce the cost of searching for suitable habitat amongst a mosaic of poor habitats. Fifth, mortality and stress related to hunting is greatest when birds first arrive at a stopover (Fleskes et al. 2002). Therefore, while favorable conditions persist, ducks, more so than non-hunted taxa, may stay at quality stopover sites once they have become familiar with them.

Regardless of the ultimate factors involved, our findings suggest ducks assessed local conditions and adjusted the amount of time they stayed in the study area. The food-based flexibility in stopover duration observed in our study provides potential evidence that ducks allocate their time adaptively among individual stopovers within the JV and the greater flyway (Harper 1982). Such a strategy would allow them to maximize resource acquisition, minimize predation risk, and maximize long-term survival and fecundity. Stopover behavior that is highly dynamic rather than annually consistent, has the potential to change the way we conserve wetland habitats for migrant waterfowl, and therefore warrants increased attention from researchers and conservation planners alike.

MANAGEMENT IMPLICATIONS

Regional waterfowl managers typically need to allocate resources among multiple sites, and abundance and use-day estimates have often been the primary metric to prioritize efforts. Herein, we demonstrated how WSR can be used to estimate the number or biomass of birds passing through a migratory site. We believe this technique provides an additional and likely more direct tool to help managers prioritize conservation actions among sites (Lee et al. 2007).

Using this technique to quantify the number of ducks moving through a specific site enabled us to examine stopover behavior in a spatially explicit way. Although our site-specific findings may not directly translate to parameters useful in the regional energetic models of JVs, several of our results can inform waterfowl conservation planning under JVs, such as the UMRGLRJV (UMRGLRJV Board 1998, Soulliere et al. 2007). First, energetic models could be improved by incorporating variability about parameter estimates of interest, such as that associated with our average estimate of stopover duration. That said, we recommend conservation planners from other regions use our data cautiously as migration strategies can differ among populations (Ellegren 1991). Second, the UMRGLRJV assumes that ducks spend 15–28 days in this region during fall. If true, our results suggest ducks use only 1–2 sites during their time in the region, and providing quality foraging habitat at traditional stopover areas within the JV region (i.e., middle IRV) may be especially important given that ducks may visit so few areas. Alternatively, because ducks in our study spent an average of 28 days at a single complex within the

UMRGLRJV, it is possible that average fall residence times throughout the entire region were greater than the assumed 15–28 days. If so, existing habitat objectives may need to be revised accordingly.

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