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Note

Stopover Duration of Mallards During Autumn in the Illinois River Valley

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ABSTRACT Estimates of time spent at migratory stopovers are often used to develop habitat conservation objectives for a variety of avian species, namely waterfowl. Because of limited previous research and a need for accurate conservation planning objectives, we estimated stopover duration and factors influencing stay of mallards (*Anas platyrhynchos*) in Illinois using radio telemetry during autumns 2009 and 2010. Total stopover duration of migrating mallards was approximately 68 days and was approximately twice that of previous studies which could have significant implications on habitat needs used for conservation planning purposes. Duration of stay post-capture did not vary by sex, body condition, year, or age but was inversely related to capture date. Our results suggest that wetland conservation objectives could increase 16.2% if our contemporary estimates were included in current planning models of the Upper Mississippi River and Great Lakes Region Joint Venture.

KEY WORDS *Anas platyrhynchos*, conservation, dabbling duck, Illinois River valley, joint venture, mallard, mark-recapture, migration, stopover duration, waterfowl.

Many species of birds suspend flights for various lengths of time during migration. The duration of stopover periods may vary relative to wetland conditions (O'Neal et al. 2012), weather severity (Schummer et al. 2010), temperature (Miller et al. 2005), precipitation (Krementz et al. 2011), and other factors (Miskimen 1955), and the amount of time between arrival and departure (i.e., stopover duration) is an important metric for conservation planning. Joint Ventures, established under the North American Waterfowl Management Plan, state agencies (e.g., wildlife action plans), and other entities use estimates of population size and stopover duration to estimate energetic carrying capacity for waterfowl and subsequently set wetland habitat objectives (Soulliere et al. 2007). Thus, estimates of stopover duration can directly affect conservation objectives and habitat management practices.

Stopover duration estimates for dabbling ducks in the upper Midwest are currently based on leg-band recoveries from 1940 to 1966 (Bellrose and Crompton 1970) and have been corroborated using waterfowl abundance indices from aerial surveys (Bellrose et al. 1979) and radar data (O'Neal et al. 2012). Estimates from these methods suggest dabbling ducks (*Anas* spp.) stay for 23–28 days in the Illinois River valley during autumn migration. However, Krementz et al. (2011, 2012) documented shorter spring (12 days) and autumn (15 days) stopover periods in mallards (*Anas platyrhynchos*) migrating between Arkansas and the Prairie

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Pothole Region using satellite transmitters, but sample sizes were small and individual variation was large (2–69 days). Consequently, considerable ambiguity exists in the estimates of stopover duration for autumn-migrating ducks. Recently, analytical methods have been suggested to deal with much of the uncertainty in properly estimating stopover duration due to imperfect detection of marked individuals and time prior to capture (Schaub et al. 2001, Lehnen and Krementz 2005).

We used telemetry and probability-based analytical techniques to estimate the stopover duration of mallards during autumn migration in central Illinois. Additionally, we investigated the factors affecting variation in stopover estimates post-capture using mark-recapture models. We provide contemporary and robust estimates of a key parameter used in wetland habitat models for conservation planning for waterfowl in the upper Midwest.

STUDY AREA

We conducted our research in the Illinois River valley (IRV), which is an important stopover region for migratory waterfowl that provides habitat for >20% of the Mississippi Flyway's wintering mallard population during autumn migration (Havera 1999:229). Our study area encompassed the La Grange Pool of the Illinois River, which extends from Peoria Lock and Dam (River Mile 158) near Peoria, Illinois, to the La Grange Lock and Dam (River Mile 80) south of Beardstown, Illinois, and the associated floodplain, lakes, ponds, and tributary streams within an agricultural matrix dominated by row crops (Fig. 1). We captured mallards at The Emiquon Preserve, Emiquon National Wildlife Refuge, and Sand Lake in Mason and Fulton counties, Illinois, USA.

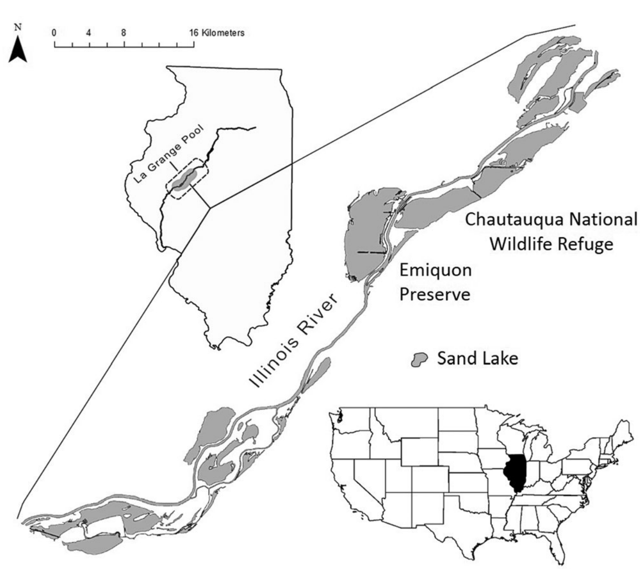

Figure 1. The primary study area consisting of the La Grange Pool of the Illinois River, Illinois, USA and backwater lakes and wetlands where we conducted trapping (i.e., Chautauqua National Wildlife Refuge, Emiquon Preserve, and Sand Lake) and tracking of individual mallards in autumns 2009–2010.

METHODS

Trapping and Telemetry

From 1 October through 1 December of 2009–2010, we captured 142 mallards (71 in 2009 and 71 in 2010) using night-lighting and swim-in traps and rocket nets baited with corn (Bishop and Barratt 1969, Cox and Afton 1998). We aged, weighed, measured (e.g., head, culmen, keel, wing chord, and tarsus length), and leg banded mallards. We attached a 23-g radio backpack-style transmitter (<2% of average body mass) equipped with an 8-hour mortality switch (Dwyer 1972) and released mallards within 3 hours of capture. We developed a size-corrected body condition index (BCI) for inclusion in stopover models using principal components analysis based on combined head and culmen lengths, tarsus length, and wing chord (Devries et al. 2008, Arsnoe et al. 2011). We adjusted for body size by regressing mass and our bird size index and dividing the predicted mass values from ordinary least-squares regression by the residuals to generate a size-corrected BCI. All methods and protocols complied with University of Illinois Institutional Animal Care and Use Committee (Permit #08029) and state and federal (Banding Permit #06507) requirements.

We triangulated radio-marked mallards via truck-mounted, null-peak antenna systems 6 days/week, excluding the first day post-capture (Samuel and Fuller 1996). If we failed to locate ducks from the ground for ≥7 days, we conducted aerial searches from a fixed-wing aircraft and had ground personnel verify all aerial locations. In addition to truck-mounted telemetry, we located radio-marked mallards from 29-m towers using 2 automated receiving units (ARU) placed centrally in our study area on Emiquon Preserve and Chautauqua National Wildlife Refuge (Ward et al. 2013). Although detection range likely varied by altitude of the transmitter and the ARU, we were able to routinely detect units placed >3 km from the receiving towers. Previous research suggests that migrating birds can be detected up to 20 km away (Ward and Raim 2011) and breeding passerines can be detected at distances up to 4 km from a tower-mounted ARU (Ward et al. 2014). If we detected birds by either ground or automated telemetry, we recorded individuals as present for that day. We terminated systematic ground tracking on 31 December and ARU tracking on 1 March of both years.

Stopover Duration Analysis

We excluded ducks from our capture histories that were harvested within the study area by hunters ($n = 42$). We then constructed daily capture histories for 100 mallards using a combination of automated and ground telemetry detections. We used ground telemetry detections only to create capture histories for 15 mallards because of interference in the automated units associated with the frequencies of those transmitters. We assumed an individual had emigrated from the study area if we failed to locate them via ground or aerial searches and 5 consecutive days elapsed with no ARU detections. Consequently, we created a grouping variable to differentiate mallards that departed the study area prior to freeze up (i.e., migrating; $n = 80$) and those that were detected after 31 December (i.e., wintering; $n = 20$). We defined freeze up as ≥90% ice coverage of lakes (excluding power plant cooling lakes) within the study area surveyed by the Illinois Natural History Survey during weekly autumn waterfowl surveys (Havera 1999). Freeze up occurred in our study area during the third week of December 2009 and 2010; therefore, we assumed that mallards remaining in the study area after 31 December were winter residents and periodic ground tracking after 31 December verified this assumption.

We calculated overall stopover duration using a combination of approaches (Stodola et al. 2014). First, we calculated minimum (i.e., observed or naïve) stopover duration of migrating mallards by subtracting capture date from the last day of detection. Second, we estimated stopover duration (i.e., time pre-departure) using encounter sampling through Program DISTANCE (Otis et al. 1993, Lehnen and Krementz 2005). We calculated strip width (i.e., stopover duration) by fitting the probability density function with 3 different models: 1) uniform key with a cosine adjustment, 2) uniform key with a simple polynomial adjustment, and 3) half-normal key with a cosine adjustment. We tested for model fit using a chi-squared goodness-of-fit test and assessed model performance and the relative fit of total stopover duration using Akaike's Information Criterion adjusted for small sample size (AIC_c). We compared the weights of evidence (Burnham and Anderson 2002) and model-averaged stopover duration and variances among competing models (Lehnen and Krementz 2005). When calculating stopover duration, we assumed that the probability of a mallard's capture was proportional to its residence time, a mallard had an equal probability of being captured at any point during its stay, and radio-marked mallards exhibited similar stopover duration as non-radio-marked mallards (Lehnen and Krementz 2005).

Thirdly, we estimated length of stay post-capture and investigated the associated biological and morphological factors using the live recaptures option and Cormack-Jolly-Seber (CJS) models in Program MARK (Lebreton et al. 1992, Schaub et al. 2001). We made detection a function of year, daily effort (whether or not we conducted ground telemetry on a particular day), whether detection was solely by an ARU, and sex of duck. We then fit 16 different models for apparent survival with all models including capture date (centered on median capture date) and a grouping variable (MIGR) to differentiate migrating and wintering individuals. One model included only MIGR and capture date, and the other 15 also included separately or in combination, year, sex, age, and BCI with MIGR and capture date.

Finally, we calculated overall stopover duration following Stodola et al. (2014) by summing stopover duration pre-departure from Program DISTANCE and time post-capture from Program MARK and then subtracting the minimum stopover duration. We used 100,000 Monte-Carlo simulations to calculate confidence intervals because each estimate of time spent within the study area (i.e., minimum stopover, total pre-departure, stay post-capture) was derived from different distributions (Stodola et al. 2014).

RESULTS

Minimum stopover duration of mallards was 34.7 days (95% CI: 30.0–39.3 days, range 1–77 days), irrespective of sex, age, and BCI. Using CJS models in Program MARK, the best approximating model of duration of stay post-capture (i.e., apparent survival) was the null model that included only migrating birds and capture date (Table 1). The 95% confidence intervals around parameter estimates for sex, BCI, year, and age from models with a $\Delta AIC_c < 2$ all overlapped 0, further indicating a lack of support. Estimates from the best approximating model indicated that migrating mallards remained in the study area after capture for 39.8 days (95% CI: 32.5–48.6 days). All models of stopover duration pre-departure in Program DISTANCE had similar parameter estimates and consequently high model uncertainty ($\Delta AIC_c \leq 0.26$); thus, we model averaged estimates across models ($\bar{x} = 62.4$ days, 95% CI: 50.3–77.4 days). Finally, using a combination of analytical methods, we estimate that total stopover duration was 67.7 days (95% CI: 54.8–82.3 days).

DISCUSSION

Our estimate of total stopover duration was more than twice previous estimates from Illinois (Bellrose and Crompton 1970, Bellrose et al. 1979, O'Neal et al. 2012) and more than 4 times those from other mid-latitude regions (Yamaguchi et al. 2008, Krementz et al. 2012). Not only was our estimate of total stopover duration far greater than previously reported, our estimates of minimum stopover duration were greater than the 22.5 days of Bellrose et al. (1979) for mallards and 28 days of O'Neal et al. (2012) for all dabbling ducks combined. It is possible that mallards monitored during our study responded to favorable wetland conditions by increasing stopover duration during our study

Table 1. Models of apparent survival with covariates for migrating mallards (MIGR), capture date (date), body condition index (BCI), sex, age, and their combinations ranked according to Akaike's Information Criterion adjusted for small sample size (AIC_c), the number of parameters (K), the change in AIC_c relative to the top model (ΔAIC_c), and the associated Akaike weight (w_i) describing stopover duration post capture of radio-marked mallards in the Illinois River valley of central Illinois during autumns 2009–2010.

Model	K	AIC_c	ΔAIC_c	w_i
MIGR + date	8	4,635.65	0.00	0.25
Sex + MIGR + date	9	4,637.06	1.41	0.13
BCI + MIGR + date	9	4,637.31	1.66	0.11
Year + MIGR + date	9	4,637.40	1.75	0.11
Age + MIGR + date	9	4,637.54	1.89	0.10
Sex + BCI + MIGR + date	10	4,638.81	3.16	0.05
Age + sex + MIGR + date	10	4,639.04	3.39	0.05
Year + BCI + MIGR + date	10	4,639.22	3.57	0.04
Age + BCI + MIGR + date	10	4,639.25	3.60	0.04
Age + year + MIGR + date	10	4,639.30	3.65	0.04
Year + sex + BCI + MIGR + date	11	4,640.77	5.12	0.02
Age + sex + BCI + MIGR + date	11	4,640.80	5.16	0.02
Year + age + sex + MIGR + date	11	4,640.89	5.24	0.02
Year + age + BCI + MIGR + date	11	4,641.16	5.51	0.02
Year + sex + age + BCI + MIGR + date	12	4,642.76	7.11	0.01
Year + sex + MIGR + date	10	4,650.91	15.26	0.00

years (O'Neal et al. 2012) or that estimates derived using other methodologies were conservative (Schaub et al. 2001). Although wetland forage quality in a large portion of the IRV during 2009–2010 was relatively low (O'Neal et al. 2012), an unusually high water table in the central portion of our study area (i.e., Mason County) in both years inundated many small and isolated farmed wetlands that likely contained waste grains, moist-soil plants, and aquatic vegetation and were of high quality to dabbling ducks (A. Yetter, Illinois Natural History Survey, personal observation). Mallards may have increased stopover duration in response to abundant and diverse wetland availability and plant communities during our study (Yetter et al. 2011:20, O'Neal et al. 2012). Thus, our estimates likely are attributable to the combined effects of stay increasing with habitat quality and increased accuracy from our analytical techniques compared to Bellrose and Crompton (1970).

Interestingly, Bellrose et al. (1979) used aerial survey data to surmise that mallards inhabit the IRV for approximately 60 days during autumn, although their data was insufficient to infer turnover of individuals. Bellrose and Crompton (1970) speculated that the mallards banded in the IRV had arrived in the area on average 6 days prior and based their estimate of total stopover duration on this assumption. However, they also concluded from banding data that mallards banded in the IRV remained in mid-latitude migration areas for 64.5 days; thus, given our improved tracking and analytical methods, our total stopover duration estimate of 68 days seems plausible. Yamaguchi et al. (2008) showed that duration of stay at stopover sites was inversely related to the number of stopover sites used. If wetland and other habitat conditions were more favorable in the IRV compared to other regions, mallards may have allocated a disproportionate amount of their time there.

Regardless of overall duration, we did not find evidence that duration of stay post-capture varied by year, sex, age, or BCI. Krementz et al. (2012) showed that autumn stopover duration was longer in females than males but did not vary with temperature or precipitation. Others have suggested that mallards migrate because of freeze-up (Drilling et al. 2002), but Krementz et al. (2012) noted birds departing prior to freeze-up. In contrast, we observed mallards exhibiting a variety of responses apparently to weather, including persistence in our study area well past freeze-up by using small and isolated patches of open water, power plant cooling lakes, agricultural ditches, and flowing streams (Illinois Natural History Survey, unpublished data). A possible explanation for longer stopover times is negative effects of transmitters on mallards themselves (Pietz et al. 1993); however, we located no studies that have related transmitter effects to stopover duration and note that Barron et al. (2010) showed in their meta-analysis that flying ability is unlikely affected by telemetry devices. Moreover, Fleskes (2003) found that distribution and departure dates of northern pintail (*Anas acuta*) in California fitted with harness transmitters were similar to unmarked pintails. Krementz et al. (2012) used larger satellite transmitters and determined that average stopover duration for female mallards was 15.4 days, significantly less than our estimate. Thus, we have no reason to conclude that relatively long stopover durations observed during this study were due to transmitters.

We collected data during January and February of both years using automated telemetry towers and periodic ground tracking when very little open water existed and found that 14.1% (20% of final sample) of our radio-marked mallards were detected within our study area during winter. These results coincide with the persistence of wintering mallards at mid-migration areas of Illinois during long-term aerial inventories of waterfowl (Illinois Natural History Survey, unpublished data). Pearse et al. (2008) noted that mallard abundances in western Mississippi in the late 1980s were almost 3 times greater than during the early 2000s, despite a >25% increase in breeding populations during that period (Zimpfer et al. 2013). Data from the United States Fish and Wildlife Service Midwinter Surveys for 1980–present expressed as a percentage of breeding population size from the traditional survey area (Zimpfer et al. 2013) for mallards indicate an upward trend in Missouri but a downward trend in Illinois, Iowa, Arkansas, Mississippi, and Louisiana (Fig. 2). These trends along with results based on harvest data presented by Green and Krementz (2008) showed that the core wintering area of mallards has not shifted northward since 1980. Thus, our relatively long stopover duration estimates are unlikely an artifact of northward shifts in wintering locations but instead may indicate flexibility of mallards to adjust their stopover duration during migration with variation in habitat quality (Krementz et al. 2012, O'Neal et al. 2012).

For migratory birds, stopover duration is likely related to the interaction of intrinsic (e.g., body condition) and extrinsic factors (e.g., food availability, weather; Gordo 2007). Poor habitat quality resulting from limited food or wetland availability, increased predation risk, or other factors could affect stopover duration (Russell et al. 1994, Schaub and Jenni 2001, Ydenberg et al. 2004). Significant increases in stopover duration during autumn could affect energetic carrying capacity estimates and habitat conservation objectives of the UMRGLR Joint Venture (Soulliere et al. 2007) and other step-down strategies (e.g., Illinois Wetlands Campaign; Krementz et al. 2012).

Post-hoc, we used the daily ration model approach of Soulliere et al. (2007) to simulate the effects of incorporating our stopover duration estimates into habitat conservation objectives of the Upper Mississippi River and Great Lakes Region (UMRGLR) Joint Venture. We estimated energetic carrying capacity for all spring- and autumn-migrating and wintering ducks in the upper Midwest using initial duration-of-stay estimates (Soulliere et al. 2007) and total stopover duration generated herein for mallards. For simplicity, we assumed that spring population estimates of Soulliere et al. (2007) were reasonable approximations of autumn populations and that food removal in autumn, winter, and spring is additive—that is, reduced food availability in autumn would equally reduce food available in the subsequent spring. We multiplied population size and population deficits by

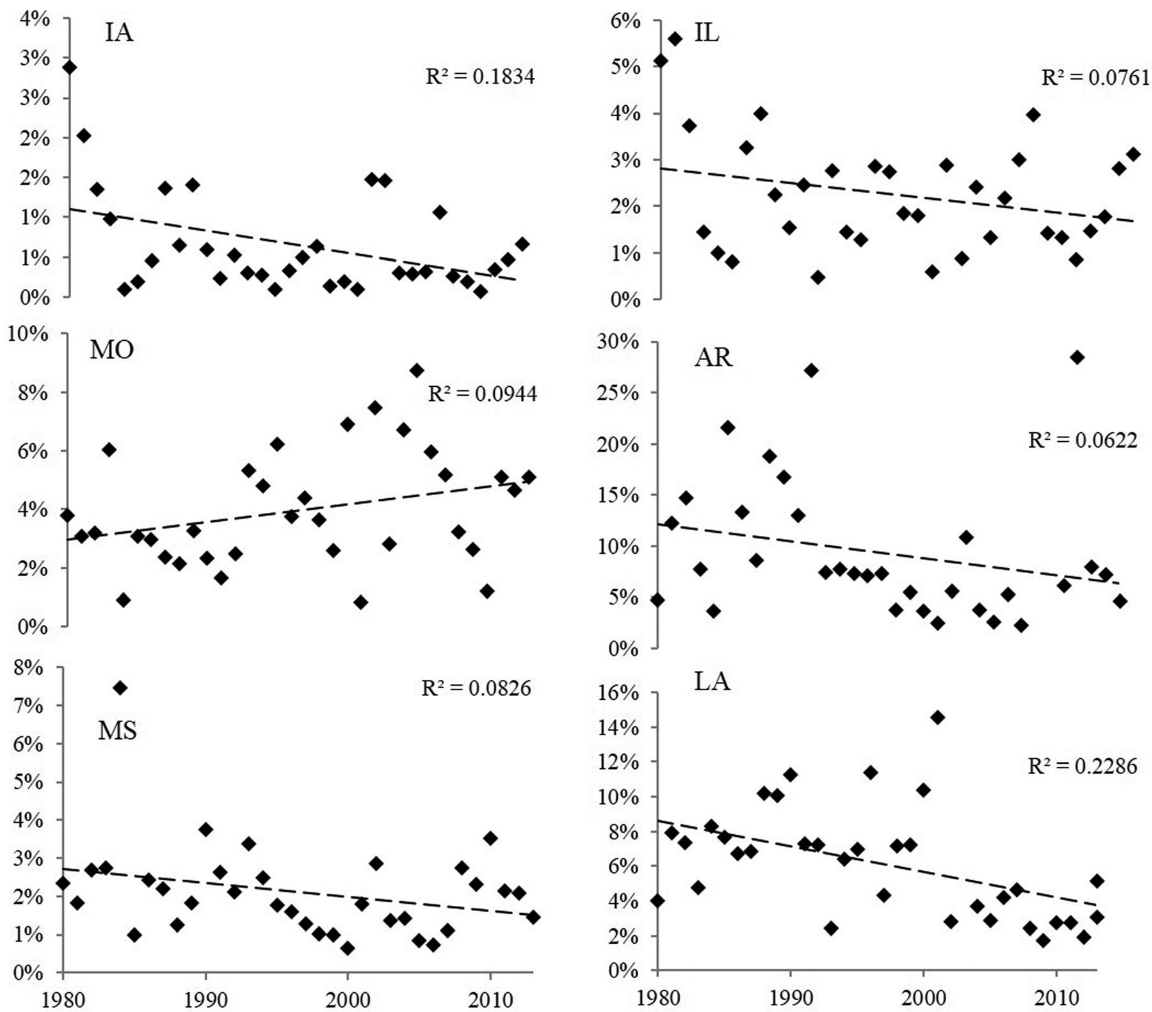

Figure 2. Mallard (*Anas platyrhynchos*) abundances for Iowa (IA), Illinois (IL), Missouri (MO), Arkansas (AR), Mississippi (MS), and Louisiana (LA), USA in the Mississippi Flyway from 1980–2013 from the United States Fish and Wildlife Service Midwinter Survey expressed as a percentage of the United States Fish and Wildlife Service breeding population size from the traditional survey area with an overall trend line and associated variance explained (R^2).

combined autumn and spring migration stopover lengths and winter use estimates to generate total use days. We multiplied total use days for each species by their daily energetic requirements and divided that product by the energy density in each wetland type. We then summed all habitat requirements across wetland types and species and determined that increasing combined spring and autumn stopover duration for mallards from 73 days (current assumption) to 113 days (revised estimate) would increase overall habitat objectives of the Joint Venture for all waterfowl, excluding geese and swans, by 16.2%. As food is already assumed to be limited for spring-migrating ducks in the upper Midwest (Soulliere et al. 2007), further reduction of food resources during autumn could further limit availability of foods during spring and affect subsequent stopover periods and ultimately fitness of spring migrants (Straub et al. 2012).

Our study investigated only mallard stopover in the IRV, but if other duck species stay in the IRV for longer periods than previously estimated (Bellrose et al. 1979), wetland conservation goals will need to be revised to compensate for the increased energetic carrying capacity demand. Furthermore, delayed freeze dates and decreased snow cover during winter may cause mallards and other species to spend more time at mid-latitude areas during migration (Schummer et al. 2010). Consequently, increased stopover durations due to the effects of climate change, alteration in land use, or other factors in the upper Midwest could cause significant increases in foraging habitat needs for migrating and wintering waterfowl.

MANAGEMENT IMPLICATIONS

Based on our results, scientists should consider the conservative bias in stopover duration estimates if time-prior-to-capture is assumed to be negligible. Longer stopover periods than currently assumed in mid-latitude regions will increase energetic carrying capacity requirements and subsequent habitat needs or require increases in food availability per unit area. Conservation planners should model potential increases in habitat requirements of longer stopover periods in mid-migration areas, especially if climate change continues to alter habitat conditions, which could result in further changes to migratory patterns in the future (Gordo 2007).

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