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RESEARCH ARTICLE

Nine years of tracking data reveal high post-breeding survival of radiomarked male woodcock in Rhode Island

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Abstract

To stabilize or increase populations of declining wildlife, it is essential to identify drivers of variation in survival. We evaluated male American woodcock (*Scolopax minor*) post-breeding survival and assessed the extent to which age, ordinal date, precipitation, and landscape habitat quality (indexed by relative probability of use scores) influenced post-breeding survival. Overall post-breeding survival estimates for 196 radiomarked male woodcock from May to September were high (i.e., 0.894, 95% credible intervals = 0.760–0.982), and the 4 covariates we assessed did not influence daily survival rate. The high post-breeding survival of woodcock during our study was consistent with the other estimates for the post-breeding period and is similar to other adult survival estimates throughout much of the annual cycle.

KEYWORDS

American woodcock, early successional forest, New England, nonbreeding, post-breeding, Rhode Island, *Scolopax minor*, shorebirds, survival, young forest

Animals that migrate divide their annual cycle among geographically disparate locations, which complicates their management (Bowlin et al. 2010). For migratory species that are declining, managers must identify factors in different portions of the annual cycle that impact population demography and implement strategies that can aid in

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reversing such declines (Marra et al. 1998, 2015; Webster and Marra 2005; Norris and Marra 2007). Since the 1970s, declines in abundance of North American avifauna have been documented, which has led to a call for intervention to prevent avifaunal collapse (Rosenberg et al. 2019). Concerns have been raised for migratory shorebirds in particular because they are a diverse and globally distributed group of species that are declining at a rate steeper than other avian taxa (Smith et al. 2023). Because shorebirds are distributed globally and partake in seasonal migrations, managers must rely on demographic data collected during both the breeding and nonbreeding periods to identify where the declines are occurring and thus more effectively manage populations (Sillett and Holmes 2002, Smith et al. 2023).

Although population dynamics of migratory birds can be determined by events during both breeding and nonbreeding periods (Sillett and Holmes 2002), a majority of research has focused on the breeding period with less known about nonbreeding periods (Bowlin et al. 2010, Marra et al. 2015). The post-breeding period is thought to be important because it is when migratory birds face physiological stress from energy depletion after nesting and raising young (Breuner 2011). During the post-breeding period, survival depends on the availability of food resources and environmental conditions. Limited access to quality foraging sites can make it difficult for individuals to restore energy reserves, and adverse weather can hinder recovery. The post-breeding period is essential for accumulating fat stores needed for migration, which affects their survival and reproductive success in the following breeding season. For well-studied migratory songbird species such as the American redstart (*Setophaga ruticilla*) and black-throated blue warbler (*Dendroica caerulescens*), poor habitat quality and adverse weather conditions on wintering grounds have been shown to negatively impact future breeding success (Marra et al. 1998, Sillett et al. 2000, Sillett and Holmes 2002, Wilson et al. 2011). Conditions at nonbreeding sites reduce adult survival, delay arrival to breeding sites, and limit reproductive output (Marra et al. 1998, Marra and Holmes 2001, Norris et al. 2004, Norris 2005, Norris and Marra 2007). In addition to negative carry-over effects to the breeding period, stationary periods of the annual cycle can play a critical role in preparing individuals for spring and fall migration, when survival of many migratory birds is low (Batt et al. 1992, Savard and Petersen 2015, Lamb et al. 2019, Senner et al. 2019, Hedh and Hedenström 2023). Recognizing that the post-breeding period is critical for replenishing energy reserves and preparing for migration highlights its significance in the overall survival and reproductive success of migratory birds. Thus, for migratory species, conditions that negatively impact survival during non-breeding periods can directly influence overall population dynamics (Fretwell 1972, Sillett et al. 2000, Sillett and Holmes 2002, Marra et al. 2015) For relatively long-lived species like shorebirds that have low reproductive potential, adult survival is crucial for maintaining population stability as even minor reductions in survival can lead to declines (Brown and Hickey 2001, Sandercock 2003, Weiser et al. 2020). Despite long-term declines in shorebird populations, very little is known about the factors limiting survival outside of the breeding season (Piersma and Lindström 2004, Smith et al. 2023), particularly for shorter-distance migrants such as the American woodcock.

The American woodcock is a shorebird and webless migratory gamebird that inhabits early and mid-successional forests throughout eastern and central North America (Sheldon 1967; Masse et al. 2014; Slezak et al. 2024a, b). Like many shorebirds, woodcock populations have declined during the last several decades (ca. 1% annually; Seamans and Rau 2024) and the cause for the decline is primarily attributed to the reduction of key early successional habitats (Dessecker and McAuley 2001, Kelley et al. 2008, Case and Sanders 2010). Hunting pressure does not appear to be contributing to population declines (Pace 2000, McAuley et al. 2005, Bruggink et al. 2013). Although initiatives focused on increasing forest management activities for woodcock have become more common during recent decades, populations in most states and provinces have continued to decline or only slightly increase despite landscape-level implementation of forest management activities (Kelley et al. 2008, Case and Sanders 2010, Weber and Cooper 2019, Seamans and Rau 2024). Given the negative population trend, it is important to conduct demographic studies on migratory woodcock to better understand their survival throughout the annual cycle and among different age classes (Case and Sanders 2010).

We used 9 years of survival data for radiomarked woodcock captured in Rhode Island, USA, to examine the influence of precipitation, age class, habitat quality (indexed using relative probability of use score), and ordinal date on this vital rate. Ordinal date reflects seasonal timing, which can influence the availability of resources and environmental conditions critical for survival. We hypothesized that post-breeding survival of male woodcock would vary with habitat quality based on previous works (Longcore et al. 1996). During the post-breeding period, males utilize diurnal coverts that are densely vegetated (Pettingill 1936, Sheldon 1967), which likely increases survival by reducing detection by ground and aerial predators (Masse et al. 2014). Also, during the post-breeding period, male woodcock exhibit little daytime movement and are primarily active during crepuscular periods when they commute to nocturnal roost fields that have less predator activity (Masse et al. 2013, 2014). Thus, we predicted that males inhabiting higher-quality sites during the post-breeding period, as indexed by probability of use scores from resource selection functions (Masse et al. 2014, Brenner et al. 2019, Slezak et al. 2024b), would have higher survival.

STUDY AREA

The study was conducted during the post-breeding period (15 May–1 September) during 2010–2021 in 5 state-owned Wildlife Management Areas (WMAs) and 2 Nature Conservancy Preserves in Kent and Washington counties, Rhode Island, USA (Figure 1). Our research occurred at Big River and Great Swamp for 9 years (2010–2012, 2016–2021), at Arcadia for 8 years (2010–2012, 2016–2017, 2019–2021), Carolina for 2 years (2017 and 2020), Nicholas Farm for 2 years (2019 and 2021), Tillinghast Preserve for 3 years (2016–2017, 2019), and Francis Carter Preserve for 6 years (2016–2021).

In this region of southern New England, mixed oaks (*Quercus* spp.), hickories (*Carya* spp.), and red maple (*Acer rubrum*) typically dominate in deciduous upland forests, whereas eastern white pine (*Pinus strobus*) was common in coniferous forests, and mixed forests typically contained combinations of oaks, white pine, and red maple. Atlantic white cedar (*Chamaecyparis thyoides*) swamps were common in forested wetlands (Enser and Lundgren 2006). Common understory flora in these mixed-age forests include Rugosa rose (*Rosa rugosa*), oriental bittersweet (*Celastrus orbiculatus*), multiflora rose (*Rosa multiflora*), and common milkweed (*Asclepias syriaca*; Enser and Lundgren 2006). Elevations in our study areas range from 13 to 172 m ($\bar{x}$ = 82 m). Our study areas included 3 broadly-described topographical divisions: narrow coastal plain, gentle rolling uplands, and hilly uplands (Slezak et al. 2024b). During the summer season in Rhode Island, mean monthly temperatures range from 13 to 23°C and mean monthly rainfall ranges from 7.1 to 8.1 cm from May to August annually. All study areas were forest-dominated and were actively managed (e.g., timber harvesting, prescribed burns, and mowing) to create and maintain stands of young forest for woodcock and other associated species of conservation concern (Buffum et al. 2019, Slezak et al. 2024b). Each area varied in its forest composition and the percentage of young forest, as detailed in a companion study (Slezak et al. 2024b).

METHODS

Woodcock capture, marking, and tracking

We used mist-nets daily during evening crepuscular periods from 5 April–1 June to capture male woodcock as they performed aerial courtship displays (Sheldon 1961, McAuley et al. 1993). At our sites, woodcock typically returned as early as late-February to early-March, with few males caught and marked before 5 April remaining at our study sites. Presumably, individuals continued migrating north (Masse et al. 2014, Brenner et al. 2019, Slezak et al. 2024b). These stops by males along their migratory routes to breed are similar to the movement pattern exhibited by itinerant breeding females (Slezak et al. 2024a). We assigned an age class (*n* = 99 second year versus *n* = 97 after second year) and sex to captured woodcock using bill length and feather characteristics (Martin 1964).

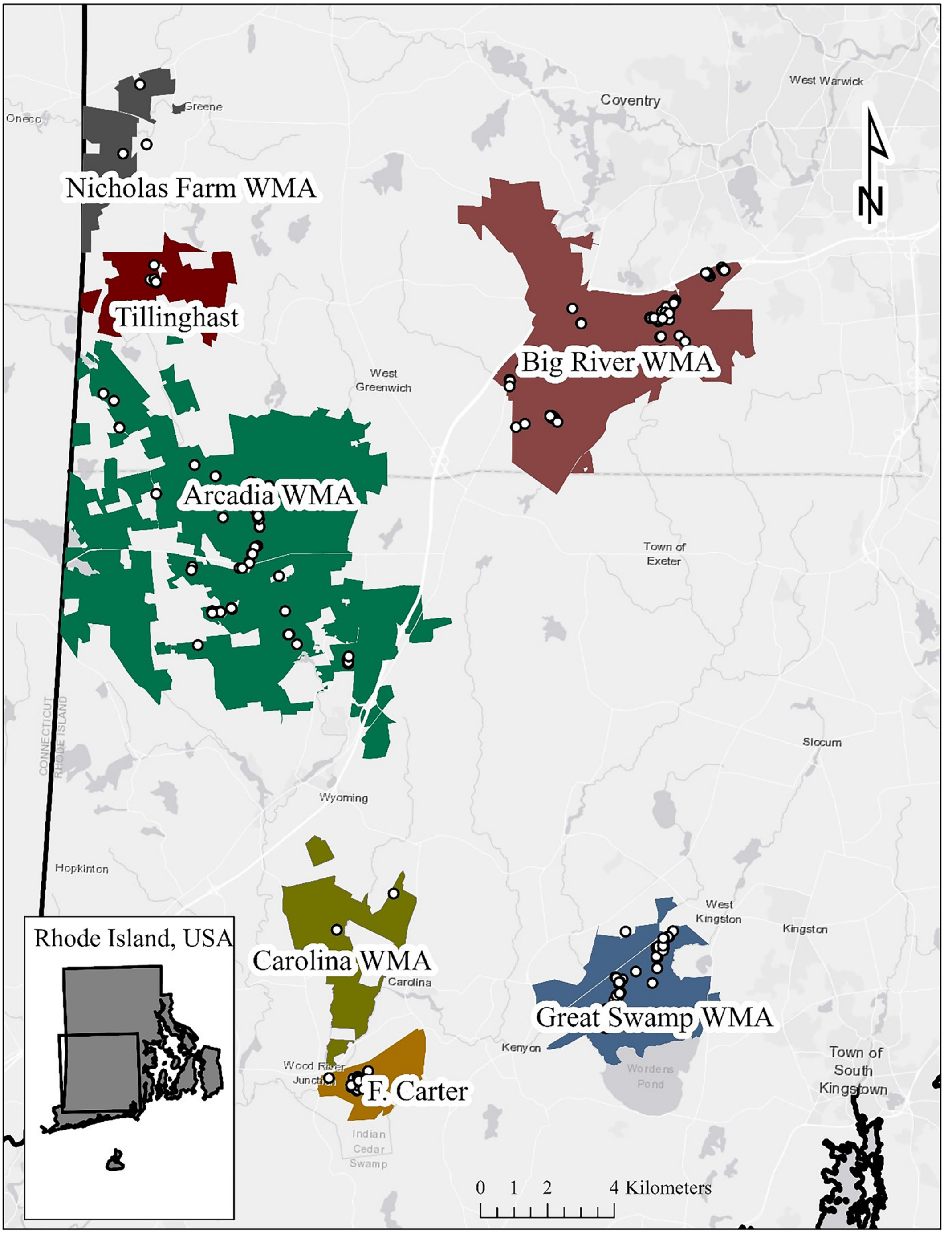

FIGURE 1 Locations of Wildlife Management Areas (Arcadia, Big River, Carolina, Great Swamp, Nicholas Farm) and Nature Conservancy Preserves (Francis Carter and Tillinghast) used as study areas to assess post-breeding (15 May–1 September) survival of male American woodcock in Rhode Island, USA, 2010–2021. White dots indicate capture locations of woodcock. Our research occurred at Big River and Great Swamp for 9 years (2010–2012, 2016–2021), at Arcadia for 8 years (2010–2012, 2016–2017, 2019–2021), Carolina for 2 years (2017 and 2020), Nicholas Farm for 2 years (2019 and 2021), Tillinghast Preserve for 3 years (2016–2017, 2019), and Francis Carter Preserve for 6 years (2016–2021).

For each captured bird, we measured mass, wing chord, width of outer 3 primaries, and culmen length (Greeley 1953, Martin 1964). We then attached an A5400 ATS (Advanced Telemetry Systems, Isanti, MN, USA) very high frequency (VHF) transmitter to a subset of males that met our criteria using a crimped wire belly band and cattle tag cement (McAuley et al. 1993). Additionally, we attached a size 3 USGS leg band to each bird. The mass of transmitters and attached materials was ≤4.0 g. The VHF packages were approximately 2.4–3.3% of the body mass of males in our study. We report annual sample sizes of tagged males for each of the study sites (Table S1, available in Supporting Information).

We tracked males ≥3 times/week ($\bar{x} = 23 \pm 1.48$ locations) from 15 May–1 September so that we could estimate post-breeding survival (McAuley et al. 1993, Masse et al. 2014, Brenner et al. 2019, Graham et al. 2022, Slezak et al. 2024b). We selected 15 May as the start of the post-breeding period because this was the date at which we observed declines in male breeding activity (e.g., singing; Brenner et al. 2019, Slezak et al. 2024b). Weekly locations for each individual were stratified across the day so that approximately equal numbers of diurnal locations were recorded in the morning (e.g., before 1200 EST) and afternoon (e.g., after 1200 EST). The location of each bird was assessed by walking in on individuals until the telemetry signal could be heard with only the antenna cord attached to the R2000 ATS receiver (Advanced Telemetry Systems, Isanti, MN, USA) and the Yagi antenna detached ($\bar{x}$ distance to bird was ≤18 m; Masse et al. 2014). Personnel could often view marked birds without flushing them using this approach. If a bird was flushed, we took a global positioning system point from the location. We exercised greater caution when approaching the bird during subsequent checks to ensure that we did not cause undue disturbance. During 2020–2021, when access was limited or we could not get landowner permission, we recorded bearings for some birds ($n = 15$) from 3 separate locations (>30 degrees apart) using Avenza maps (version 5.3.3) and then triangulated the bird's location using the package Sigloc (version 0.0.4; Berg 2015) in Program R (version 4.2.2; R Development Core Team 2024). In the case of suspected mortality of tagged males, we attempted to locate the VHF tag or carcass to identify a potential cause of death. Due to the absence of mortality switches in the VHF tags, we inferred mortality based on 3 or more consecutive relocations within the same location. All recovered males showed evidence of depredation (e.g., bite marks on the neck or missing body parts) or their VHF tags had visible signs of predator damage (i.e., damaged harness or teeth marks; Derleth and Sepik 1990).

We radiomarked 210 males that remained on the study area until at least 15 May. We excluded one individual for which the telemetry locations could not be associated with a probability of use score; relocations for this bird did not fall within habitat cover types deemed available to woodcock (Slezak et al. 2024b). We also excluded 13 males that were not aged in the field. Thus, 196 males were used in the analysis, and 18 of these 196 males died prior to the end of the study period across all years (Table S1).

For the 196 males, we extracted probability of use scores to each telemetry location using ArcGIS Pro (version 3.2; Esri, Redlands, CA, USA), and ensured that we used the relative probability of use map (2010–2012 or 2016–2021) that most closely corresponded with the time that the data were collected as described in Slezak et al. (2024b). We also retrieved precipitation (amount of rainfall that fell each day) data from the Kingston, RI, cooperative station using past weather archived on the National Oceanic and Atmospheric Administration website (NOAA; https://www.weather.gov/wrh/Climate?wfo=box). We chose the Kingston, RI weather station because it was most representative of the climatic conditions at the 7 study sites in southern Rhode Island (Figure 1; ≤30 km from all study sites). Finally, for ordinal date, which serves as a continuous variable and linear predictor of survival, we arranged the dates in each summer tracking dataset in sequential order.

Statistical analysis

We estimated post-breeding (15 May–1 September) daily survival rate (hereafter, DSR) using a nest survival model within a Bayesian framework (Schmidt et al. 2010). We used a nest survival model because it does not require the exact dates on which mortalities occurred to be specified (Mayfield 1975, Dinsmore et al. 2002).

We constructed an encounter history for each individual that documented its live-dead status during our study period (Schmidt et al. 2010). If an individual survived the entire study period, the encounter history contained a continuous string of 1s for each day we knew the individual was alive and in our study area. If mortality occurred, the encounter history showed 1s for the days the individual was confirmed alive, followed by NA values (i.e., blank values) for the days between the last confirmed live sighting and the visit that confirmed mortality. For individuals that died, the encounter history ended with a 0 on the day field observers confirmed mortality.

We derived estimates of DSR through a series of Bernoulli trials as

$$y_{i,t} \sim Bernoulli\,(y_{i,t\text{-}1} * DSR_i),$$

where $y_{i,t}$ was the assigned vital status for individual *i* at time *t* and $y_{i,t\text{-}1}$ was the assigned vital status of individual *i* at time *t-1*. Bernoulli trials ended on the last day an individual was observed alive or when mortality was confirmed. To evaluate the relationship between covariates and DSR, we used the logit link function as

$$logit\,(DSR_i) = \beta_0 + \beta_1 * age_i + \beta 2 * time + \beta 3 * precipitation_{i,t} + \beta 4 * probability\ of\ use\ score_{i,t} + year,$$

where β_0 was the baseline DSR on the logit scale and overall post-breeding season survival was DSR^{109} (i.e., the number of days within our study period). The linear predictor in our DSR model considered age (second year versus after second year), ordinal day, precipitation (rainfall), and probability of use score (Slezak et al. 2024b) as fixed effects; year was considered as a random effect. The probability of use score represents the likelihood that a woodcock will select a particular habitat type over others, based on factors such as food availability, cover, and environmental conditions, thereby reflecting the habitat's quality for supporting woodcock populations. We allowed values of precipitation and probability of use scores to vary temporally, where these values were assigned to individual *i* at each time *t* in which they were observed. We assigned precipitation and probability of use scores for days individuals were not monitored using a Normal (0, 0.001) prior for both the observed (i.e., field observations) and unobserved values (i.e., missing covariate values; Kéry and Royle 2016). This modeling process involved estimating hyperparameters for the previously mentioned prior, which was done using a Uniform (0, 100) prior. We used Uniform (0, 1) priors for modeling DSR and Normal (0, 0.001) priors for fixed effect coefficients for the remaining parameter estimates. We fit a single global model and a second model that contained only the random effect of year to calculate the variance explained by the fixed effects (Grosbois et al. 2008). We fit our DSR models in JAGS 4.3.1 (Plummer 2003) using the jagsUI 1.6.2 package (Kellner 2024) in Program R (version 4.2.2; R Development Core Team 2024). We ran 4 chains of 25,000 iterations, considered 5,000 as burn-in, and saved every tenth iteration. We confirmed our models converged using the Gelman-Rubin statistic, where $\hat{R}$ values < 1.05 indicated convergence (Gelman and Rubin 1992). We report coefficient values (β), where 95% credible intervals (hereafter, CrI) that did not overlap zero indicated significant effects from model coefficients.

RESULTS

Our DSR models successfully converged according to $\hat{R}$ values. Baseline DSR was 0.999 (CrI = 0.997, 1.000), resulting in an overall post-breeding survival estimate of 0.894 (CrI = 0.760, 0.982). The variance estimate for the global model was 0.639 (CrI = 0.506, 0.859) and 0.646 (CrI = 0.507, 0.865) for the null model. Our fixed effects model explained 1.5% of the observed variation in male post-breeding survival across years. The CrIs for all our model covariates overlapped zero, indicating none of them had a significant effect on DSR (Figure 2), thus, we did not consider variation among those variables to be important.

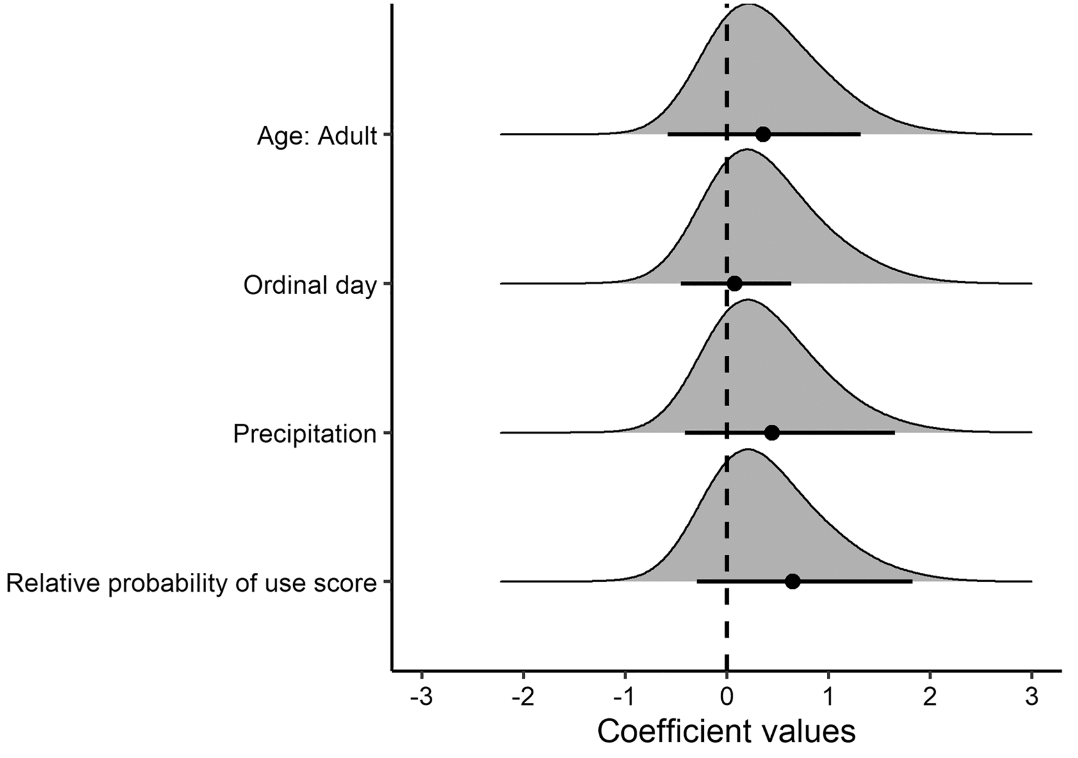

FIGURE 2 Posterior predictions from a post-breeding (15 May–1 September) daily survival model for male American woodcock captured in Rhode Island, USA, 2010–2021. The posterior predictions illustrate the distribution of possible coefficient values for the fixed effects of 4 covariates. The points represent the mean values, while the horizontal black lines indicate the corresponding 95% credible intervals. The vertical black dashed line is at zero and used to visualize the direction of effects.

DISCUSSION

Our study provided an assessment of male woodcock post-breeding (15 May–1 September) survival. As predicted, post-breeding survival of males was high (90%), as was also found in Maine, a more northerly region of the woodcock's breeding range (90%–93%; Derleth and Sepik 1990). Like Derleth and Sepik (1990), we were unable to reject our null model (constant daily survival), and we observed a small number of mortalities over the course of our study. Thus, there was no effect of the covariates that we assessed.

The post-breeding survival estimates from our study of males in Rhode Island along with those from other studies done elsewhere at other periods of the annual cycle (Table 1) suggest that adult survival during the post-breeding period may not be limiting population growth (Derleth and Sepik 1990). Survival estimates are generally lower during winter than other portions of the year, especially during years with exceptional snowfalls (McAuley et al. 2019), which has led others to suggest that the wintering period may be more limiting (Krementz et al. 1994, Krementz and Berdeen 1997, Pace 2000, McAuley et al. 2005). Studies that have assessed sex- and age- specific survival in different portions of the annual cycle have found little to no significant differences among age groups or sex (Derleth and Sepik 1990, Krementz and Berdeen 1997, Pace 2000, McAuley et al. 2005, Bruggink et al. 2013) aside from recently fledged young having lower survival than adults during the post-breeding period (Derleth and Sepik 1990). Survival rates for woodcock during different portions of the annual cycle were similar or higher than annual survival estimates of many other shorebird species, some of which have stable or increasing populations (Méndez et al. 2018). In addition, studies of hunted populations have shown

TABLE 1 Season-specific survival estimates from throughout the annual cycle of American woodcock in eastern North America. Most studies compared survival of males (M) and females (F) and <1 yr old (hatch-year; HY) compared to >1 yr old (after-hatch-year; AHY). If sex was not separated or if no age or sex differences were found, then we report a single overall survival estimate for that period. If survival differed by age and/or sex, then we report each separately. These estimates were generated using various methodologies; they serve as general approximations of summer survival for comparative purposes across studies rather than definitive values.

Life cycle phases	Dates	Year(s) and location(s) of study	Sample size	Survival estimate	Citation
Pre-migration (spring)	unspecified*	eastern N. America	107	0.810	Fish, A. 2021. American woodcock (*Scolopax minor*) migration ecology in eastern North America. Dissertation, University of Maine, Orono, USA
Spring migration	16 Feb–1 Mar	(1987–1989) Maine	150	0.881	Longcore, J. R., D. G. McAuley, G. F. Sepik, and G. W. Pendleton. 1996. Survival of breeding male American woodcock in Maine. Canadian Journal of Zoology 74:2046–2054.
Spring migration	unspecified*	eastern N. America	107	0.880	Fish, A. 2021. American woodcock (*Scolopax minor*) migration ecology in eastern North America. Dissertation, University of Maine, Orono, USA
Post-migration (spring)	unspecified 7-week period*	eastern N. America	107	0.520	Fish, A. 2021. American woodcock (*Scolopax minor*) migration ecology in eastern North America. Dissertation, University of Maine, Orono, USA
Breeding	15 May–15 Aug	(1963–2015) eastern and central N. America	See appendix (https://doi.org/10.5281/zenodo.2532006)	0.79 (M); 0.77 (F); 0.40 (HY)	Saunders, S. P., M. T. Farr, A. D. Wright, C. A. Bahlai, J. W. Ribeiro, S. Rossman, A. L. Sussman, T. W. Arnold, and E. F. Zipkin. 2019. Disentangling data discrepancies with integrated population models. Ecology 100:1–14.
Breeding	1 Apr–15 Jun	(males 1987–1989) and females (1986–1989 Maine	150 (M) 89 (F)	0.789 (M); 0.826 (F)	Longcore, J. R., D. G. McAuley, G. F. Sepik, and G. W. Pendleton. 1996. Survival of breeding male American woodcock in Maine. Canadian Journal

TABLE 1 (Continued)

Life cycle phases	Dates	Year(s) and location(s) of study	Sample size	Survival estimate	Citation
					of Zoology 74:2046–2054. Longcore, J. R., D. G. McAuley, G. F. Sepik, and G. W. Pendleton. 2000. Survival of female American woodcock breeding in Maine. Pages 65–76 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium, United States Geological Survey Information and Technology Report 2000-0009, Laurel, Maryland, USA.
Post-breeding	15 Jun–20 Oct	(1982–1984) Maine	32 (AHY) 96 (HY)	0.89–0.92 (AHY) 0.64–0.68 (HY)	Derleth, E. L., and G. F. Sepik. 1990. Summer-fall survival of American woodcock in Maine. The Journal of Wildlife Management 54:97–106.
Post-breeding	15 May–1 Sep	(2010–2021) Rhode Island	196	0.894	Slezak, C. R., D. L. Bakner, R. J. Masse, and S. R. McWilliams. 2025. Nine years of tracking data reveal high post-breeding survival of radiomarked male woodcock in Rhode Island. Wildlife Society Bulletin e1591.
Hunting season and fall migration	21 Oct–14 Dec	(1987–1989) Maine	150	0.853	Longcore, J. R., D. G. McAuley, G. F. Sepik, and G. W. Pendleton. 1996. Survival of breeding male American woodcock in Maine. Canadian Journal of Zoology 74:2046–2054.
Fall (hunted sites)	1 Sep–30 Nov	(1997–2000) northeast (ME, NH, PA, and VT)	913	0.636	McAuley, D. G., J. R. Longcore, D. A. Clugston, R. B. Allen, A. Weik, S. Williamson, J. Dunn, B. Palmer, K. Evans, W. Staats, G. F. Sepik, and W. Halteman. 2005.

(Continues)

TABLE 1 (Continued)

Life cycle phases	Dates	Year(s) and location(s) of study	Sample size	Survival estimate	Citation
					Effects of hunting on survival of American woodcock in the northeast. The Journal of Wildlife Management 69: 1565–1577.
Fall (non-hunted sites)	1 Sep–30 Nov	(1997–2000) northeast (ME, NH, PA, and VT)	913	0.661	McAuley, D. G., J. R. Longcore, D. A. Clugston, R. B. Allen, A. Weik, S. Williamson, J. Dunn, B. Palmer, K. Evans, W. Staats, G. F. Sepik, and W. Halteman. 2005. Effects of hunting on survival of American woodcock in the northeast. The Journal of Wildlife Management 69: 1565–1577.
Fall western Great Lakes (non-hunted sites)	10 Sep–8 Nov	(2001–2004) midwest (MI, MN, and WI)	1035	0.893	Bruggink, J. G., E. J. Oppelt, K. E. Doherty, D. E. Andersen, J. Meunier, and R. S. Lutz. 2013. Fall survival of American woodcock in the western Great Lakes Region. The Journal of Wildlife Management 77:1021–1030.
Fall western Great Lakes (hunted sites)	10 Sep–8 Nov	(2001–2004) midwest (MI, MN, and WI)	1035	0.820	Bruggink, J. G., E. J. Oppelt, K. E. Doherty, D. E. Andersen, J. Meunier, and R. S. Lutz. 2013. Fall survival of American woodcock in the western Great Lakes Region. The Journal of Wildlife Management 77:1021–1030.
Pre-migration (fall)	unspecified*	eastern N. America	129	0.910	Fish, A. 2021. American woodcock (*Scolopax minor*) migration ecology in eastern North America. Dissertation, University of Maine, Orono, USA
Fall migration	unspecified*	eastern N. America	129	0.950	Fish, A. 2021. American woodcock (*Scolopax minor*) migration ecology in eastern North America.

TABLE 1 (Continued)

Life cycle phases	Dates	Year(s) and location(s) of study	Sample size	Survival estimate	Citation
					Dissertation, University of Maine, Orono, USA
Post-migration (fall)	unspecified*	eastern N. America	129	0.800	Fish, A. 2021. American woodcock (*Scolopax minor*) migration ecology in eastern North America. Dissertation, University of Maine, Orono, USA
Wintering	15 Dec–15 Feb	GA (1982–1983), SC (1989–1990), and VA (1991)	256	0.647	Krementz, D. G., J. T. Seginak, D. R. Smith, and G. W. Pendleton. 1994. Survival rates of American woodcock wintering along the Atlantic Coast. The Journal of Wildlife Management 58: 147–155.
Wintering	1 Nov–early Jan	(2010–2013) New Jersey	271	0.365–0.706	McAuley, D. G., G. Zimmerman, B. Allen, C. Dwyer, and T. R. Cooper. 2019. Survival rates and stopover persistence of American Woodcock using Cape May, New Jersey, during fall migration. *Proceedings of the Eleventh Woodcock Symposium* (D. G. Krementz, D. E. Anderson and T. R. Cooper, Editors). University of Minnesota, Minneapolis, MN, USA. pp. 146–153.
Wintering	1 Dec–15 Feb	(1994–1996) Louisiana	160	0.720 (AHY) 0.587–763 (HY)	Pace III, R. M. 2000. Winter survival rates of American woodcock in south central Louisiana. The Journal of Wildlife Management 64:933.
Wintering	25 Dec–7 Feb	(1994–1995) Georgia	25	0.720	Krementz, D. G., and J. B. Berdeen. 1997. Survival rates of American woodcock wintering in the Georgia Piedmont. The Journal of Wildlife Management 61:1328–1332.

(Continues)

TABLE 1 (Continued)

Life cycle phases	Dates	Year(s) and location(s) of study	Sample size	Survival estimate	Citation
Nonbreeding	15 Aug–15 May	(1963–2015) eastern N. America	See appendix (https://doi.org/10.5281/zenodo.2532006)	0.46 (M) 0.61 (F) 0.76 (HY)	Saunders, S. P., M. T. Farr, A. D. Wright, C. A. Bahlai, J. W. Ribeiro, S. Rossman, A. L. Sussman, T. W. Arnold, and E. F. Zipkin. 2019. Disentangling data discrepancies with integrated population models. Ecology 100:1–14.

little to no additive mortality from hunting, suggesting that this is also not a contributing factor in woodcock declines (Pace 2000, McAuley et al. 2005, Bruggink et al. 2013). Despite the relatively high woodcock survivorship (Table 1), along with a wide-scale effort to increase young forest (Weber and Cooper 2019), woodcock populations have continued to decline (Weber and Cooper 2019, Seamans and Rau 2024).

MANAGEMENT IMPLICATIONS

The relatively high post-breeding survival estimates that we and others observed suggest that adult male survival is highly unlikely to be the primary cause of woodcock population declines. Given the strong evidence that adult male survival is not limiting, future research could benefit from examining other vital rates or factors influencing populations beyond this cohort. Furthermore, wildlife management efforts should focus on maintaining suitable habitats that support this demographic, as the post-breeding period appears to be a portion of the annual cycle contributing to population resilience. Given the low and variable nest and brood survival documented in other studies, habitat management focused on enhancing female nesting success may be key to stabilizing woodcock population declines.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ETHICS STATEMENT

All woodcock trapping, handling, and tagging activities were conducted in accordance with the University of Rhode Island Animal Care and Use Guidelines under Animal Care and Use Protocol AN#10-02-017.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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