AMERICAN WOODCOCK (*SCOLOPAX MINOR*) MIGRATION ECOLOGY IN EASTERN NORTH AMERICA

Year 4 Report of the Eastern Woodcock Migration Research Cooperative

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The Eastern Woodcock Migratory Research Cooperative is a collaborative group partnered to understand the migratory ecology of American Woodcock in eastern North America. This project would not have been possible without the support from multiple state, federal, international, non-profit agencies, and universities. This document contains draft information that has not yet been subject to peer review. As such any results or information reported herein should be cited as unpublished data, and we anticipate interpretation may change as additional years of data are collected.

Cover photo: Tagged woodcock on nest after being followed from Virginia to Quebec. Credit to Mathieu Tetreault, Environment and Climate Change Canada

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Executive Summary

Declining populations of migrant animals worldwide have prompted a renewed interest in understanding migration ecology. Migrating birds are particularly vulnerable as habitat loss, anthropogenic structures, and novel predators are widely believed to contribute to population declines. The American Woodcock (*Scolopax minor*) is a migratory forest bird that has experienced population declines of 1.1 percent per year for the past five decades. Relatively little is known about woodcock migration, so we initiated the Eastern Woodcock Migration Research Cooperative in 2017 to provide insights into woodcock migration in the Eastern Management Region. From Fall 2017 – Spring 2021, we deployed 463 GPS transmitters on woodcock captured in 14 states and 3 Canadian provinces throughout eastern North America, which provided data on 422 migration attempts and 379 full migratory paths. We have used these data to provide insights into the migratory phenology of woodcock, including their migratory initiation dates, length of their migration, and number of stopover sites used. We have also described how weather affects the likelihood that woodcock will migrate, conducted a preliminary assessment of migratory connectivity between the Eastern and Central Management Regions, and modeled areas which are likely candidates for woodcock habitat management. During spring 2022, we also documented nesting attempts of GPS-marked birds, including unprecedented observations of females making long-distance migrations between successive nesting attempts. We will continue to collect data from Fall 2021 through Spring 2022, and we also plan to expand analyses to address survival during migration, regional differences in private and public land use, habitat use throughout the full annual cycle, response to light pollution during migration, a genomic analysis of woodcock population connectivity, and nesting/post-breeding dispersal.

Introduction

Across temperate regions of North America, animals must contend with seasonally influenced thermal extremes, changing food abundance, and stochastic weather events. Some species cope with these dynamic conditions by traveling between seasonally suitable habitats in predictive cyclical movements termed migrations (Dingle 2014). Migratory ecology remains an understudied portion of the annual lifecycle for many species (Faaborg et al. 2010). Migrating individuals must continually locate suitable areas, termed stopover locations, to rest and rebuild energy reserves needed to continue migration (Rodewald and Brittingham 2004, Taylor et al. 2011). At the same time, animals must also contend with hazards such as anthropogenic structures (e.g., mobile communication towers, buildings, wind turbines; Loss et al. 2014, Graff et al. 2016, Zimmerling and Francis 2016) and unpredictable weather (Newton 2007). For some species mortality peaks during migration (Sillett and Holmes 2002, Klaassen et al. 2014), and navigating this risky period may contribute to the observed declines of migratory species and possibly affect population viability (Frick et al. 2017).

The American Woodcock (*Scolopax minor*; woodcock hereafter) is a migratory forest bird that has experienced long-term declines of 1.1% per year over the past 50 years (Seamans and Rau 2018). Woodcock are distributed throughout eastern North America; primarily breeding in the northern United States and southern Canada and overwintering in the southern United States. The species is managed as two discrete populations associated with the Central and the Eastern Management Regions (Figure 1). Previous research suggests woodcock migrate south between October – December and north between January – April (Krementz et al. 1994, Butler 2003, Meunier et al. 2008, Moore 2016). These prior studies are principally derived from observations of local changes in woodcock abundance (e.g. arrival of spring migrants) and radio-tracking studies at breeding, wintering, and stopover sites. While this information is useful, it is inherently limited in scope and cannot be applied broadly across the species' range. This migratory knowledge gap prompted the Association of Fish and Wildlife Agencies to identify migratory ecology as one of the woodcock's greatest research needs (Case and Associates 2010).

Tracking woodcock throughout migration presents numerous challenges, as individuals must be continually relocated over vast distances, almost always spanning numerous states and often two countries (Myatt and Krementz 2007, Klaassen et al. 2014). Recent advances in transmitter tracking technologies allow for woodcock to be tracked using satellite transmitters (Moore 2016). Satellite transmitters can now simultaneously collect global positioning system (GPS) location data and remotely transmit locations to a central database via satellite or cellular networks. Between 2014 and 2016, Moore (2016) used satellite transmitters to track migrating woodcock in the Central Management Region, but were unable to track more than a few woodcock that migrated into the eastern half of the range. To that end, we created the Eastern Woodcock Migration Research Cooperative with the goal of describing the migratory ecology of woodcock in the Eastern Management Region. Our specific objectives are to 1) describe departure and arrival phenology for migrating woodcock, 2) determine how weather affects woodcock migratory decisions, 3) evaluate migratory connectivity for woodcock, including movements between the Central and Eastern Management Regions via migration, 4) determine how to best prioritize landscapes for woodcock management, 5) quantify the survival of woodcock during migratory periods, 6) measure woodcock use of public, private, and protected lands, 7) determine how woodcock habitat selection changes throughout the full annual cycle, 8) quantify woodcock responses to light pollution, 9) measure genetic connectivity between woodcock populations, and 10) document nesting of GPS-marked woodcock and evaluate migratory movements associated with nesting. Objectives 4 and 6 – 10 are new objectives for the EWMRC this year, and will be the focus of two new doctoral students. This report documents results obtained during the project's first four years of data collection, and will focus on what we have learned so far with respect to objectives 1 – 4, with future work to focus on objectives 5 – 10.

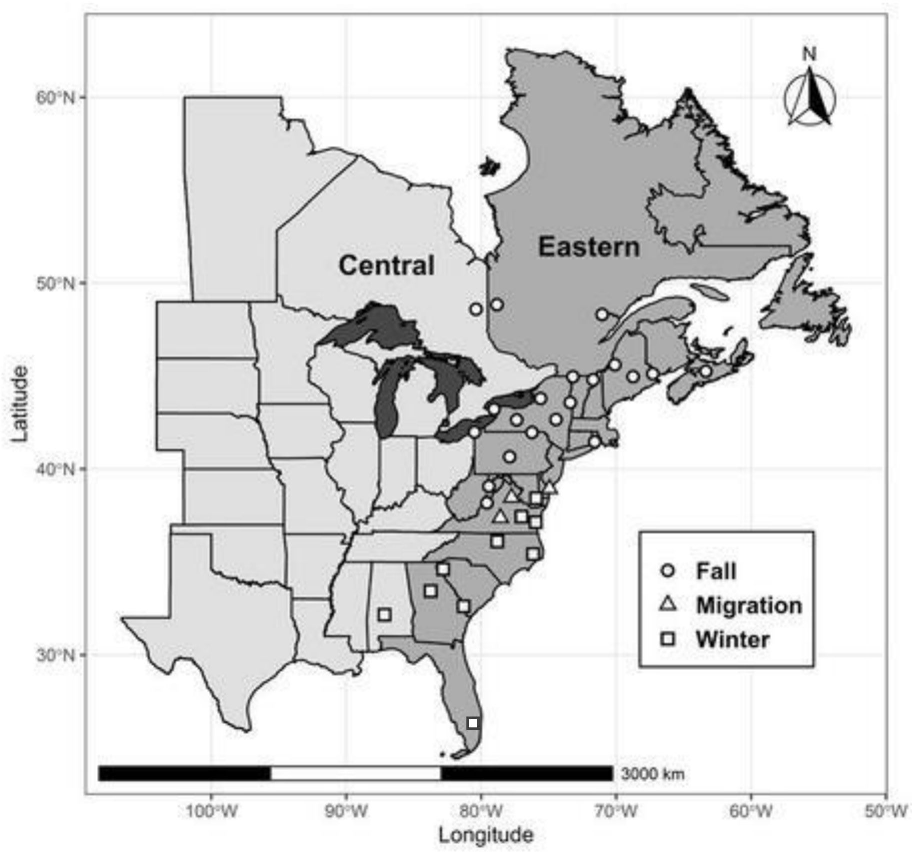

Figure 1. American Woodcock Central and Eastern Management Regions, with distribution of EWMRC capture locations, by season of capture.

Methods

Study Area

The Eastern Woodcock Migration Research Cooperative study area is primarily comprised of the Eastern Woodcock Management Region, the spatial unit at which the United States Fish and Wildlife Service and Environment and Climate Change Canada manage woodcock populations (Figure 1). During the fall (September – October), we focused capture efforts in ME, NY, PA, RI, VA, VT, and WV, as well as Nova Scotia, Ontario, and Quebec. During winter (December-February), we focused captures in AL, FL, GA, MD, NC, NJ, SC, and VA. We relied on the knowledge of local biologists to identify areas suitable for woodcock capture within states and provinces, and we deployed transmitters on a wide variety of land ownership types, including state, federal, non-governmental organization, and private. As woodcock departed for spring and fall migration, they left capture locations and migrated either north or south, respectively, traversing multiple states and provinces throughout the eastern United States and Canada.

Capture

Woodcock were captured using mist nets during crepuscular flights (Sheldon 1960) and by spot-lighting roosting birds (Rieffenberger and Kletzly 1966, McAuley et al. 1993). We set mist net arrays near roosting fields, travel corridors, and forested wetlands to capture birds as they left diurnal use areas and flew to night roosts. Additionally, we used spotlights and thermal imaging scopes to locate woodcock roosting in fallow or agricultural fields and captured them using handheld nets. Once captured, we aged woodcock to two ages classes (adult [after hatch year or after second year; > 1 year old] or young [hatch year or second year; < 1 year old]) using wing plumage characteristics and sexed (male or female) them using a combination of wing plumage and bill length (Mendall and Aldous 1943, Martin 1964). Woodcock were fitted with a Lotek PinPoint 75, 120, or 150 ARGOS-compatible satellite transmitter, attached with a leg-loop style harness (Moore 2016). The GPS collected locations at pre-programmed dates and times, and transmitted data to a central database using the ARGOS satellite system. We stopped receiving locations when birds either dropped their transmitter or the bird died, thereby causing the transmitter to rest on the ground and attenuate the signal, or if the transmitter's battery died or the transmitter otherwise failed. We have developed methods to differentiate tag loss/failure from mortality in order to estimate survival from the GPS location data (see Future Directions).

Transmitter Schedules

Transmitters were manually programmed using Lotek PinPoint Host software (Lotek Wireless Inc., Newmarket, Ontario, CA), which allowed us to specify the exact date and time locations were collected. Transmitters had limited battery life and were expected to collect a maximum of 75, 100, and 125 locations for the PinPoint 75, 120, and 150 tags, respectively, before losing power. We created three location collection schedules; frequent (one location per day), infrequent (one location every few days), and hybrid (combinations of frequent and infrequent periods) to maximize the amount of data we collected for each woodcock. Hybrid schedules contained a frequent collection period (~30 days) during the peak of migration, and infrequent collection periods before and after the frequent period. Frequent and infrequent schedules were used on both sexes during both fall and spring migration, with hybrid schedules used during spring migration as the potential migration periods exceeded the expected number of GPS locations possible under a frequent schedule. Frequent schedules were useful to evaluate fine scale movement and provide the finest resolution (i.e., one day) to document stopover ecology. Infrequent schedules allowed for woodcock to be tracked for longer periods of time, thus possibly providing data on both spring and fall migration for an individual bird. Infrequent schedules also increased the probability of receiving future data transmissions when individuals used stopover sites with poor satellite signal and failed to upload locations (e.g., mountainous areas with a steep slope).

From Fall 2017 – Spring 2020, we set these transmitter schedules to take locations exclusively during the afternoon to capture woodcock stopover habitat use. Beginning in Fall 2020, PinPoint tags were manufactured to record the altitude of GPS locations, which introduced the capability to differentiate between night flight and night stopover locations. Accordingly, in Fall 2020 we began using transmitter schedules that alternated between taking day and night locations, and introduced a subset of schedules that took only night locations, to capture as many migratory flight points as possible. We randomly assigned a transmitter schedule to each captured woodcock while attempting to control for equal sex and age ratios among programming treatments and capture locations. Location data were transmitted to a remote database using the ARGOS satellite system after every third GPS location was collected. We manually downloaded woodcock locations every 1 to 5 days, and used Movebank (Movebank Project, accessed 13 August 2021) to store all location data.

To determine whether each woodcock movement included a full migratory departure, transit, and settling stage, we classified the beginning and end point of each track. The first point in a sustained, directional movement of greater than 7km per step was classified as the beginning of a migratory movement, while the last point before that movement switched to undirected, < 7km steps was classified as the end of the migratory movement. If the last location received from the bird was a part of a migratory step, then the migratory trajectory was classified as incomplete and excluded from statistics on the distance traveled during migration and time spent migrating. Additional analyses were performed for specific objectives, as described in each corresponding results section.

Preliminary Results

Data collected to date

Since the EWMRC began deploying transmitters in Fall 2017, we have deployed 463 transmitters on birds in 17 states and provinces (Table A1). These transmitters have gathered over 27,000 locations (Figures 2, 3) since 2017, and during the Fall 2020 and Spring 2021 migration seasons alone, we recorded over 173,000 kilometers of migratory movements (Figure 3). In total, we documented 422 migration attempts and 379 full migratory paths (Table A2). Since altitude capacity was introduced on PinPoint transmitters in Fall 2020, we have also recorded at least 160 night flight locations that can be used to characterize woodcock flight altitudes during migration (Figure 4).

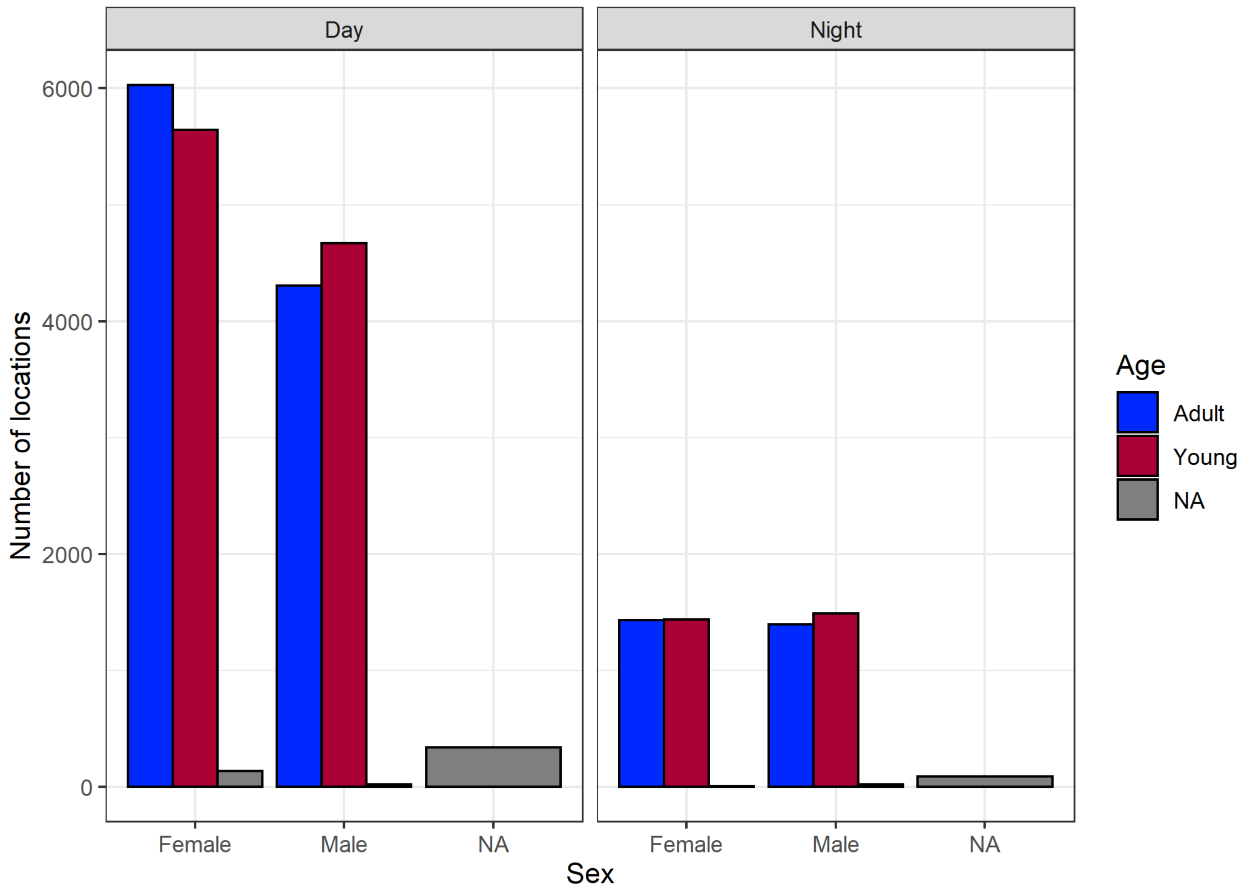

Figure 2. Counts of GPS locations recorded by tagged woodcock from Fall 2017 – Summer 2021. Over 27,000 locations have been gathered since the project began, including day and night locations and large sample sizes from each combination of sex and age classes. NA reflects birds not assigned a sex or age class at capture.

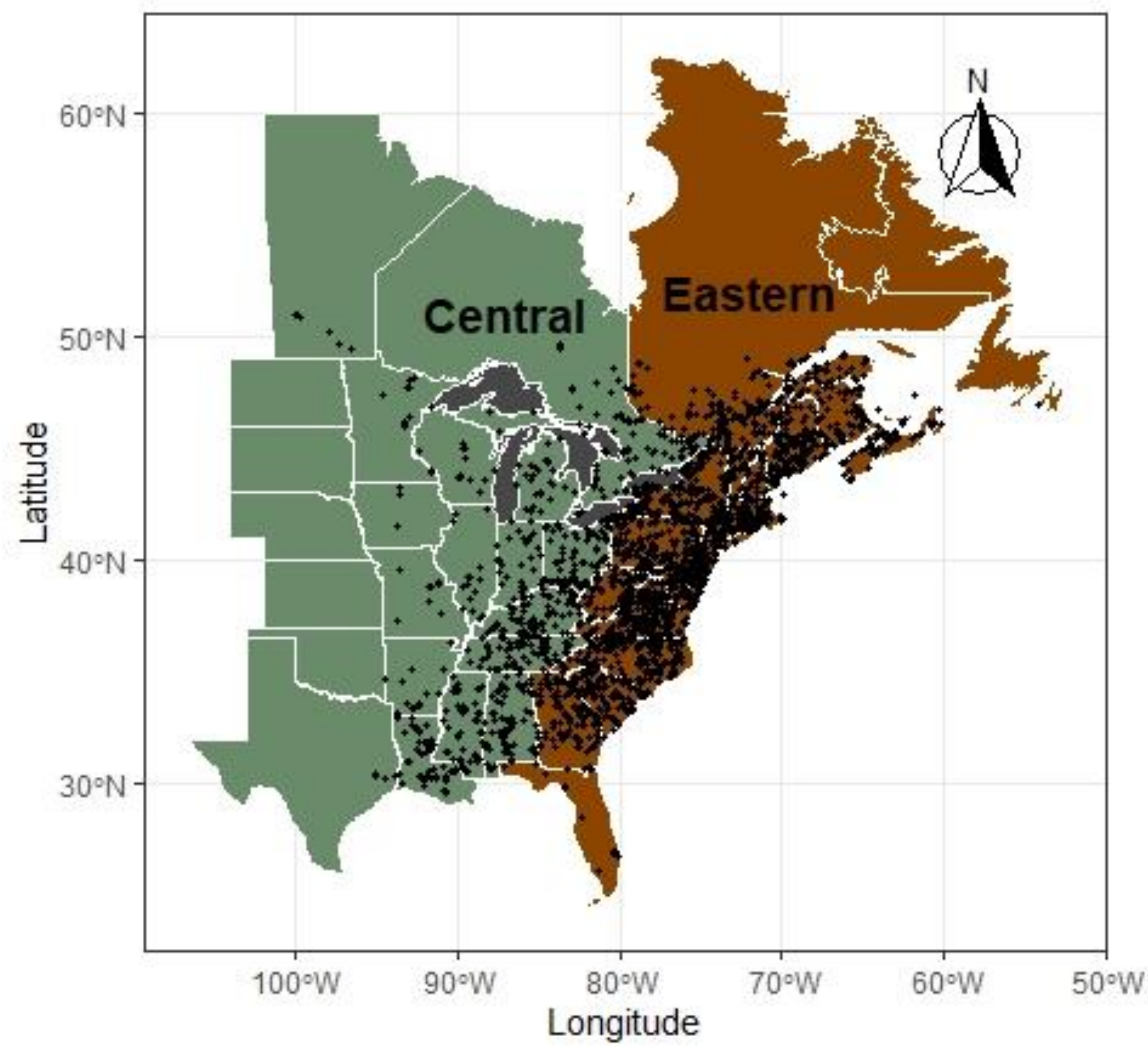

Figure 3. GPS locations collected by woodcock marked through the EWMRC from Fall 2017 – Summer 2021. Over 27,000 locations have been gathered since the project began, including day and night locations and large sample sizes from each combination of sex and age classes. NA reflects birds not assigned a sex or age class at capture.

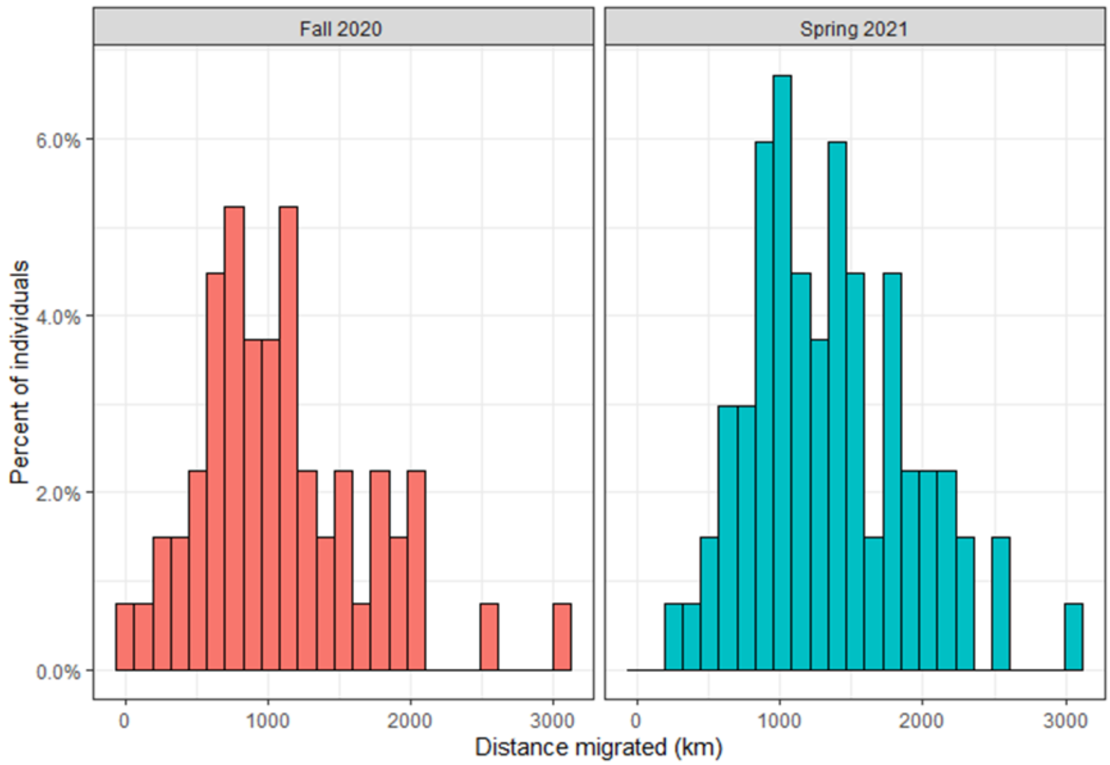

Figure 3. Distance migrated by GPS-tagged American Woodcock in Fall 2020 and Spring 2021. Distance migrated is the sum of all individual steps between the initiation and the termination of migratory movements. Woodcock moved slightly further during Spring 2021 than Fall 2020, likely due to disproportionate sampling of woodcock at the southern extent of their range during winter captures.

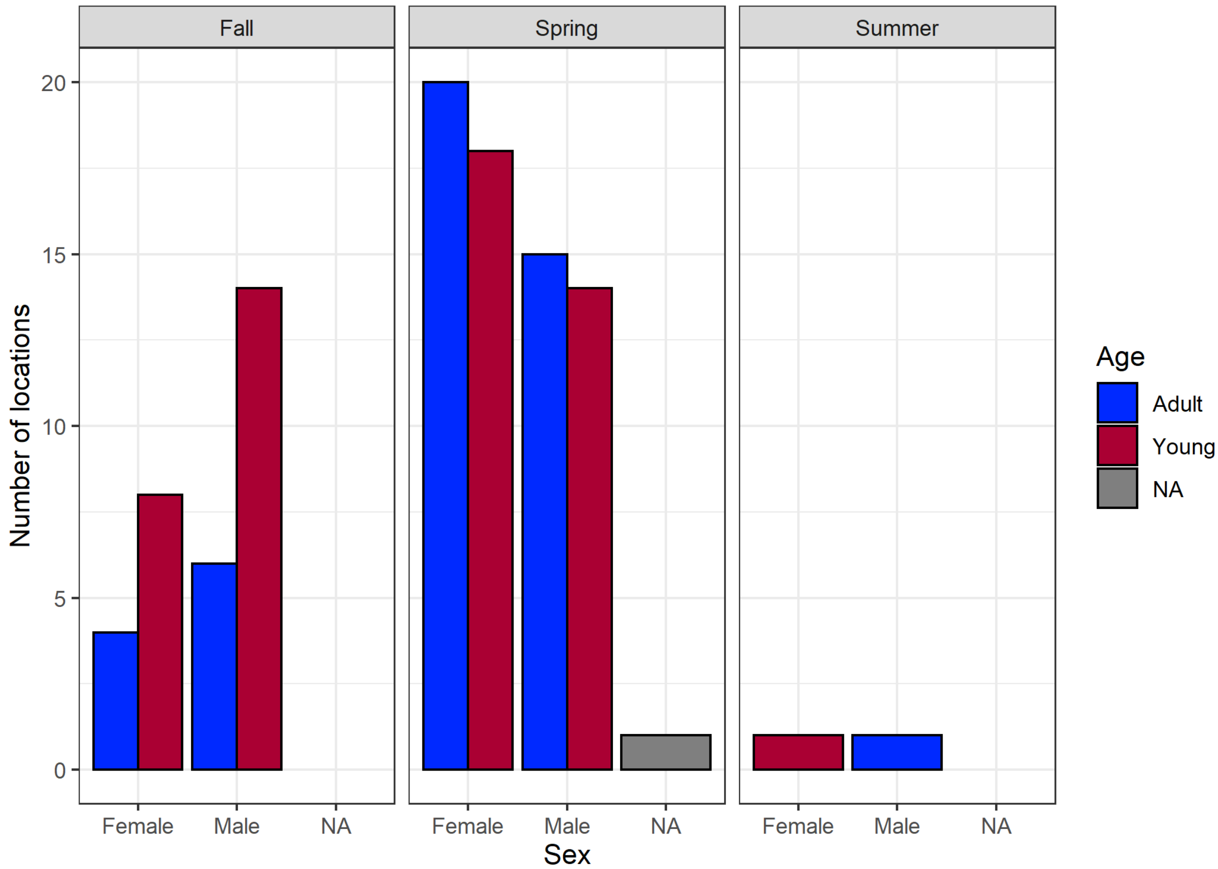

Figure 4. Counts of night flight locations gathered by the EWMRC since the debut of transmitters with altitude capacity in Fall 2020. Over 160 locations have been collected including fall and spring locations and samples from each combination of sex and age classes.

Migratory phenology

We fit woodcock GPS data using Multivariate Hidden Markov Models (MHMM), implemented with the momentuHMM package (McClintock and Michelot 2018) in program R (R version 3.6.3, www.r-project.org, accessed 1 Dec 2020). We used MHMMs to identify three woodcock behavioral states; pre-migration, migration, and post-migration, and from these states evaluated the timing of migratory departure during fall and spring migration, timing of stopover, and timing of arrival on the wintering grounds. This analysis was based on a subset of data from 304 woodcock captured in three Canadian provinces and ten US states from 2017 to 2020. We assessed whether migration initiation, termination, or stopover timing of woodcock migration varied geographically, differed among age and sex classes, or was based on individual body condition. Using general linear and linear mixed effect models, we found support for geographic variation in every analysis. During fall, woodcock initiated migration, and had earlier stopovers farther north and west (e.g., Ontario, Quebec) compared with later timing farther south and east (e.g., Rhode Island). Woodcock that initiated migration farther north and west also terminated migration earlier in the fall. Adult woodcock initiated fall migration four days before young woodcock, and during migration adult females progressed through migration prior to young birds (5 days), and adult males (9 days). During spring migration, woodcock farther west initiated migration before birds farther east, and males migrated an average of six days before females. A draft manuscript of this work is currently being prepared for submission to a peer-reviewed journal and will form the first chapter of Alex Fish's dissertation. An example result for initiation of fall migration is provided in Figure 5 below.

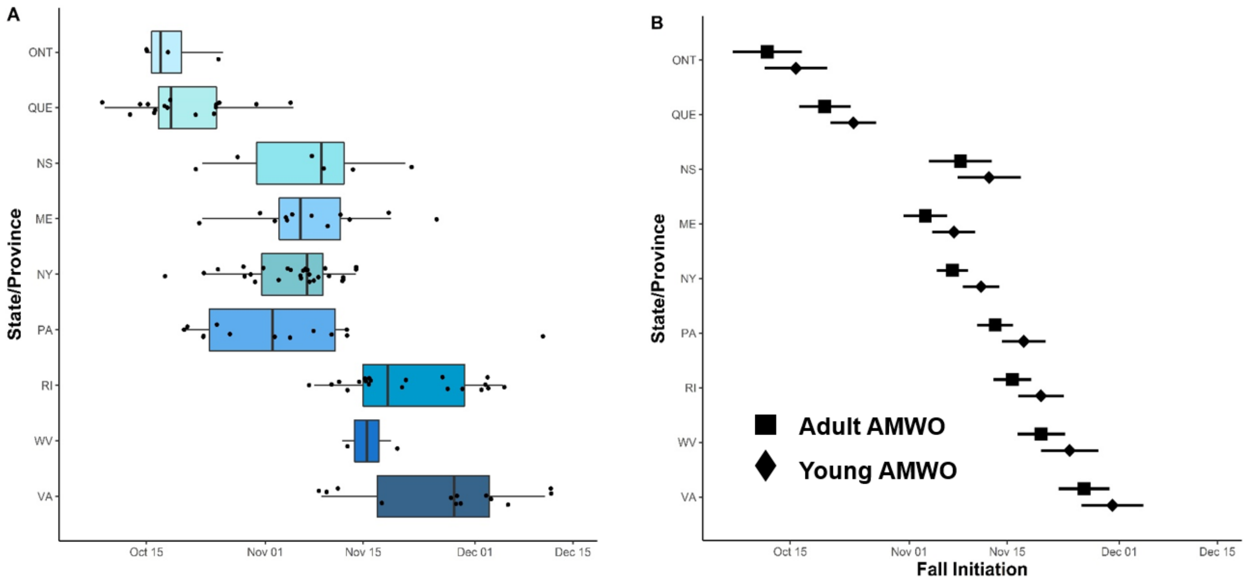

Figure 5. Initiation of fall migration for American Woodcock (*Scolopax minor*) marked in Eastern North America, 2017-2019. The distribution of migration initiation dates by administrative division (A), and the predicted initiation of fall migration while accounting for spatial distribution and age (B). Squares represent adults >1 year of age and diamonds reflect young woodcock <1 year of age.

Weather effects

Migratory animals rely on external cues to make decisions about the timing of migratory departures, however individuals' response to specific cues often varies interspecifically by age or sex class. We evaluated woodcock use of environmental cues to make migratory departure decisions, and explored patterns of intraspecific variation in these decisions and how they affected migratory efficiency. This analysis used a subset of data from 304 woodcock captured prior to migration between 2017 and 2020, and the MHMM migratory state designations described above. We used conditional logistic regression and general linear models to explore effects of weather and lunar variables on woodcock departure from breeding, wintering, and stopover sites, and asked how these relationships varied between age and sex classes. We further explored how an individual's use of specific wind conditions influenced flight distance, and how the overall pace of migration varied based on geography and interspecific characteristics. Woodcock responded to barometric pressure, moon illumination, temperature, wind assistance, and wind speed when making departure decisions, but selection often varied by season, age, and sex. Adult woodcock generally showed greater selection for wind compared to young birds in the fall, which were more dependent on temperature. During spring migration, female woodcock showed a greater selection for wind and barometric pressure but males showing stronger response to temperature and moon illumination. Woodcock that departed using tailwinds generally had longer flight distances, which we assume reflected a more efficient flight. We found intraspecific variation in cue use that was dependent on age during fall migration and sex during the spring, which provides an example of the latent variation that can exists within a species. A draft manuscript of this work is currently being prepared for submission to a peer-reviewed journal and will form the second chapter of Alex Fish's dissertation. Figure 6 below provides a summary of results for each environmental characteristic, separated by age and sex class as well as stage of migration.

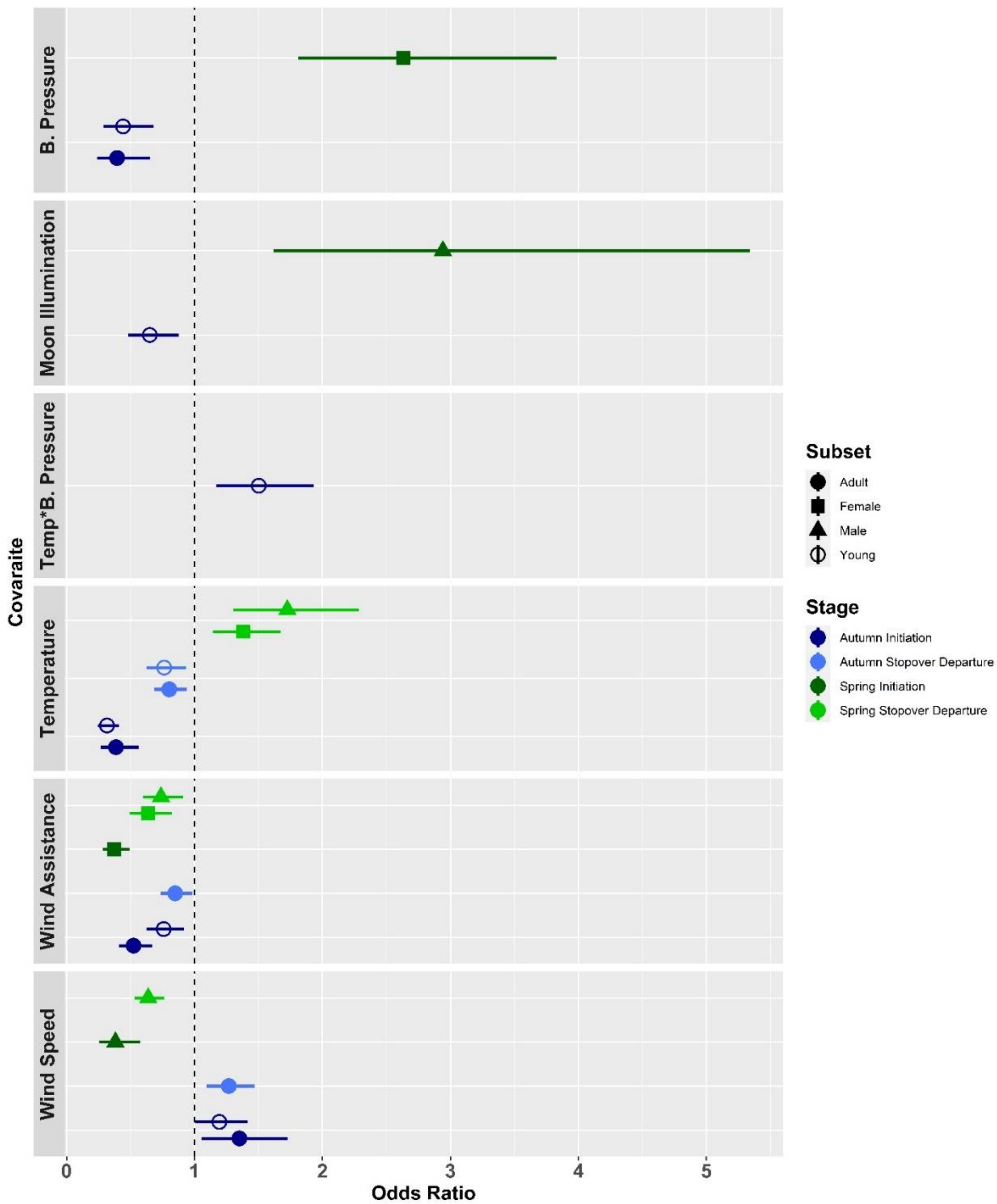

Figure 6. American Woodcock (*Scolopax minor*) relied on a variety of environmental cues when making migratory decisions during 2017-2020. Decisions varied by season, age, and sex of the individual, as reflected in the odds ratios presented above. Only odds ratios with confidence intervals that did not overlap one from the competitive model sets were included in the plot. All covariates were z-standardized, so the magnitudes of the effects within and between covariates are directly comparable.

Migratory connectivity

Our migratory connectivity results to date have reinforced the conclusions of Moore and Krementz (2017) and Moore et al. (2019) that woodcock frequently cross the boundary between the Eastern and Central Management Regions. During some portion of the full annual cycle, 29% of birds tagged in the Eastern Management Region crossed management region boundaries (Figure 7A). Most birds that undergo crossovers spend their summers in the Eastern Management Region and winter in the Central Management Region (16% of all tagged birds; Figure 7B). The inverse migration pattern, where birds winter in the Eastern Management Region and spend summers in the Central Management Region, is relatively infrequent (4% of all tagged birds; Figure 7C). Another 9% of tagged birds both summered and wintered in the Eastern Management Region but crossed into a portion of the Central Management Region during migration (Figure 7D). We plan to expand on this further using a multi-scalar connectivity analysis to determine not only if there are certain regional populations that are more apt to cross management region boundaries, but also if finer scale connectivity structure occurs within the Eastern Management Region.

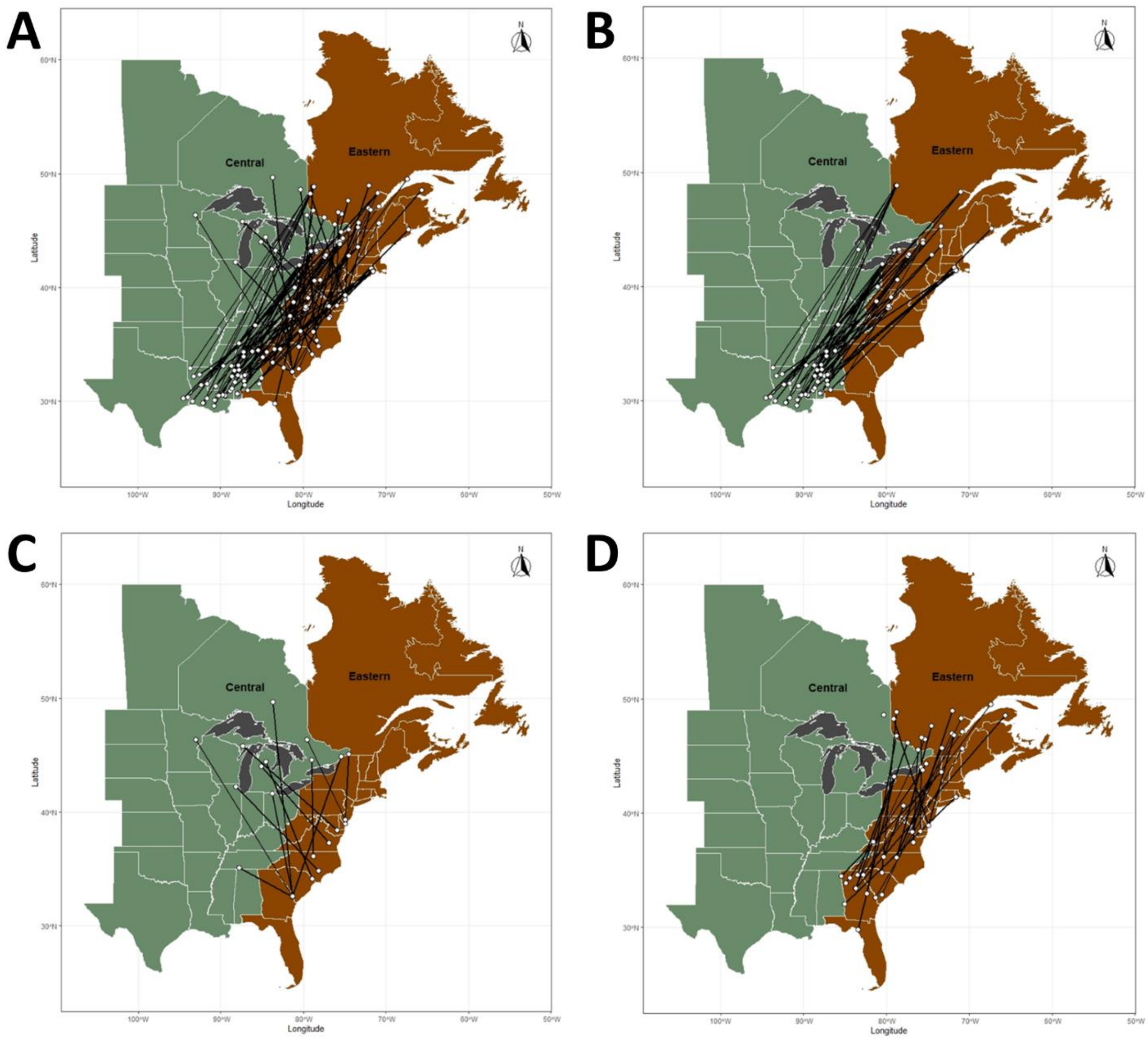

Figure 7. Migratory routes of woodcock tagged in the Eastern Management Region which (A) crossed management region boundaries at some point during the full annual cycle; (B) crossed over from breeding areas in the Eastern Management Region to wintering areas in the Central Management Region; (C) crossed over from wintering areas of the Eastern Management Region to breeding areas of the Central Management Region; and (D) passed through or stopped over in a portion of the Central Management Region during migration.

Landscape prioritization for woodcock management in Pennsylvania

One complicating factor for woodcock habitat management planning is uncertainty on how woodcock use of landscapes change as birds transition between different stages of the full annual cycle, such as from breeding to migration. To address this problem, we designed a tool for the Pennsylvania Game Commission that combines migratory and residential species distribution models to determine where woodcock habitat management is most likely to be successful. Data informing the migratory species distribution model were migratory stopover locations from EWMRC-marked woodcock, while data informing the residential model was obtained from USFWS Singing Ground Survey and Pennsylvania Game Commission woodcock survey datasets. The explanatory variables for both models were landscape characteristics, including topography, moisture, land use/land cover, and fragmentation, quantified at several spatial scales between 500m and 10km. Species distribution models were created using a Random Forest modeling technique to account for non-linear relationships between woodcock occupancy and the explanatory variables. The migratory and residential models were then combined under a user-defined weighting scheme to encourage our users to make conscious decisions regarding the value of migratory and residential habitat to their woodcock management strategy. We have incorporated this tool into a Shiny app that land managers can use to identify areas with high potential on state gamelands, based on customized prioritization of residential and migratory habitat based on their full annual cycle management strategy (Figure 8). The Pennsylvania Game Commission is currently using this tool to support requests for funding habitat management in the northeast region, and intends to broaden implementation throughout the state.

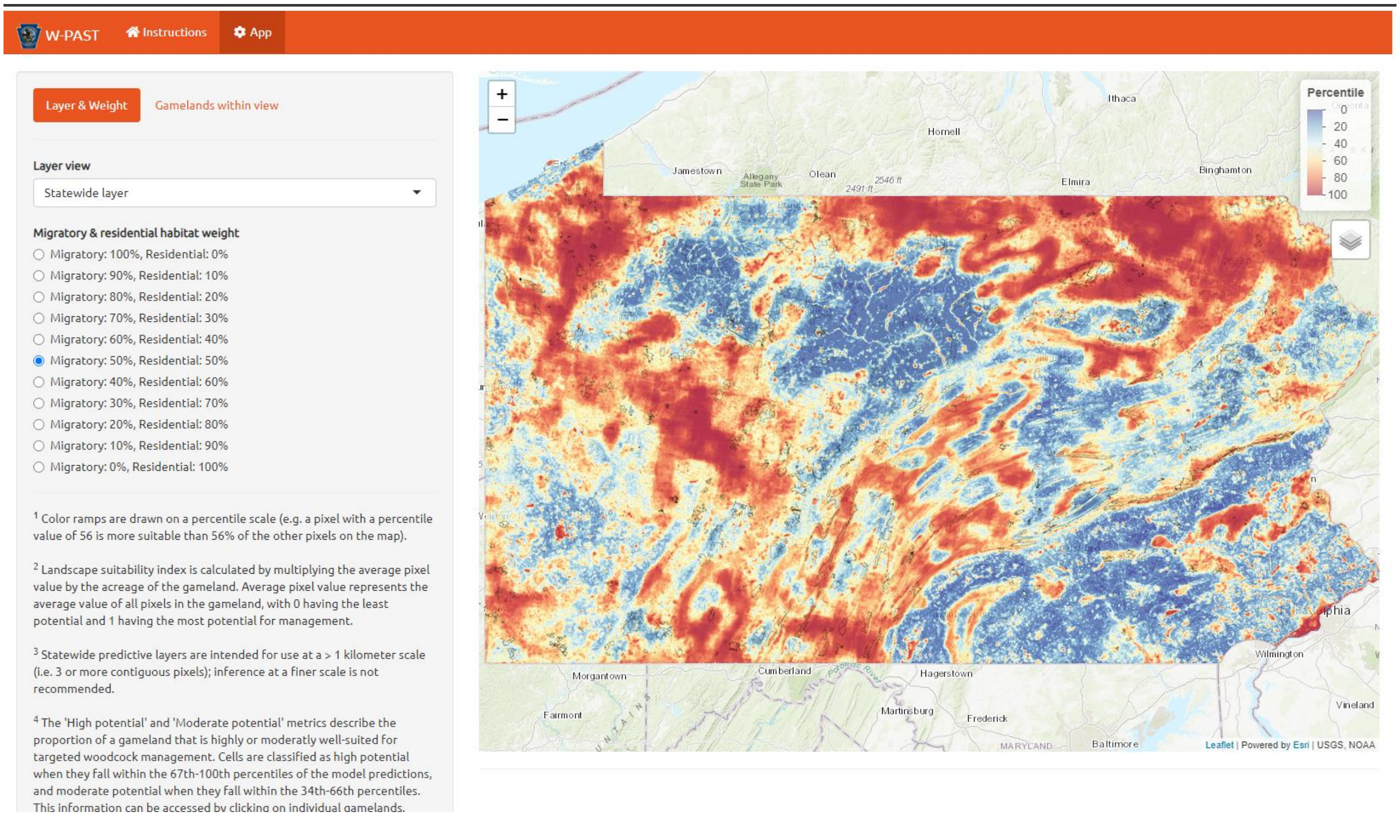

Figure 8. Image from W-PAST (Woodcock Priority Area Siting Tool), a tool that the University of Maine has built for the Pennsylvania Game Commission to aid in identification of landscapes with high potential for woodcock management. Landscape prioritization is based on a combination of residential and migratory species distribution models, with the exact weighting of those models controlled by the user.

Future Directions

Survival during migration

Mortality risk is high during migration for many species and may even limit population growth. We used data collected from our GPS-tagged woodcock to estimate survival during the periods of migration. Our Pinpoint ARGOS transmitters generally stop sending their PTT signals following a mortality, as the signal becomes attenuated when the antenna comes into contact with the ground. This provides ‘live encounter’ data similar to a traditional mark-recapture analysis, and allows us to fit multi-state mark-recapture models to the data to estimate rates of survival as woodcock move between pre-migratory, migratory, and post-migratory intervals. A first step, however, required that we account for potential transmitter loss and failure, each of which mimic apparent mortality and could confound estimates of survival. To assess the life span of transmitter batteries, we first fit our live encounter data using a Cormack-Jolly-Seber analysis, implemented in RMark (Laake, 2013) to assess apparent survival as a function of time since capture. The point at which survival rates begin to decline indicates the beginning of widespread battery failure, which we interpreted as occurring approximately 14 weeks post-capture (Figure 9). Using this information, we can censor survival histories such that birds only contribute information to the analysis for the time period in which battery failure is unlikely. We further assessed 22 re-encounters of GPS-marked woodcock (e.g., recaptures, hunter harvests), and determined that only two individuals dropped their transmitter prior to recovery. In both cases, woodcock had retained their transmitters (based on data transmissions) for at least 16 weeks (6 October to 27 January; 102 locations collected) and 24 weeks (3 September to 22 February; 38 locations collected) following capture. For woodcock with retained transmitters ($n = 20$), birds were re-encountered on average 22.1 ± 24 weeks (mean ± SD; min = <1, max = 88) post-capture. We concluded that transmitter retention was essentially 100% during the 14-week interval used in our analysis, which is consistent with other studies of tag retention in shorebirds using similar rump-mounted harnesses (Mong and Sandercock 2007). This analysis further confirmed that high mortality post-capture was not an appreciable concern, as survival probabilities for the first week following capture were very similar to those of subsequent weeks, suggesting no immediate short-term effects of marking (Figure 9). Moving forward, we will assess the survival of migrant woodcock during fall and spring and evaluate whether survival varies among age and sex classes or based on site of capture. This work will comprise Alex Fish's 3rd dissertation chapter, with a manuscript forthcoming.

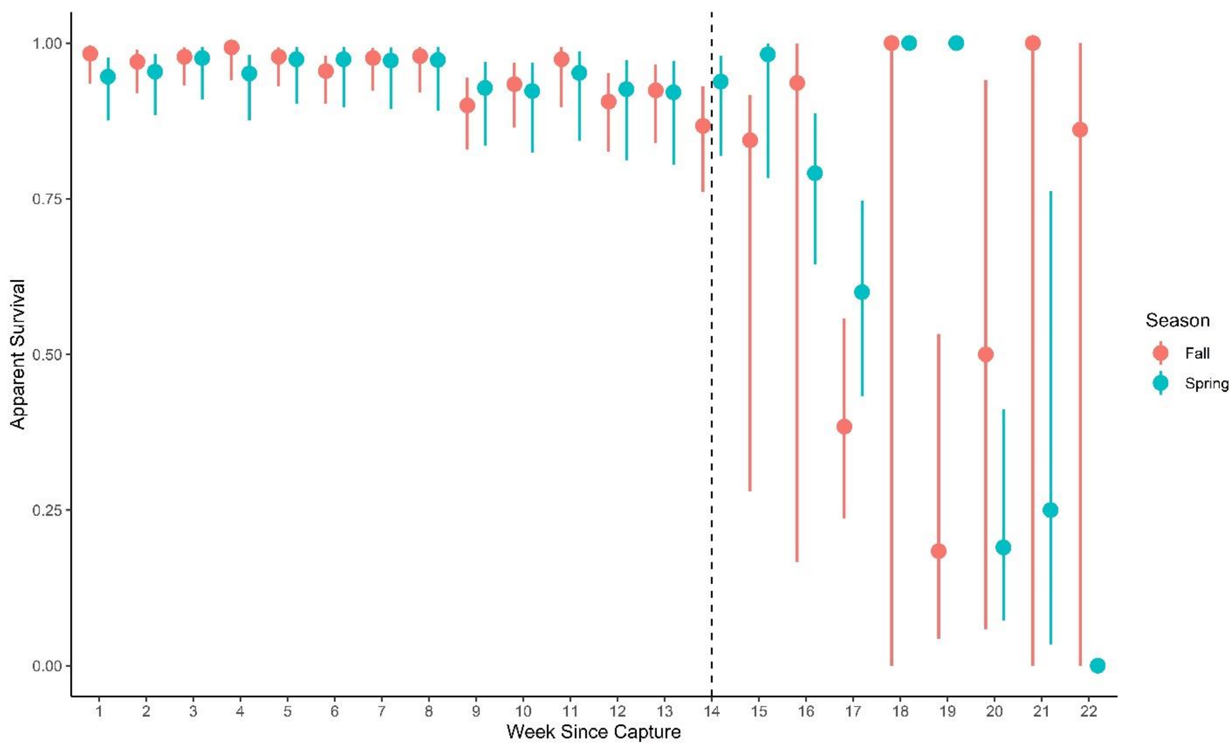

Figure 9. Weekly apparent survival of American Woodcock (*Scolopax minor*) during the fall and spring after capture. Marked shift in survival estimates and their confidence intervals suggest substantial battery failure beginning at week 14 post-capture.

Regional and seasonal differences in private and public land use

Wildlife management agencies have been working to bolster early successional habitat throughout the woodcock's range using a variety of public and private land conservation initiatives at both state (Buffum et al. 2019) and regional (Weber and Cooper 2019) scales. These initiatives are most effective when they target the land ownership type that woodcock are most likely to use. However, we currently have little information on how woodcock apportion their use of private and public land throughout their range, or during different stages of their annual cycle. To fill this information gap, we will quantify the amount of private and public lands available, and the proportion of woodcock locations in that land ownership category, within each Bird Conservation Region (Sauer et al. 2003). We will further analyze how that use of public vs private ownership changes throughout each stage of the woodcock annual cycle. This analysis will make use of the U.S. Protected Areas Database and the Canadian Protected and Conserved Areas Database (USGS GAP 2020, Environment and Climate Change Canada 2021), which additionally allow for the delineation of private land that is protected or under conservation easement. By determining how woodcock use public, private unprotected, and private protected land in each Bird Conservation Region, we hope to aid land managers in deciding whether private or public land conservation initiatives are more likely to be successful in their region. This work will contribute to the dissertation of Liam Berrigan at the University of Maine.

Habitat selection throughout the full annual cycle

Bird species frequently select habitat with different characteristics in different seasons, or in different parts of their range (Stanley et al. 2021). Quantifying these differences is especially important for woodcock management, not only to ensure that land managers have access to regionally specific habitat management guidelines, but also to allow managers to differentiate between residential and migratory habitat and understand where there are opportunities to manage for both. To this end, we are performing a full annual cycle habitat selection analysis on the woodcock locations collected by the EWMRC. We plan to test multi-scale selection for several habitat characteristics that have been shown to be useful in other woodcock habitat studies (Allen et al. 2020), including landscape composition, configuration, soil moisture, and slope. We will conduct the selection analysis by region and season so that we can provide local recommendations for full annual cycle management of woodcock populations. To expand our ecological knowledge of woodcock, we will also examine how the scale of woodcock selection for habitat changes through different stages of the full annual cycle by examining metrics such as seasonal home range size, and will investigate variation in habitat selection strategies within regional populations. This work will contribute to the dissertation of Liam Berrigan at the University of Maine.

Response to light pollution during migration

There is a growing body of evidence suggesting that light pollution can cause widespread disruption during bird migration, both through local attraction of birds to high intensity light sources (Van Doren et al. 2017) and regional selection of artificially lit areas for migratory stopovers (McLaren et al. 2018). As woodcock are disproportionately the victims of window strikes (Loss et al. 2014), they are believed to be especially vulnerable to light pollution. We will use the EWMRC's woodcock migratory stopover locations to test how light pollution affects woodcock stopover propensity, and how age and sex class affect attraction to light pollution either due to inexperience with navigational obstacles or increased/decreased susceptibility due to migration timing. This work will contribute to the dissertation of Liam Berrigan at the University of Maine.

Genomic analysis of population connectivity

To expand our current analysis of migratory connectivity, we will be evaluating genomic and stable isotopic signatures from blood and feather samples that we have been collecting from marked woodcock since the beginning of the project. These data will provide regional markers to identify the subpopulation of natal origin for each woodcock, and in combination with the migratory data that we have gathered from GPS transmitters during the project, determine the frequency that woodcock return to natal regions, or disperse to others. Our objectives for this work are to 1) conduct a range-wide assessment of population genomic structure for American Woodcock and relate this to breeding and wintering areas of each management region, 2) relate genomic signatures from GPS-marked woodcock to their movements throughout the annual cycle to identify mechanisms governing population structure via migratory connectivity, 3) compare isotopic assignment of GPS-marked woodcock to their migration and dispersal throughout the Eastern and Central Management Regions, and 4) based on results of objectives 1 through 3, evaluate evidence for finer-scale population structure within each management region. This work is being supported by a grant from the US Fish and Wildlife Service Webless Migratory Gamebird Research fund, which we received in 2021.

Nesting and post-breeding dispersal

During the 2020-2021 field season, EWMRC collaborators began deploying GPS tags on females with program schedules designed to identify nest-attempts throughout the eastern AMWO breeding range. We further worked with cooperators and other biologists to conduct field visits and confirm suspected nests. In this first year, EWMRC collaborators captured and attached GPS units to 37 female AMWO, confirmed nest attempts for 14 of the tagged hens, and located 17 nests including 3 rensts. Nest site locations ranged from North Carolina to northern Quebec. For 3 of the tagged hens, we were able to locate a 2nd nest attempt after failure of the first nest. Interestingly, four of the five hens that lost their initial nest made long-distance movements after nest failure, and we were able to locate the second nest for two of these four hens. Thus, some hens appear to nest (and renest) throughout spring migration, and this suggests that American Woodcock may use an itinerant breeding strategy (Figure 10). We are quite interested to see if hens exhibit similar patterns of nesting and movements in 2022. Using information obtained from our validated nesting dataset, we will attempt to used automated methods of nest detection to identify likely nesting attempts throughout the larger EWMRC database, hopefully elucidating whether migratory movements among nesting attempts are pervasive within the population. This research will contribute to the dissertation of Colby Slezak at the University of Rhode Island.

Figure 10. Confirmed nest site locations and post-nest failure movements of female AMWO tagged as part of the EWMRC nesting project during 2020-2021.

Outreach

As our analyses could potentially be valuable to a wide range of stakeholders engaged in woodcock management, we devote considerable time and energy to disseminating our results to interested parties. Our primary means of distributing information is the EWMRC email listserv, which includes representatives from 36 states, provinces, federal agencies, and non-governmental organizations engaged in woodcock conservation. We also use our website, www.woodcockmigration.org, to distribute up-to-date woodcock migration information to any interested parties. Since it was launched, the website has gained a considerable following (>35,000 unique visitors, > 100,000 page views), and this year we also incorporated interactive Shiny apps to allow users to interface with our migratory data and hopefully drive more traffic. As we finalize analyses, we will also include our results on the website, as well as links to our published studies. Finally, we continue to present our results at wildlife and ornithology conferences, including an upcoming presentation at The Wildlife Society's Annual Conference in November 2021.

Project Partners

Alabama Department of Conservation and Natural Resources

American Woodcock Society

Association des Savaginiers du Saguenay-Lac-St-Jean

Atlantic Flyway Council

Canaan Valley National Wildlife Refuge

Club des Becassiers du Quebec

Silvio O. Conte National Wildlife Refuge

Environment and Climate Change Canada

Florida Fish and Wildlife Conservation Commission

Friends of the 500th

Friends of Missisquoi National Wildlife Refuge

Georgia Department of Natural Resources

Maine Department of Inland Fisheries and Wildlife

Maryland Department of Natural Resources

Missisquoi National Wildlife Refuge

Moosehorn National Wildlife Refuge

The Nature Conservancy

New Jersey Department of Environmental Protection

New York Department of Environmental Conservation

North Carolina Wildlife Resources Commission

Old Hemlock Foundation

Pennsylvania Game Commission

Rhode Island Dept. of Environmental Management

Ruffed Grouse Society

State University of New York - Cobleskill

South Carolina Department of Natural Resources

U.S. Forest Service

USFWS National Wildlife Refuge System

USFWS Webless Migratory Game Bird Research Program

USFWS Office of Migratory Birds

USGS - Patuxent Wildlife Research Center

University of Maine

University of Rhode Island

Vermont Fish & Wildlife Department

Virginia Department of Wildlife Resources

West Virginia Highlands Conservancy

Wildlife Management Institute

Woodcock Conservation Society

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Appendix

Additional Tables

Table A1. American Woodcock captured and tagged with satellite GPS transmitters in each state/province collaborating in the Eastern Woodcock Migration Research Cooperative, summarized by year, age, and sex.

		Male			Female			Unknown	Total
State	**Year**	**Young**	**Adult**	**Unk**	**Young**	**Adult**	**Unk**	**Unk**	
Alabama	*2020*	1	2		2	2			7
	2021		2		2	2			6
Florida	*2021*	1	3		1				5
Georgia	*2020*	3	3		1	5			12
	2021	1	3		2	5			11
Maine	*2017*	4				2			6
	2018	1	1		3	2			7
	2020	1	2			3			6
Maryland	*2018*		1		3				4
	2019		3		5	2			10
	2020	1	3		4	1			9
	2021	3	3		1	1			8
New Jersey	*2018*	7			8				15
	2019	8			9				17
New York	*2018*	4	1		1	3			9
	2019	4	6		11	9			30
North Carolina	*2019*	2	2			2			6
	2020	7	1		4	3			15
	2021	6	1		1	2			10

		Male			Female			Unknown	Total
State	**Year**	**Young**	**Adult**	**Unk**	**Young**	**Adult**	**Unk**	**Unk**	
Nova Scotia	*2019*	3			4				7
Ontario	*2018*		1			1			2
	2019	1			1	1			3
Pennsylvania	*2018*	1	4		3	4			12
	2019	3	1		1	7			12
	2020	3	2		1	7			13
Quebec	*2018*	2			2	1			5
	2019	5			2	3			10
	2020	2	1		1	3			7
Rhode Island	*2018*		12			3			15
	2019		12			3			15
	2020				7	7	3		17
South Carolina	*2019*	2	1		4	2			9
	2020	2	3		2	1			8
	2021	2	4		1				7
Virginia	*2018*		6		2	1			9
	2019	11	10		11	13		2	47
	2020	15	5	1	7	16			44
	2021		1					4	5
Vermont	*2020*	8	5		3	2			18
West Virginia	*2019*	2	1		1				4
	2021				1				1
Total		**116**	**106**	**1**	**112**	**119**	**3**	**6**	**463**

Table A2. Number of attempted and complete migratory movements by GPS-tagged American Woodcock by season from Fall 2017 through Spring 2021.

	Migratory movements	
Season	**Attempted**	**Complete**
Fall 2017	6	3
Fall 2018	47	41
Spring 2019	55	48
Fall 2019	83	79
Spring 2020	84	74
Fall 2020	64	59
Spring 2021	83	75

Table A3. Migration initiation and termination dates for American Woodcock tagged with satellite GPS transmitters in the Eastern Management Region from Fall 2018 through Spring 2021.

	n	Mean Mig. Initiation	First Mig. Initiation	Last Mig. Initiation	Mean Mig. Termination	First Mig. Termination	Last Mig. Termination
Fall							
2018	38	11/7/2018	10/12/2018	1/1/2019	12/5/2018	10/28/2018	2/3/2019
2019	74	11/11/2019	10/12/2019	12/13/2019	11/30/2019	11/8/2019	1/15/2019
2020	59	10/28/2020	8/3/2020	12/15/2020	11/30/2020	10/30/2020	1/12/2021
Spring							
2019	42	3/10/2019	1/26/2019	3/29/2019	4/7/2019	2/6/2019	5/15/2019
2020	55	3/6/2020	2/3/2020	5/4/2020	4/5/2020	2/11/2020	5/15/2020
2021	76	2/28/2021	1/14/2021	4/23/2021	4/3/2021	3/2/2021	5/18/2021

Table A4. Migration records of GPS-tagged American Woodcock from the migratory seasons of Fall 2020 (September 1st, 2020 – January 31st, 2021) and Spring 2021 (February 1st, 2021 - May 31st, 2021). [a]Age at capture reflects whether the bird was in its first molt cycle (HY or SY) or had adult plumage (AHY or ASY). [b]The number of GPS locations that each bird recorded during that migratory season. [c]The date at which the bird initiated migration. [d]The date at which the bird completed its migration (missing if the bird stopped transmitting before migration concluded). [e]The number of days between the initiation and termination of migration. [f]The state or province in which the bird ended its migration. [g]The sum distance of all migratory steps recorded by the individual in kilometers.

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
Fall 2020										
Alabama										
AL-2020-07	2/3/2020	F	SY	17	-	-	-	AL	-	-
Georgia										
GA-2020-08	1/27/2020	M	ASY	12	-	-	-	GA	-	-
Maryland										
MD-2020-10	2/26/2020	M	ASY	9	-	-	-	MD	-	-
MD-2020-11	2/26/2020	M	ASY	14	-	-	-	MD	-	-
MD-2020-12	2/26/2020	M	ASY	12	-	-	-	MD	-	-
MD-2020-17	2/26/2020	M	SY	15	10/26/2020	-	-	MD	-	-
Maine										
ME-2020-14	10/9/2020	M	HY	60	10/25/2020	12/4/2020	40	ME	FL	2057
ME-2020-15	10/8/2020	F	AHY	6	-	-	-	ME	-	-

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
ME-2020-16	10/6/2020	M	AHY	80	10/27/2020	11/24/2020	28	ME	NC	1526
ME-2020-17	10/8/2020	F	AHY	76	10/27/2020	11/24/2020	28	ME	NC	1219
ME-2020-18	10/6/2020	M	AHY	81	10/29/2020	12/8/2020	40	ME	NC	1383
North Carolina										
NC-2020-06	2/18/2020	M	SY	8	-	-	-	NC	-	-
NC-2020-11	2/19/2020	M	ASY	17	11/14/2020	-	-	NC	-	-
NC-2020-13	2/19/2020	M	SY	18	11/14/2020	-	-	NC	-	-
NC-2020-14	2/19/2020	M	SY	21	10/29/2020	11/7/2020	9	NC	OH	1061
NC-2020-15	2/19/2020	F	SY	27	10/22/2020	11/1/2020	10	NC	SC	1173
NC-2020-16	2/19/2020	F	ASY	15	-	-	-	NC	-	-
NC-2020-20	2/19/2020	M	SY	9	-	-	-	NC	-	-
Pennsylvania										
PA-2020-21	9/13/2020	M	HY	1	-	-	-	PA	-	-
PA-2020-22	9/28/2020	F	HY	75	11/23/2020	11/26/2020	3	PA	NC	723
PA-2020-23	9/13/2020	M	AHY	12	-	-	-	PA	-	-
PA-2020-24	9/28/2020	M	AHY	54	11/8/2020	11/14/2020	6	PA	SC	701
PA-2020-25	9/29/2020	M	HY	40	12/2/2020	12/6/2020	4	PA	NC	649
PA-2020-26	9/16/2020	F	AHY	81	12/6/2020	12/7/2020	1	PA	VA	316
PA-2020-27	9/28/2020	F	AHY	75	11/17/2020	12/30/2020	43	PA	SC	893

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
PA-2020-29	9/29/2020	F	AHY	38	10/24/2020	10/31/2020	7	PA	GA	980
PA-2020-31	9/28/2020	F	AHY	43	-	-	-	PA	-	-
PA-2020-32	9/13/2020	F	AHY	49	11/12/2020	1/6/2021	55	PA	NC	808
PA-2020-33	9/15/2020	M	HY	47	10/17/2020	11/22/2020	36	PA	SC	776
Quebec										
QUE-2020-16	9/20/2020	F	HY	41	10/23/2020	11/30/2020	38	QUE	NC	1897
QUE-2020-17	9/20/2020	M	HY	41	10/27/2020	12/2/2020	36	QUE	LA	2992
QUE-2020-18	9/21/2020	F	AHY	85	10/24/2020	11/3/2020	10	QUE	GA	2015
QUE-2020-19	9/22/2020	F	AHY	3	-	-	-	QUE	-	-
QUE-2020-20	9/22/2020	M	AHY	89	10/27/2020	11/1/2020	5	QUE	MD	1197
QUE-2020-21	9/22/2020	F	AHY	48	10/29/2020	12/20/2020	52	QUE	LA	2581
QUE-2020-22	9/20/2020	M	HY	1	-	-	-	QUE	-	-
Rhode Island										
RI-2020-30	8/27/2020	F	HY	5	8/29/2020	12/8/2020	101	RI	NC	-
RI-2020-31	8/27/2020	F	HY	12	8/28/2020	1/12/2021	137	RI	MD	1001
RI-2020-32	9/10/2020	F	ASY	16	9/11/2020	12/1/2020	81	RI	FL	1735
RI-2020-33	9/10/2020	F	HY	18	9/12/2020	12/22/2020	101	RI	VA	647
RI-2020-34	9/17/2020	F	HY	18	9/19/2020	12/1/2020	73	RI	VA	904
RI-2020-35	9/19/2020	F	ASY	19	9/21/2020	12/1/2020	71	RI	NC	796

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
RI-2020-36	10/13/2020	F	HY	2	-	-	-	RI	-	-
RI-2020-37	9/6/2020	F	-	14	11/10/2020	12/15/2020	35	RI	MD	514
RI-2020-38	9/9/2020	F	HY	26	12/15/2020	1/1/2021	17	RI	VA	639
RI-2020-39	9/3/2020	F	-	26	11/24/2020	12/15/2020	21	RI	NJ	423
RI-2020-40	9/2/2020	F	HY	23	11/17/2020	11/24/2020	7	RI	VA	633
RI-2020-41	8/29/2020	F	AHY	22	12/15/2020	1/1/2021	17	RI	NC	891
RI-2020-42	9/2/2020	F	AHY	27	9/4/2020	11/17/2020	74	RI	SC	1227
RI-2020-43	10/13/2020	F	AHY	19	10/15/2020	12/8/2020	54	RI	VA	775
RI-2020-44	8/29/2020	F	-	19	8/31/2020	12/29/2020	120	RI	MS	32
RI-2020-45	9/14/2020	F	ASY	15	-	-	-	RI	-	-
South Carolina										
SC-2020-12	2/25/2020	F	SY	7	-	-	-	SC	-	-
SC-2020-13	2/29/2020	M	SY	12	8/3/2020	-	-	SC	-	-
SC-2020-14	2/28/2020	M	ATY	21	10/17/2020	11/2/2020	16	SC	SC	1792
SC-2020-16	2/27/2020	F	SY	14	-	-	-	SC	-	-
SC-2020-17	2/25/2020	M	ASY	10	-	-	-	SC	-	-
Virginia										
VA-2019-46	11/23/2019	F	AHY	20	10/2/2020	11/7/2020	36	VA	VA	1483

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
VA-2019-47	11/23/2019	F	HY	14	10/17/2020	11/1/2020	15	VA	VA	1162
VA-2020-51	1/3/2020	M	HY	1	-	-	-	VA	-	-
VA-2020-52	1/14/2020	M	HY	18	-	-	-	VA	-	-
VA-2020-57	3/24/2020	M	SY	44	10/2/2020	11/18/2020	47	VA	GA	1686
VA-2020-58	3/24/2020	M	SY	37	10/26/2020	11/3/2020	8	VA	SC	426
VA-2020-61	10/11/2020	M	HY	13	-	-	-	VA	-	-
VA-2020-62	10/11/2020	M	HY	42	11/27/2020	12/4/2020	7	VA	GA	517
VA-2020-63	10/11/2020	M	HY	44	11/23/2020	11/26/2020	3	VA	GA	617
VA-2020-64	10/11/2020	M	HY	36	11/23/2020	11/26/2020	3	VA	SC	557
VA-2020-65	10/11/2020	M	-	44	12/1/2020	12/28/2020	27	VA	AL	1133
VA-2020-66	10/11/2020	F	AHY	43	11/23/2020	11/25/2020	2	VA	GA	653
VA-2020-67	10/15/2020	F	HY	42	12/5/2020	12/10/2020	5	VA	VA	160
VA-2020-68	10/11/2020	F	HY	42	11/28/2020	12/4/2020	6	VA	GA	723
VA-2020-69	10/11/2020	F	AHY	42	10/29/2020	12/4/2020	36	VA	MS	1157
VA-2020-70	11/11/2020	M	HY	5	-	-	-	VA	-	-
VA-2020-71	11/15/2020	M	AHY	29	-	-	-	VA	-	-
VA-2020-72	11/11/2020	F	AHY	29	12/1/2020	12/20/2020	19	VA	NC	206
VA-2020-73	11/11/2020	F	AHY	27	-	-	-	VA	-	-
VA-2020-74	11/11/2020	F	HY	14	-	-	-	VA	-	-

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
VA-2020-75	11/15/2020	F	AHY	4	-	-	-	VA	-	-
VA-2020-76	11/11/2020	M	HY	27	-	-	-	VA	-	-
VA-2020-77	11/11/2020	F	AHY	26	-	-	-	VA	-	-
VA-2020-78	11/11/2020	M	AHY	25	-	-	-	VA	-	-
VA-2020-79	11/19/2020	F	HY	23	-	-	-	VA	-	-
VA-2020-80	11/11/2020	F	AHY	5	-	-	-	VA	-	-
VA-2020-81	11/24/2020	F	AHY	25	-	-	-	VA	-	-
VA-2020-82	11/24/2020	F	AHY	10	-	-	-	VA	-	-
VA-2020-83	12/7/2020	F	AHY	20	-	-	-	VA	-	-
VA-2020-84	12/14/2020	F	AHY	14	-	-	-	VA	-	-
VA-2020-85	12/16/2020	F	AHY	8	-	-	-	VA	-	-
VA-2020-86	12/16/2020	F	AHY	17	-	-	-	VA	-	-
VA-2020-87	12/14/2020	F	HY	8	-	-	-	VA	-	-
VA-2020-88	10/28/2020	M	HY	29	-	-	-	VA	-	-
VA-2020-89	11/11/2020	M	AHY	9	-	-	-	VA	-	-
VA-2020-90	12/17/2020	F	HY	6	-	-	-	VA	-	-
VA-2021-91	-	-	-	3	-	-	-	VA	-	-
VA-2021-92	-	-	-	2	-	-	-	VA	-	-
VA-2021-94	1/25/2021	M	AHY	1	-	-	-	VA	-	-

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
Vermont										
VT-2020-01	9/12/2020	M	HY	14	-	-	-	VT	-	-
VT-2020-02	9/13/2020	M	HY	4	-	-	-	VT	-	-
VT-2020-03	9/13/2020	M	HY	118	-	-	-	VT	-	-
VT-2020-04	9/13/2020	M	AHY	109	10/5/2020	-	-	VT	-	-
VT-2020-05	9/16/2020	M	HY	88	11/12/2020	11/24/2020	12	VT	VA	883
VT-2020-06	9/16/2020	M	HY	89	11/16/2020	11/20/2020	4	VT	NC	1073
VT-2020-07	9/16/2020	M	AHY	81	11/12/2020	11/20/2020	8	VT	SC	1341
VT-2020-08	9/16/2020	F	AHY	3	-	-	-	VT	-	-
VT-2020-09	9/16/2020	M	AHY	87	11/24/2020	12/30/2020	36	VT	GA	1783
VT-2020-10	9/17/2020	M	HY	80	11/14/2020	12/4/2020	20	VT	SC	1474
VT-2020-11	9/17/2020	F	AHY	55	11/17/2020	11/29/2020	12	VT	AL	1922
VT-2020-12	9/13/2020	M	AHY	66	-	-	-	VT	-	-
VT-2020-13	9/23/2020	M	HY	109	11/21/2020	11/25/2020	4	VT	VA	902
VT-2020-14	9/23/2020	M	AHY	53	9/24/2020	12/6/2020	73	VT	MS	2071
VT-2020-15	9/29/2020	F	HY	81	10/29/2020	11/28/2020	30	VT	VA	1042
VT-2020-16	9/30/2020	F	HY	74	10/6/2020	11/1/2020	26	VT	NC	1238
VT-2020-17	9/29/2020	F	HY	80	10/6/2020	10/30/2020	24	VT	NC	1166
VT-2020-18	9/30/2020	M	HY	49	10/24/2020	12/2/2020	39	VT	VA	1160

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
West Virginia										
WV-2020-05	9/21/2020	F	HY	25	-	-	-	WV	-	-
Spring 2021										
Alabama										
AL-2021-08	2/8/2021	M	ASY	62	2/24/2021	3/29/2021	33	AL	QUE	2030
AL-2021-09	2/8/2021	M	ASY	65	2/26/2021	4/10/2021	43	AL	NB	2319
AL-2021-09	2/8/2021	M	ASY	65	2/26/2021	4/10/2021	43	AL	ME	2319
AL-2021-10	2/9/2021	F	ASY	65	2/26/2021	4/1/2021	34	AL	NY	1463
AL-2021-11	2/9/2021	F	SY	54	2/26/2021	3/26/2021	28	AL	KY	1512
AL-2021-12	2/8/2021	F	ASY	42	2/27/2021	3/26/2021	27	AL	PA	1243
AL-2021-13	2/8/2021	F	SY	20	2/27/2021	-	-	AL	-	-
Florida										
FL-2021-01	2/5/2021	M	SY	57	-	-	-	FL	-	-
FL-2021-02	1/29/2021	M	ASY	11	-	-	-	FL	-	-
FL-2021-03	1/27/2021	M	ASY	41	2/21/2021	3/25/2021	32	FL	MI	2126
FL-2021-04	1/28/2021	F	SY	71	2/26/2021	3/25/2021	27	FL	PA	1631
Georgia										
GA-2021-13	2/1/2021	M	ASY	66	2/24/2021	3/31/2021	35	GA	MI	1585
GA-2021-14	2/4/2021	M	ASY	66	3/8/2021	3/28/2021	20	GA	NY	1172

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
GA-2021-15	2/1/2021	M	SY	58	3/8/2021	3/19/2021	11	GA	NY	1203
GA-2021-16	2/1/2021	M	ASY	60	3/10/2021	3/23/2021	13	GA	PA	1036
GA-2021-17	2/1/2021	F	ASY	70	2/27/2021	4/10/2021	42	GA	ME	1742
GA-2021-18	2/1/2021	F	SY	68	3/8/2021	5/12/2021	65	GA	WV	896
GA-2021-19	2/1/2021	F	ASY	45	2/27/2021	5/6/2021	68	GA	QUE	2501
GA-2021-20	2/1/2021	F	ASY	37	2/24/2021	3/13/2021	17	GA	WV	815
GA-2021-21	2/1/2021	F	ASY	70	2/27/2021	4/18/2021	50	GA	MN	1943
GA-2021-22	2/2/2021	F	SY	19	2/26/2021	3/19/2021	21	GA	IN	901
Maryland										
MD-2021-18	2/10/2021	M	SY	42	3/10/2021	4/27/2021	48	MD	NS	1579
MD-2021-19	2/10/2021	M	SY	50	3/1/2021	3/26/2021	25	MD	VT	920
MD-2021-20	2/10/2021	M	ASY	51	3/7/2021	3/25/2021	18	MD	QUE	1048
MD-2021-21	2/10/2021	M	ASY	59	3/8/2021	4/1/2021	24	MD	QUE	1004
MD-2021-22	2/10/2021	M	ASY	58	3/7/2021	3/13/2021	6	MD	ON	735
MD-2021-23	2/18/2021	F	SY	15	-	-	-	MD	-	-
MD-2021-24	2/18/2021	F	ASY	30	2/24/2021	3/23/2021	27	MD	NH	690
Maine										
ME-2020-16	10/6/2020	M	AHY	8	2/19/2021	-	-	ME	-	-
ME-2020-17	10/8/2020	F	AHY	15	3/19/2021	4/9/2021	21	ME	ME	1194

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
ME-2020-18	10/6/2020	M	AHY	4	-	-	-	ME	-	-
North Carolina										
NC-2021-21	2/9/2021	F	SY	51	3/11/2021	4/4/2021	24	NC	PEI	2142
NC-2021-22	2/17/2021	M	SY	60	3/8/2021	5/13/2021	66	NC	PA	1131
NC-2021-23	2/17/2021	M	SY	55	3/10/2021	4/3/2021	24	NC	ME	1375
NC-2021-24	2/16/2021	M	SY	60	3/2/2021	5/15/2021	74	NC	QUE	1881
NC-2021-25	2/16/2021	M	SY	59	3/20/2021	3/26/2021	6	NC	QUE	1412
NC-2021-26	2/16/2021	M	SY	52	3/10/2021	4/10/2021	31	NC	QUE	1385
NC-2021-27	2/16/2021	M	SY	8	-	-	-	NC	-	-
NC-2021-28	2/17/2021	F	ASY	69	3/29/2021	4/12/2021	14	NC	NB	1731
NC-2021-29	2/16/2021	M	ASY	4	-	-	-	NC	-	-
NC-2021-30	3/2/2021	F	ASY	58	3/20/2021	4/4/2021	15	NC	QUE	1819
Pennsylvania										
PA-2020-25	9/29/2020	M	HY	22	2/10/2021	3/27/2021	45	PA	PA	879
PA-2020-27	9/28/2020	F	AHY	4	-	-	-	PA	-	-
PA-2020-32	9/13/2020	F	AHY	4	2/5/2021	-	-	PA	-	-
PA-2020-33	9/15/2020	M	HY	13	2/20/2021	3/17/2021	25	PA	PA	1943
Quebec										
QUE-2020-17	9/20/2020	M	HY	17	1/26/2021	4/16/2021	80	QUE	QUE	3087

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
QUE-2020-20	9/22/2020	M	AHY	10	-	-	-	QUE	-	-
QUE-2020-21	9/22/2020	F	AHY	19	2/20/2021	5/1/2021	70	QUE	QUE	2543
Rhode Island										
RI-2020-31	8/27/2020	F	HY	42	3/10/2021	3/28/2021	18	RI	RI	640
RI-2020-32	9/10/2020	F	ASY	20	2/14/2021	3/10/2021	24	RI	VA	1229
RI-2020-33	9/10/2020	F	HY	16	-	-	-	RI	-	-
RI-2020-34	9/17/2020	F	HY	32	3/8/2021	3/12/2021	4	RI	CT	817
RI-2020-35	9/19/2020	F	ASY	37	3/26/2021	3/30/2021	4	RI	RI	900
RI-2020-37	9/6/2020	F	-	14	-	-	-	RI	-	-
RI-2020-38	9/9/2020	F	HY	42	2/24/2021	4/19/2021	54	RI	ME	979
RI-2020-39	9/3/2020	F	-	24	3/10/2021	3/14/2021	4	RI	RI	485
RI-2020-40	9/2/2020	F	HY	31	-	-	-	RI	-	-
RI-2020-41	8/29/2020	F	AHY	41	2/28/2021	4/3/2021	34	RI	QUE	2093
RI-2020-42	9/2/2020	F	AHY	11	1/21/2021	-	-	RI	-	-
RI-2020-43	10/13/2020	F	AHY	41	1/31/2021	3/28/2021	56	RI	ME	1427
RI-2020-44	8/29/2020	F	-	40	1/29/2021	4/23/2021	84	RI	RI	2083
RI-2020-45	9/14/2020	F	ASY	37	1/25/2021	4/9/2021	74	RI	NY	1390
South Carolina										

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
SC-2021-18	2/10/2021	M	ASY	64	2/27/2021	4/9/2021	41	SC	ME	1774
SC-2021-19	2/10/2021	M	ASY	60	3/7/2021	3/11/2021	4	SC	MD	822
SC-2021-20	2/10/2021	F	SY	20	2/27/2021	3/2/2021	3	SC	VA	250
SC-2021-21	2/16/2021	M	ASY	56	3/13/2021	3/28/2021	15	SC	OH	1018
SC-2021-22	2/8/2021	M	ASY	62	2/24/2021	3/23/2021	27	SC	ME	1639
SC-2021-23	2/16/2021	M	SY	60	2/21/2021	3/11/2021	18	SC	WV	954
SC-2021-24	2/22/2021	M	SY	23	3/17/2021	-	-	SC	-	-
Virginia										
VA-2020-61	10/11/2020	M	HY	1	-	-	-	VA	-	-
VA-2020-62	10/11/2020	M	HY	22	2/23/2021	3/5/2021	10	VA	VA	564
VA-2020-63	10/11/2020	M	HY	16	2/27/2021	4/4/2021	36	VA	PA	1301
VA-2020-64	10/11/2020	M	HY	2	-	-	-	VA	-	-
VA-2020-66	10/11/2020	F	AHY	33	4/12/2021	4/17/2021	5	VA	VA	652
VA-2020-67	10/15/2020	F	HY	36	2/28/2021	3/12/2021	12	VA	MD	341
VA-2020-68	10/11/2020	F	HY	32	2/18/2021	4/2/2021	43	VA	WV	991
VA-2020-69	10/11/2020	F	AHY	32	2/13/2021	4/5/2021	51	VA	VA	1198
VA-2020-71	11/15/2020	M	AHY	18	3/9/2021	3/19/2021	10	VA	MI	1061
VA-2020-72	11/11/2020	F	AHY	40	3/24/2021	4/5/2021	12	VA	QUE	1589
VA-2020-73	11/11/2020	F	AHY	8	-	-	-	VA	-	-

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
VA-2020-74	11/11/2020	F	HY	6	-	-	-	VA	-	-
VA-2020-76	11/11/2020	M	HY	11	3/19/2021	-	-	VA	-	-
VA-2020-77	11/11/2020	F	AHY	2	-	-	-	VA	-	-
VA-2020-78	11/11/2020	M	AHY	21	3/15/2021	4/4/2021	20	VA	NY	670
VA-2020-79	11/19/2020	F	HY	47	2/24/2021	3/25/2021	29	VA	ON	1357
VA-2020-81	11/24/2020	F	AHY	39	2/28/2021	4/6/2021	37	VA	VT	1090
VA-2020-82	11/24/2020	F	AHY	12	-	-	-	VA	-	-
VA-2020-83	12/7/2020	F	AHY	44	3/21/2021	3/31/2021	10	VA	NY	861
VA-2020-84	12/14/2020	F	AHY	50	2/24/2021	5/18/2021	83	VA	QUE	1752
VA-2020-86	12/16/2020	F	AHY	3	-	-	-	VA	-	-
VA-2020-87	12/14/2020	F	HY	4	-	-	-	VA	-	-
VA-2020-88	10/28/2020	M	HY	5	-	-	-	VA	-	-
VA-2021-91	-	-	-	16	1/25/2021	4/12/2021	77	VA	QUE	1373
VA-2021-92	-	-	-	39	1/14/2021	4/25/2021	101	VA	QUE	1772
VA-2021-93	-	-	-	20	3/5/2021	4/23/2021	49	VA	ME	1295
VA-2021-94	1/25/2021	M	AHY	17	3/25/2021	4/4/2021	10	VA	PEI	1553
VA-2021-95	-	-	-	23	-	-	-	VA	-	-
Vermont										
VT-2020-05	9/16/2020	M	HY	13	3/5/2021	3/26/2021	21	VT	VT	864

Bird ID	Capture Date	Sex	Age at Capture[a]	No. Loc[b]	Init. Date[c]	Term. Date[d]	Days Migr[e]	State of Capture	Terminal State[f]	Mig. Distance[g]
VT-2020-06	9/16/2020	M	HY	13	3/26/2021	4/2/2021	7	VT	VT	1052
VT-2020-07	9/16/2020	M	AHY	5	2/19/2021	-	-	VT	-	-
VT-2020-09	9/16/2020	M	AHY	9	2/19/2021	3/26/2021	35	VT	NY	1478
VT-2020-14	9/23/2020	M	AHY	13	2/10/2021	3/28/2021	46	VT	VT	2111
VT-2020-15	9/29/2020	F	HY	15	4/23/2021	5/7/2021	14	VT	NH	1003
VT-2020-17	9/29/2020	F	HY	16	-	-	-	VT	-	-
VT-2020-18	9/30/2020	M	HY	11	2/16/2021	3/28/2021	40	VT	NY	1211

Additional Figures

Figures A1 – A21. Maps showing American Woodcock migratory movements in Fall 2020 and Spring 2021, broken out by the state or province in which each bird was originally captured.

Fall 2020

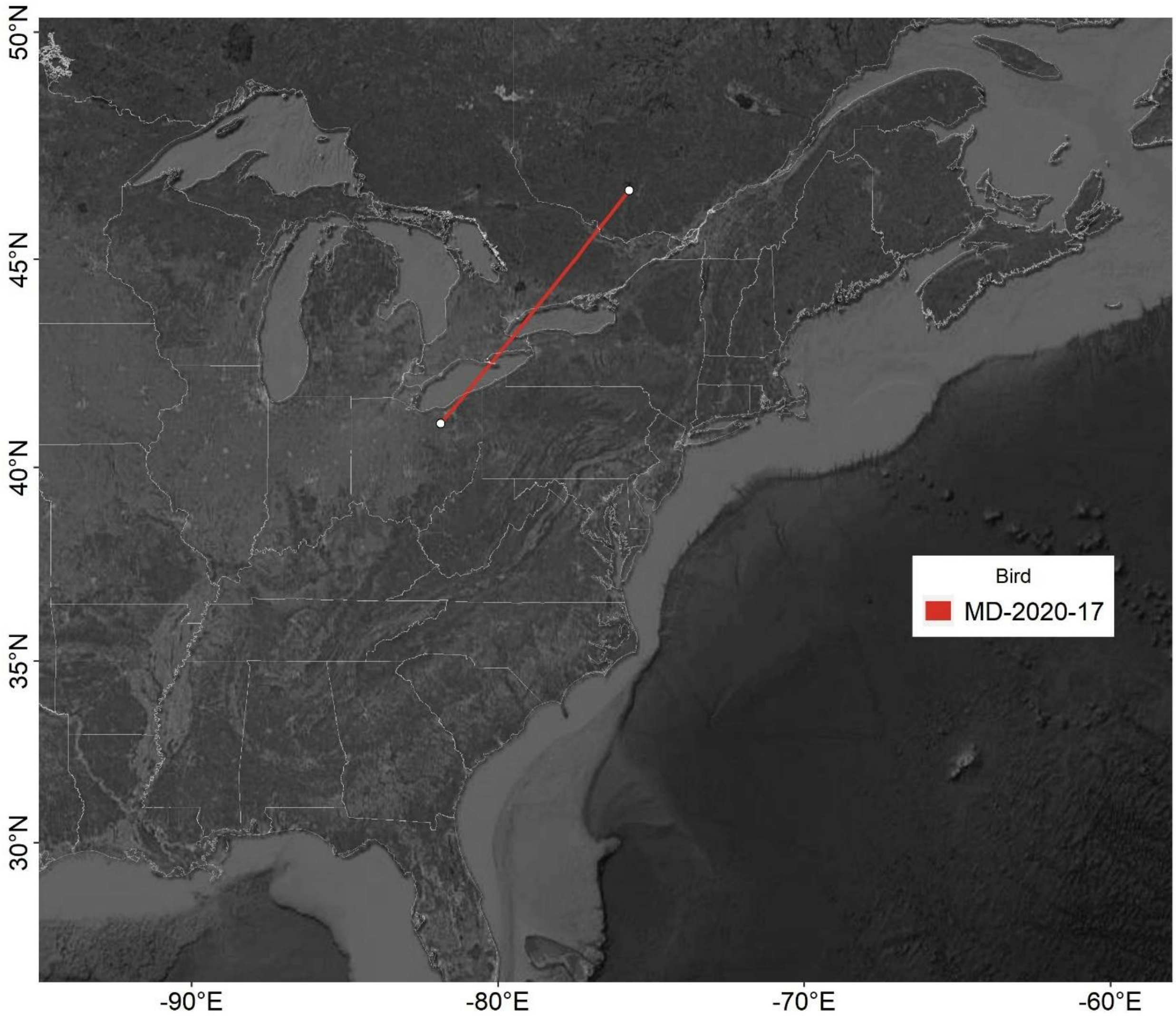

Figure A1. Fall migration of woodcock tagged in Maryland in Spring 2020.

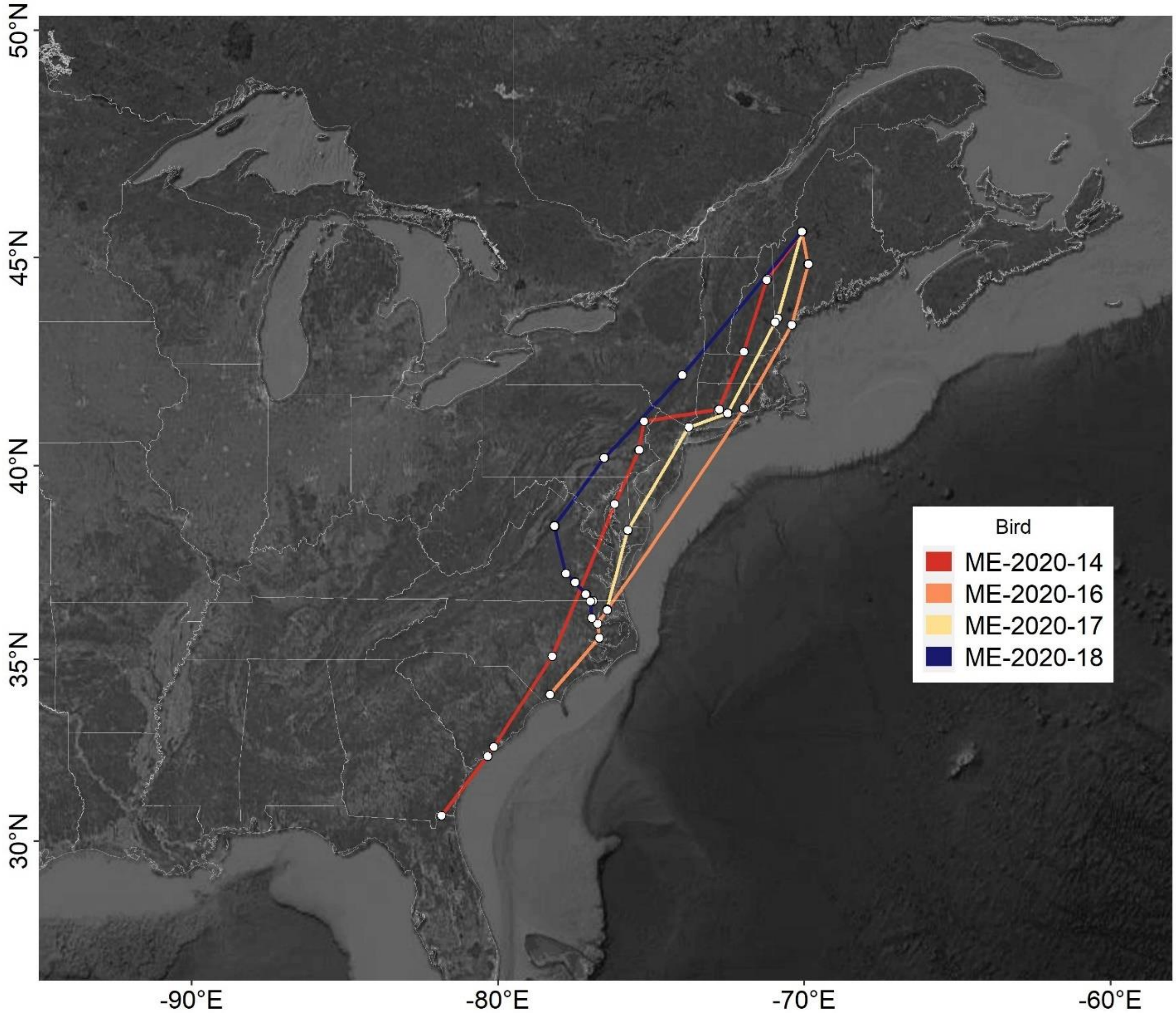

Figure A2. Fall migration of woodcock tagged in Maine in Fall 2020.

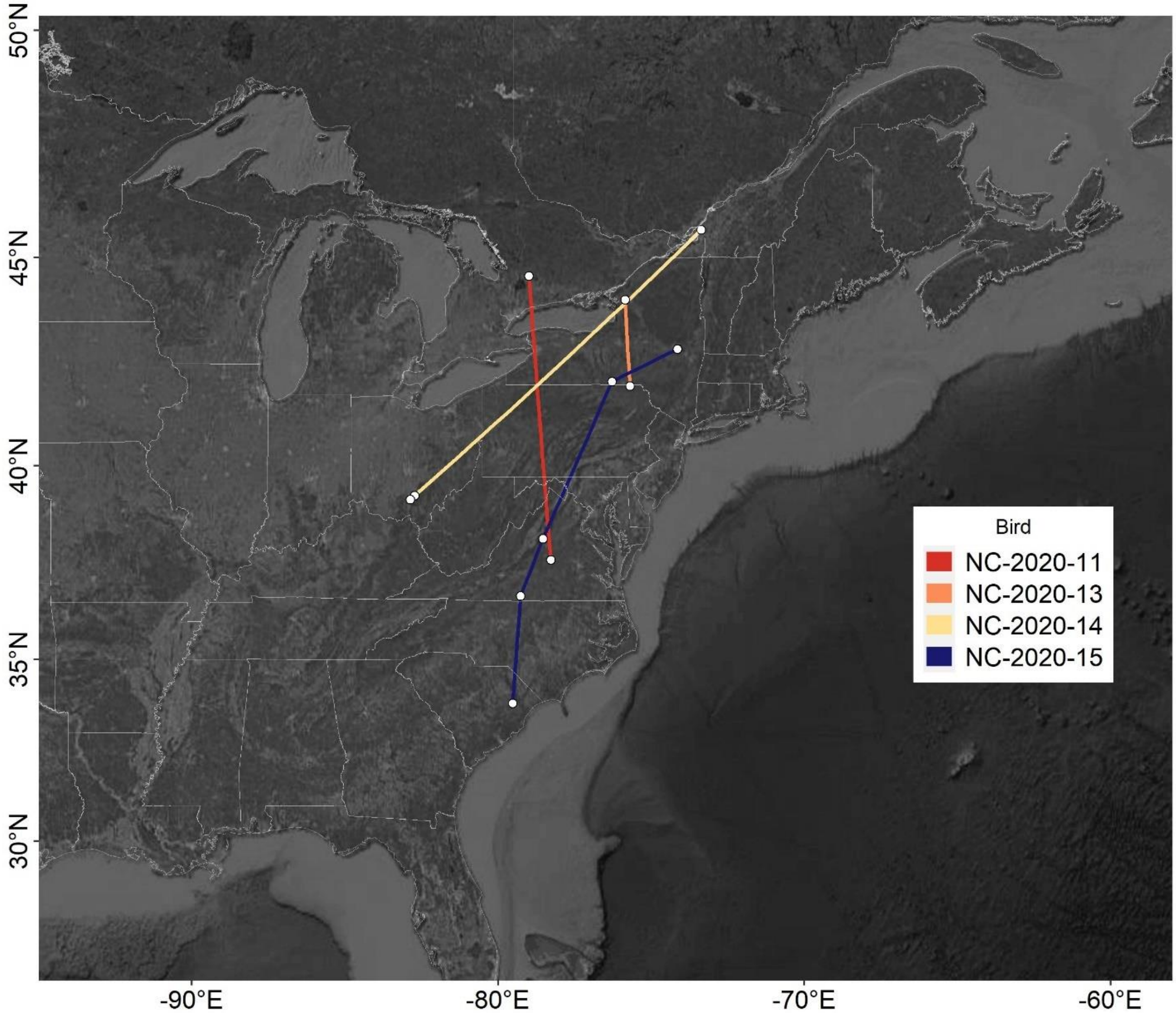

Figure A3. Fall migration of woodcock tagged in North Carolina in Spring 2020.

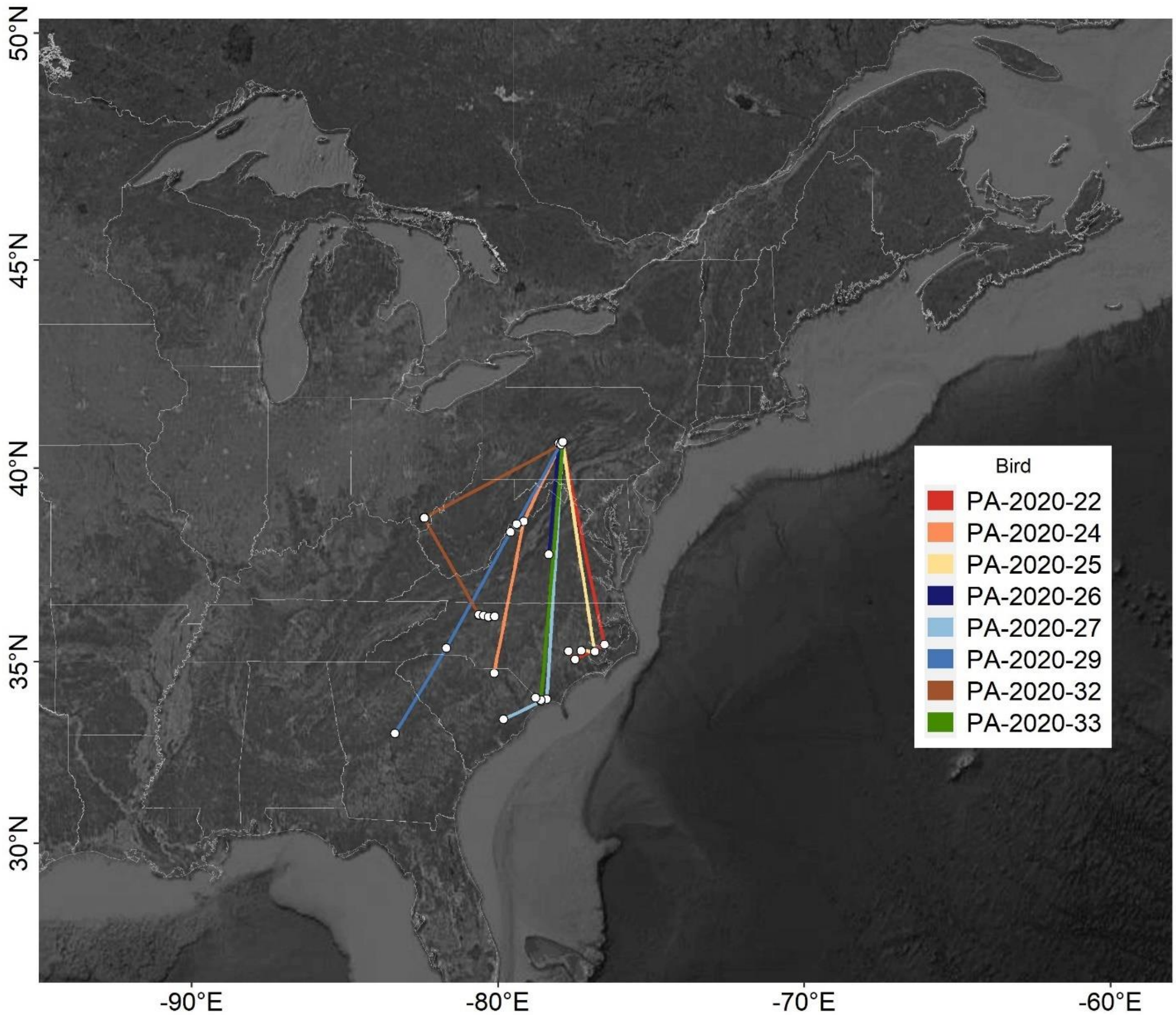

Figure A4. Fall migration of woodcock tagged in Pennsylvania in Fall 2020.

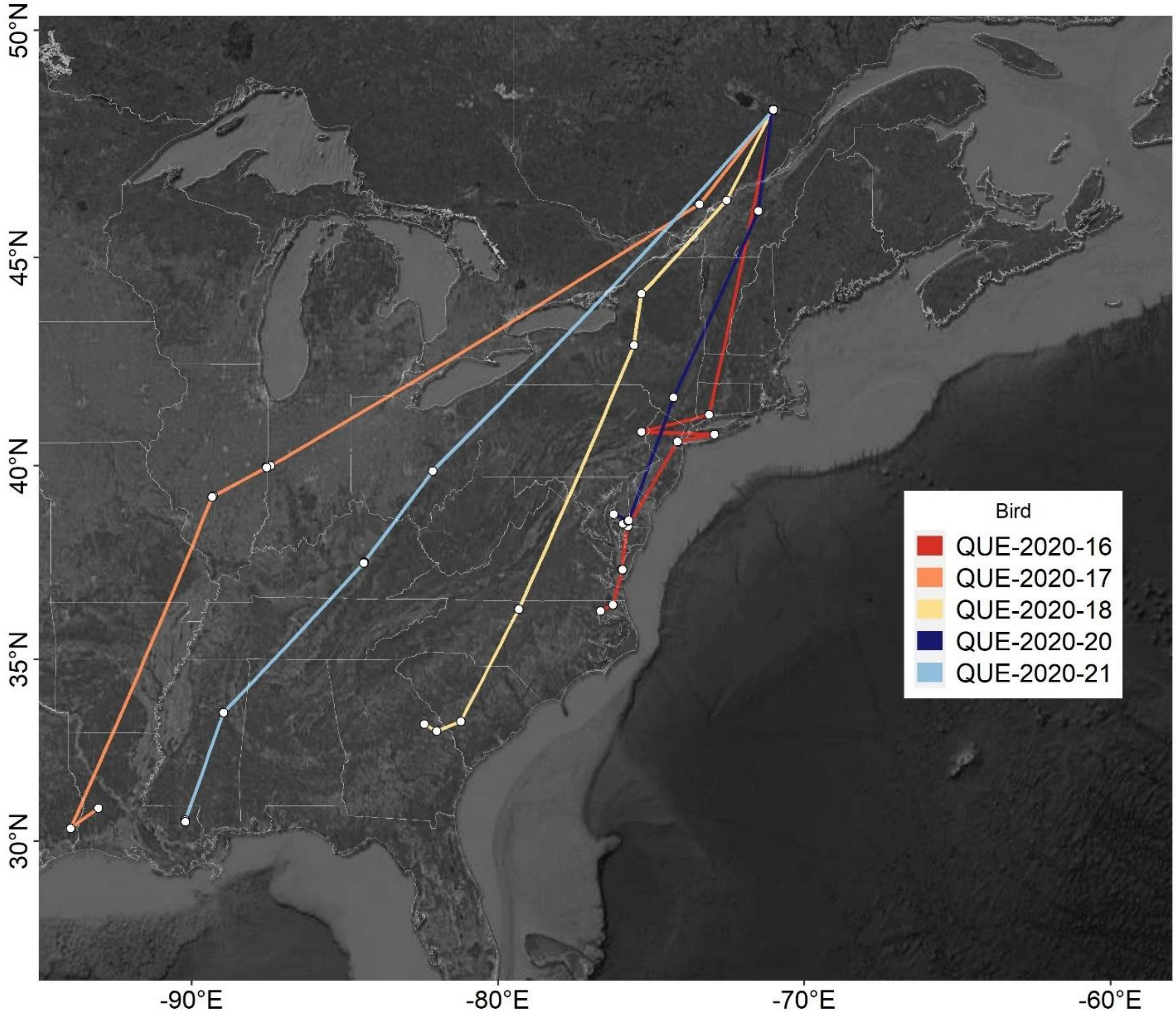

Figure A5. Fall migration of woodcock tagged in Quebec in Fall 2020.

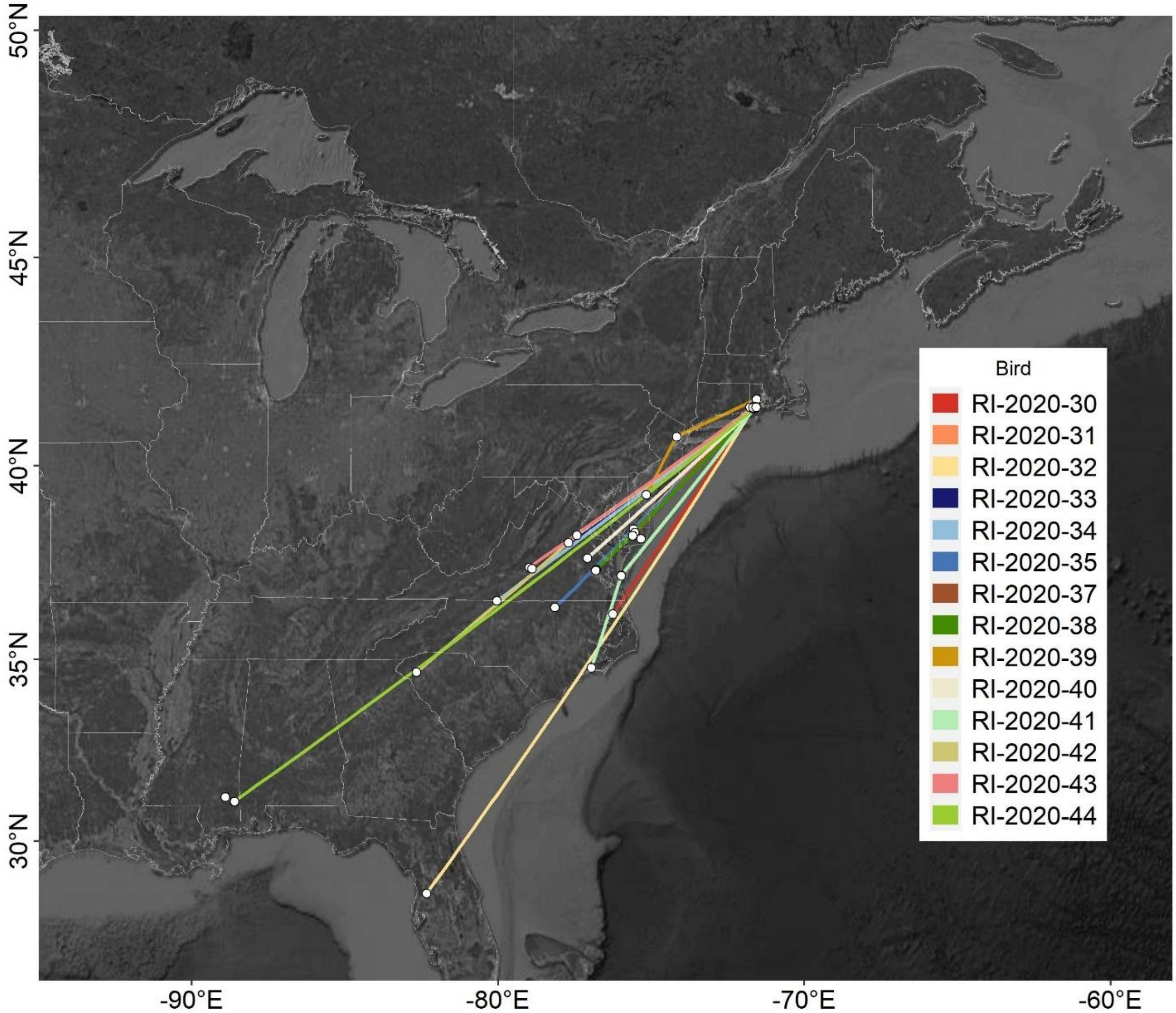

Figure A6. Fall migration of woodcock tagged in Rhode Island in Fall 2020.

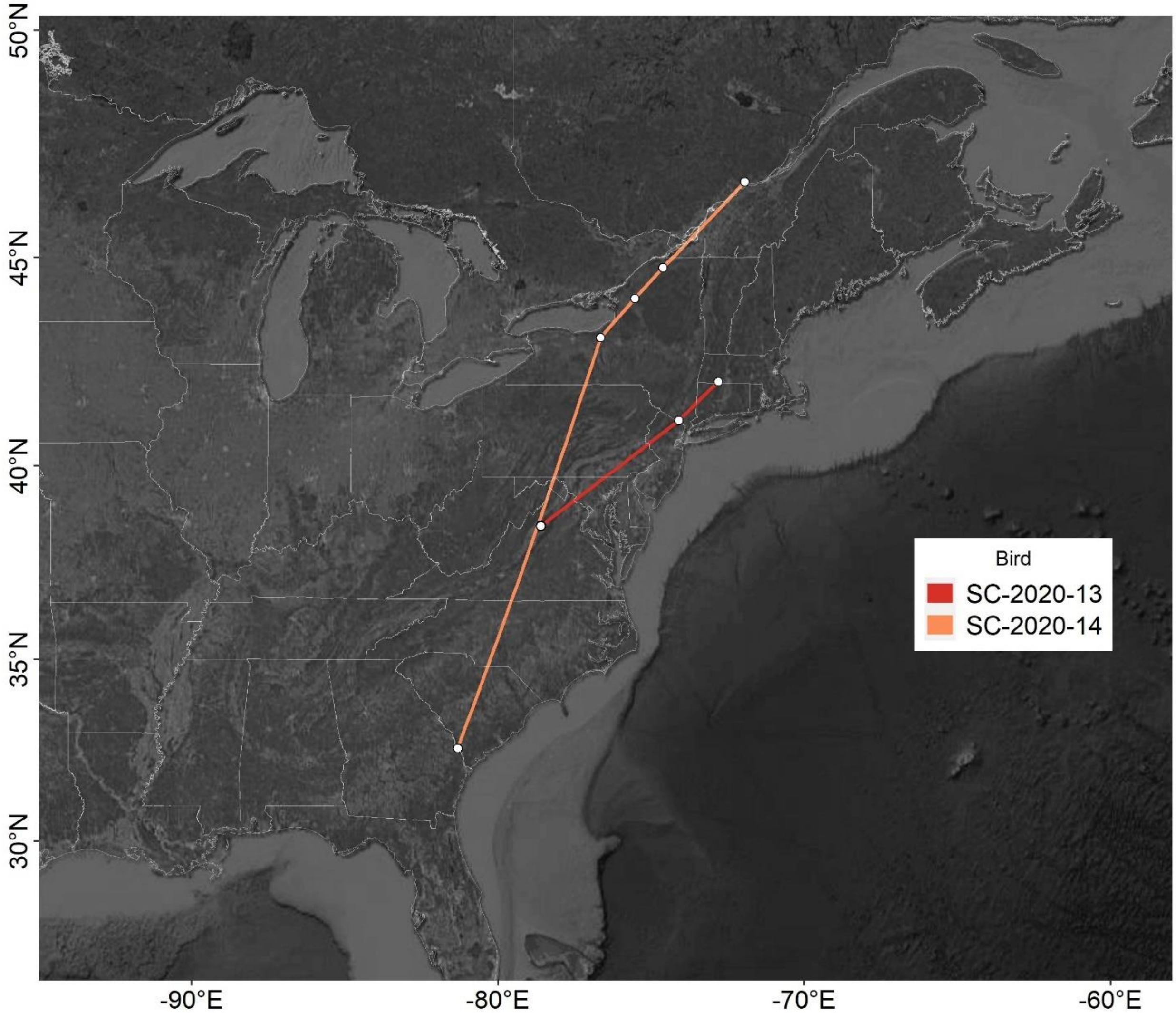

Figure A7. Fall migration of woodcock tagged in South Carolina in Spring 2020.

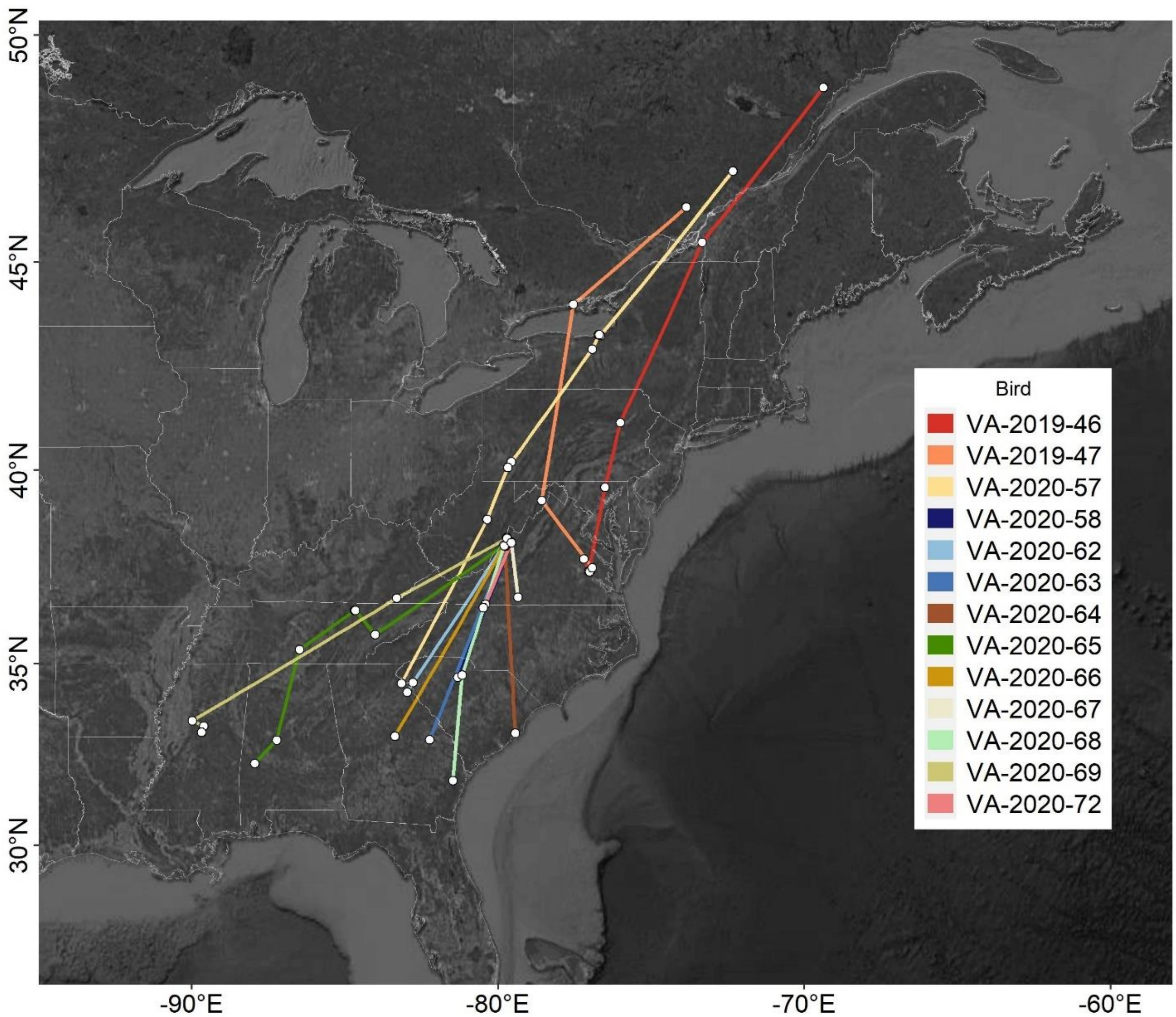

Figure A8. Fall 2020 migration of woodcock tagged in Virginia in Fall 2019, Spring 2020, and Fall 2020.

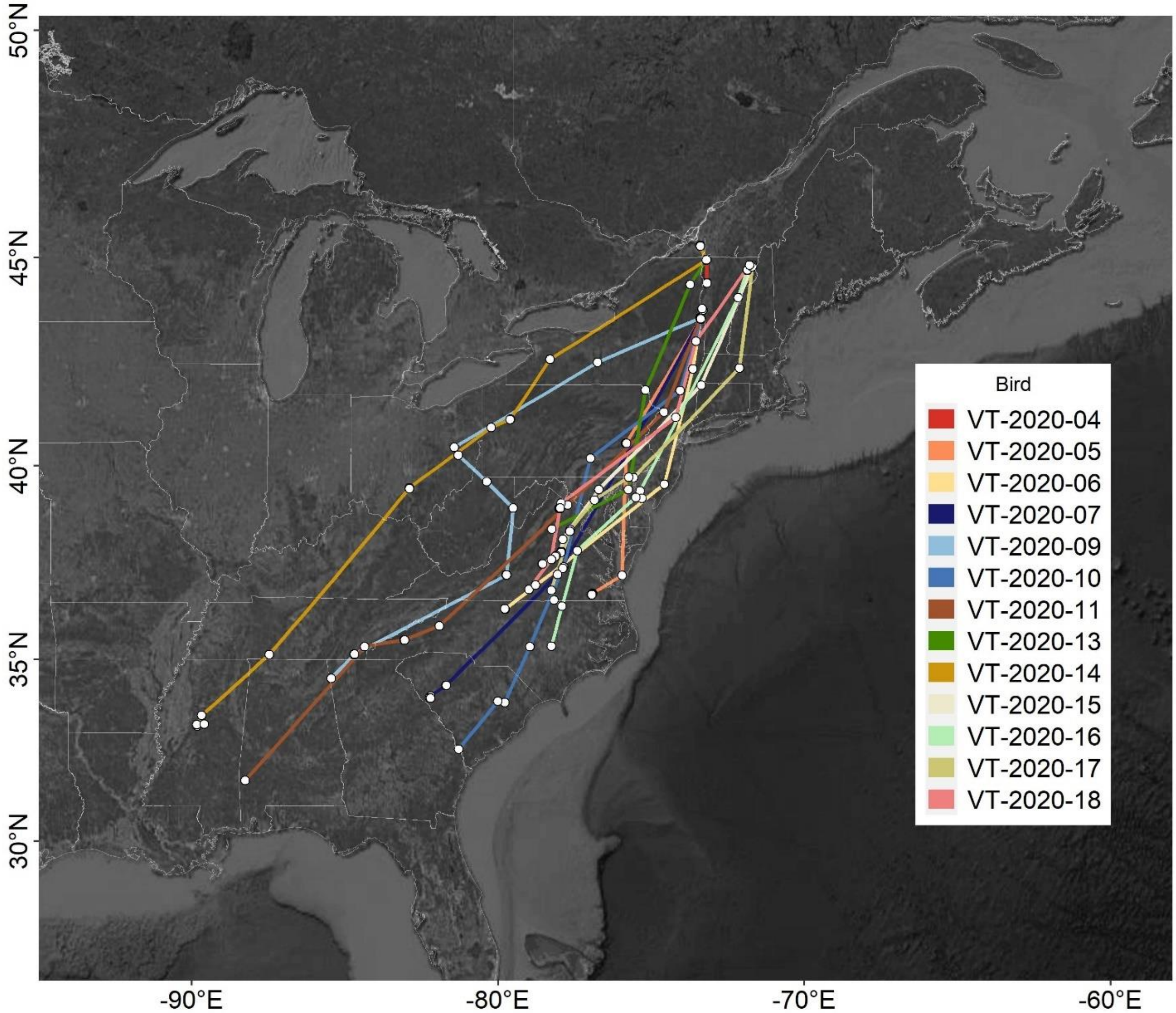

Figure A9. Fall migration of woodcock tagged in Vermont in Fall 2020.

Spring 2021

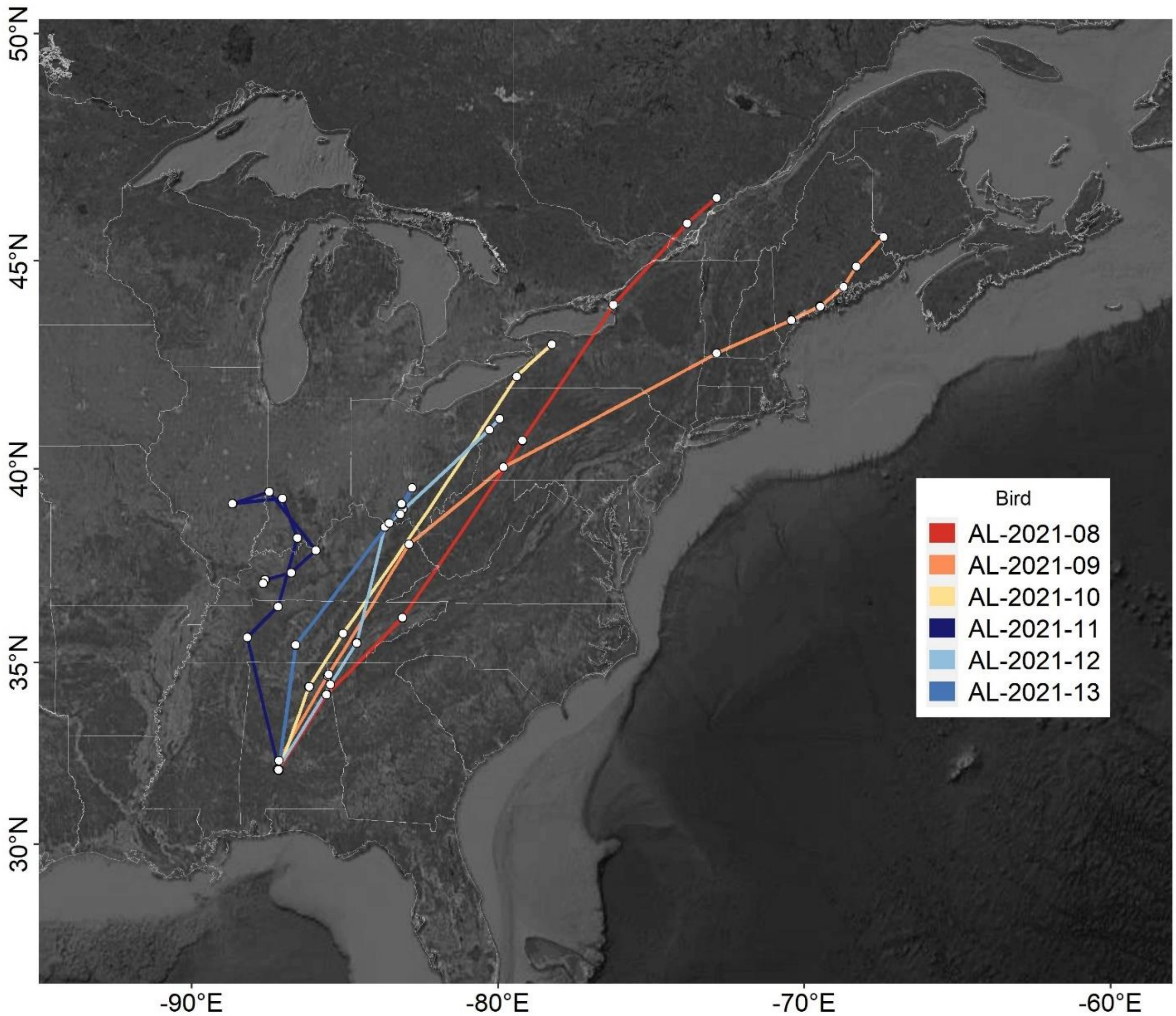

Figure A10. Spring migration of woodcock tagged in Vermont in Spring 2021.

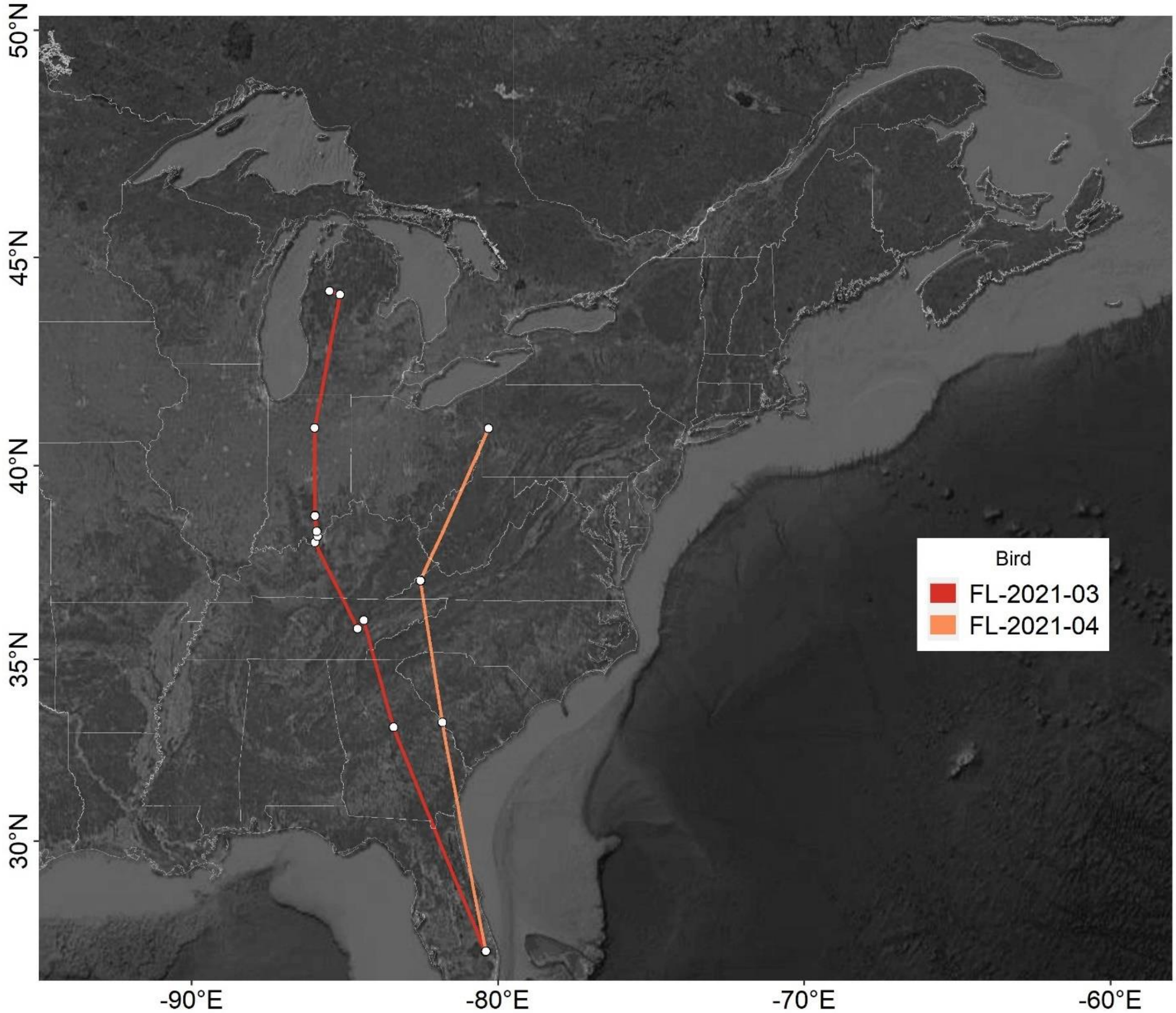

Figure A11. Spring migration of woodcock tagged in Florida in Spring 2021. A third woodcock (FL-2021-01) tagged in Florida declined to migrate, undergoing several within-state ranging movements instead.

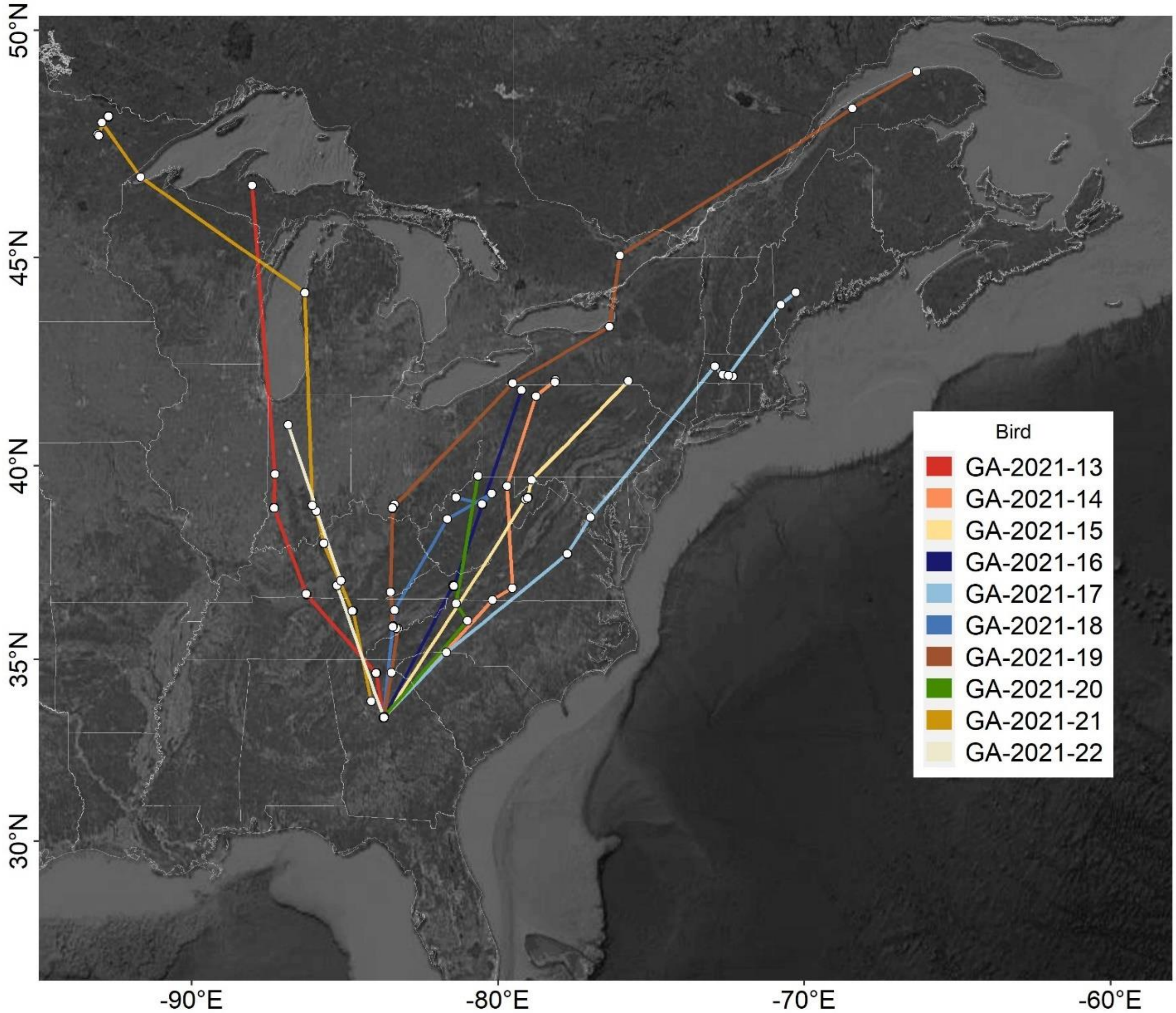

Figure A12. Spring migration of woodcock tagged in Georgia in Spring 2021.

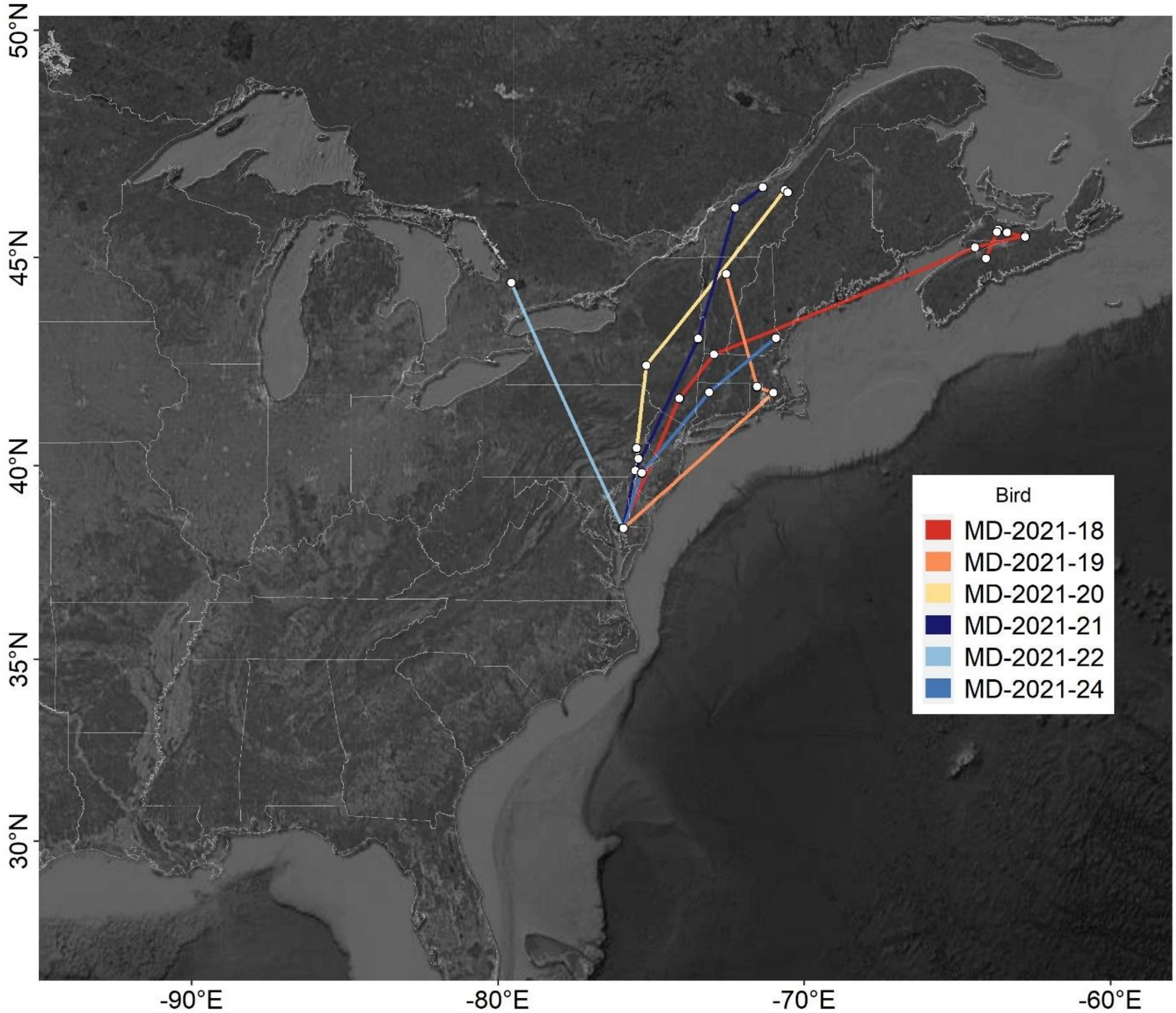

Figure A13. Spring migration of woodcock tagged in Maryland in Spring 2021.

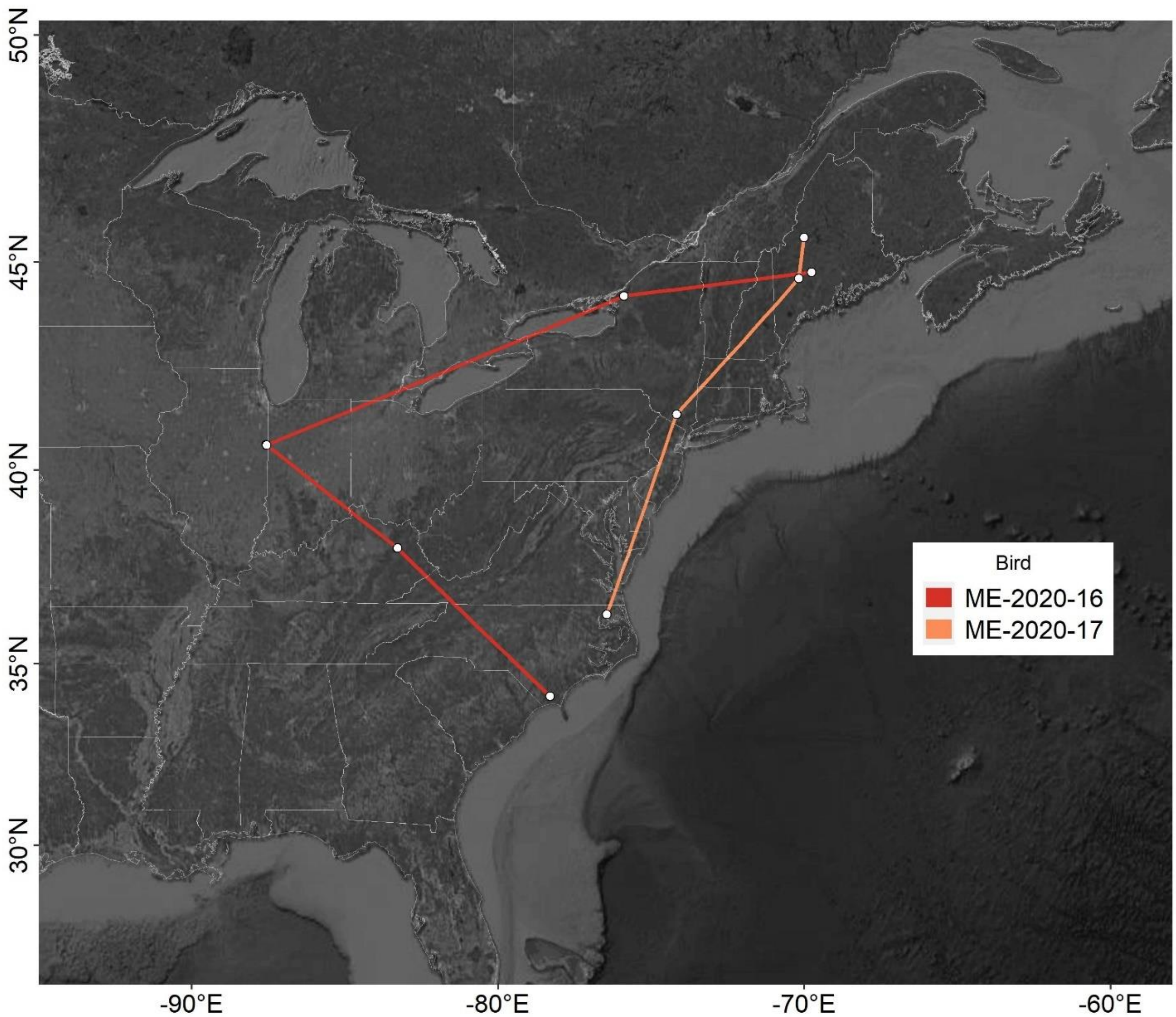

Figure A14. Spring migration of woodcock tagged in Maine in Fall 2020.

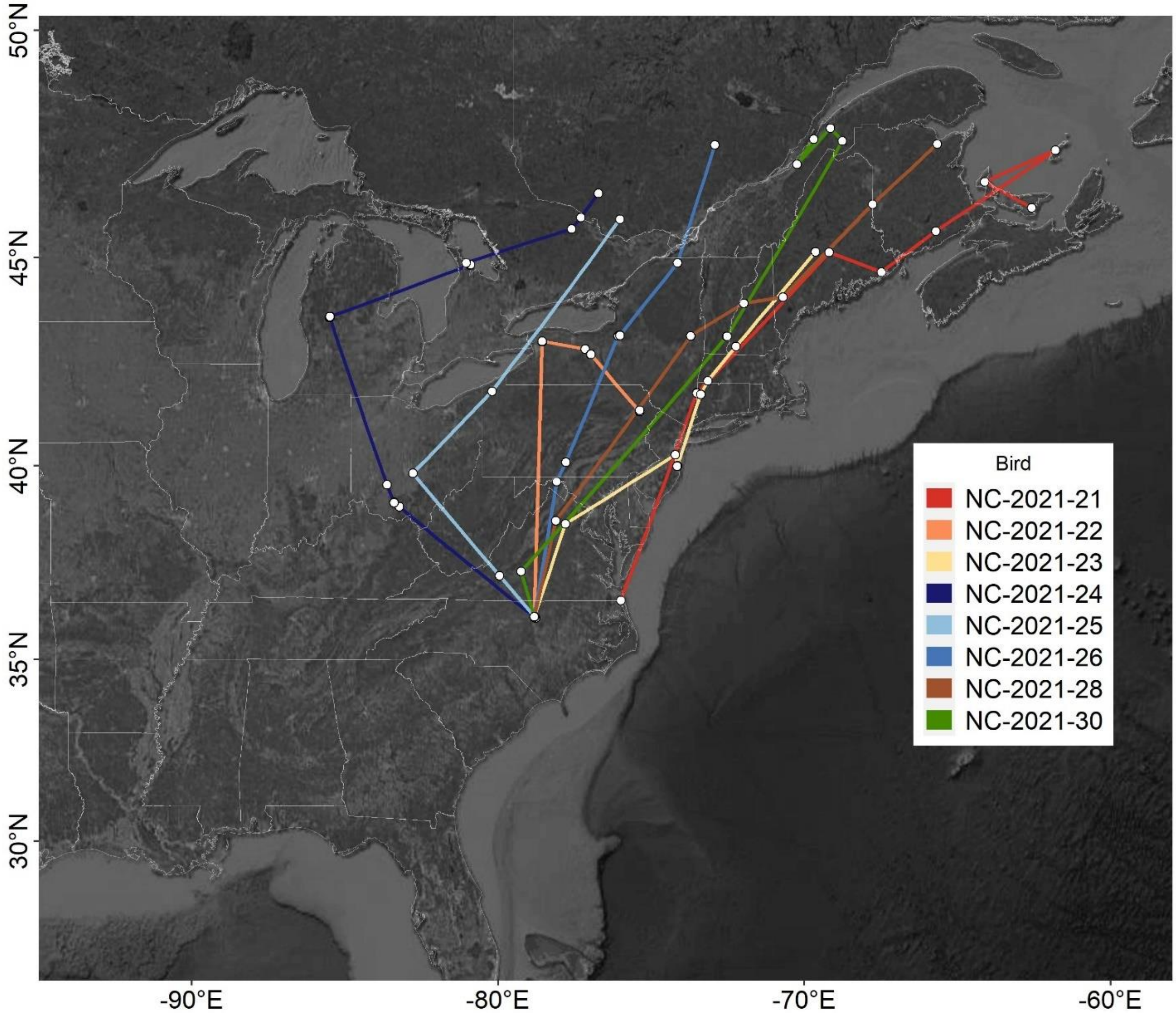

Figure A15. Spring migration of woodcock tagged in North Carolina in Spring 2021.

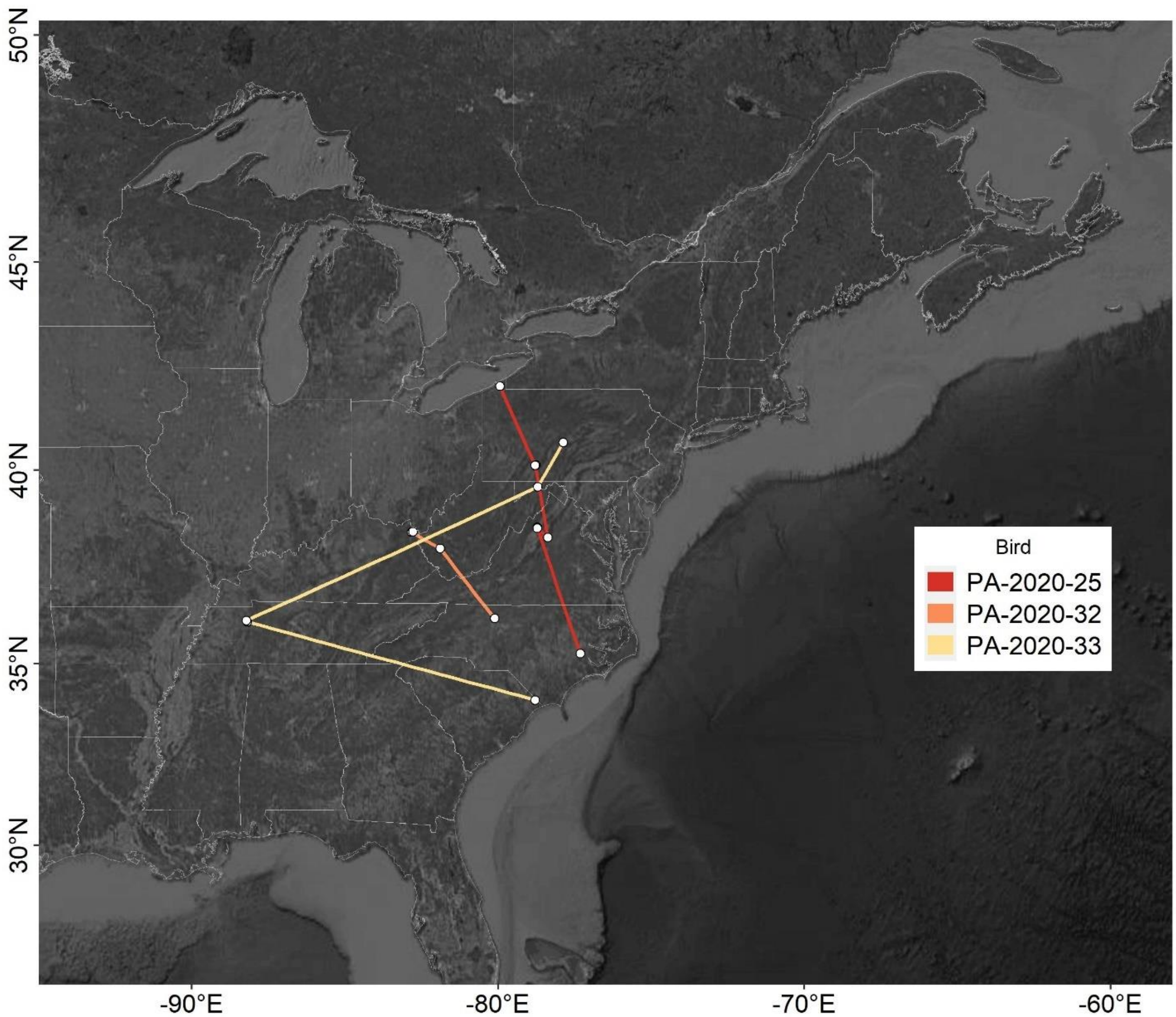

Figure A16. Spring migration of woodcock tagged in Pennsylvania in Fall 2020.

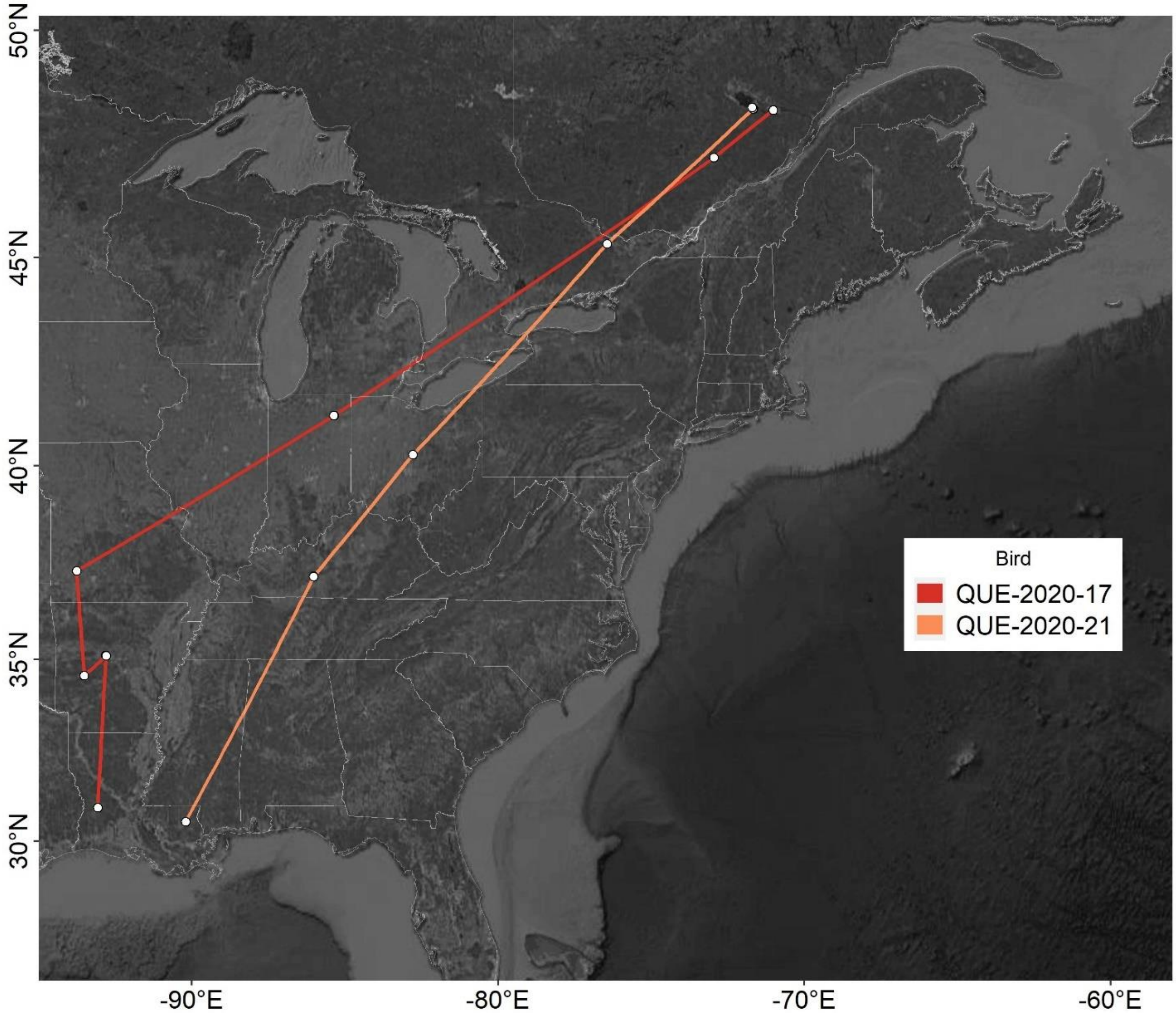

Figure A17. Spring migration of woodcock tagged in Quebec in Fall 2020.

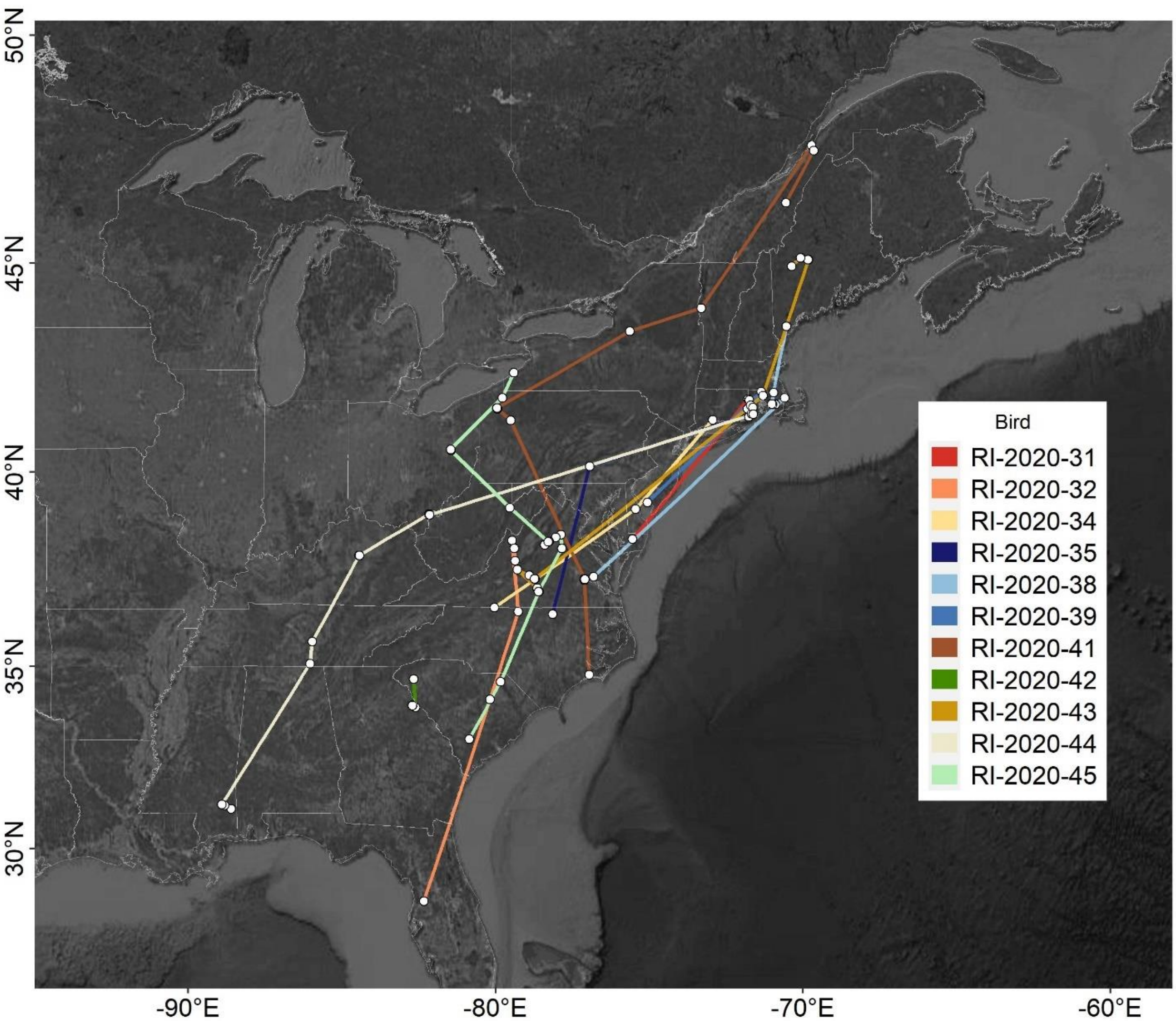

Figure A18. Spring migration of woodcock tagged in Rhode Island in Fall 2020.

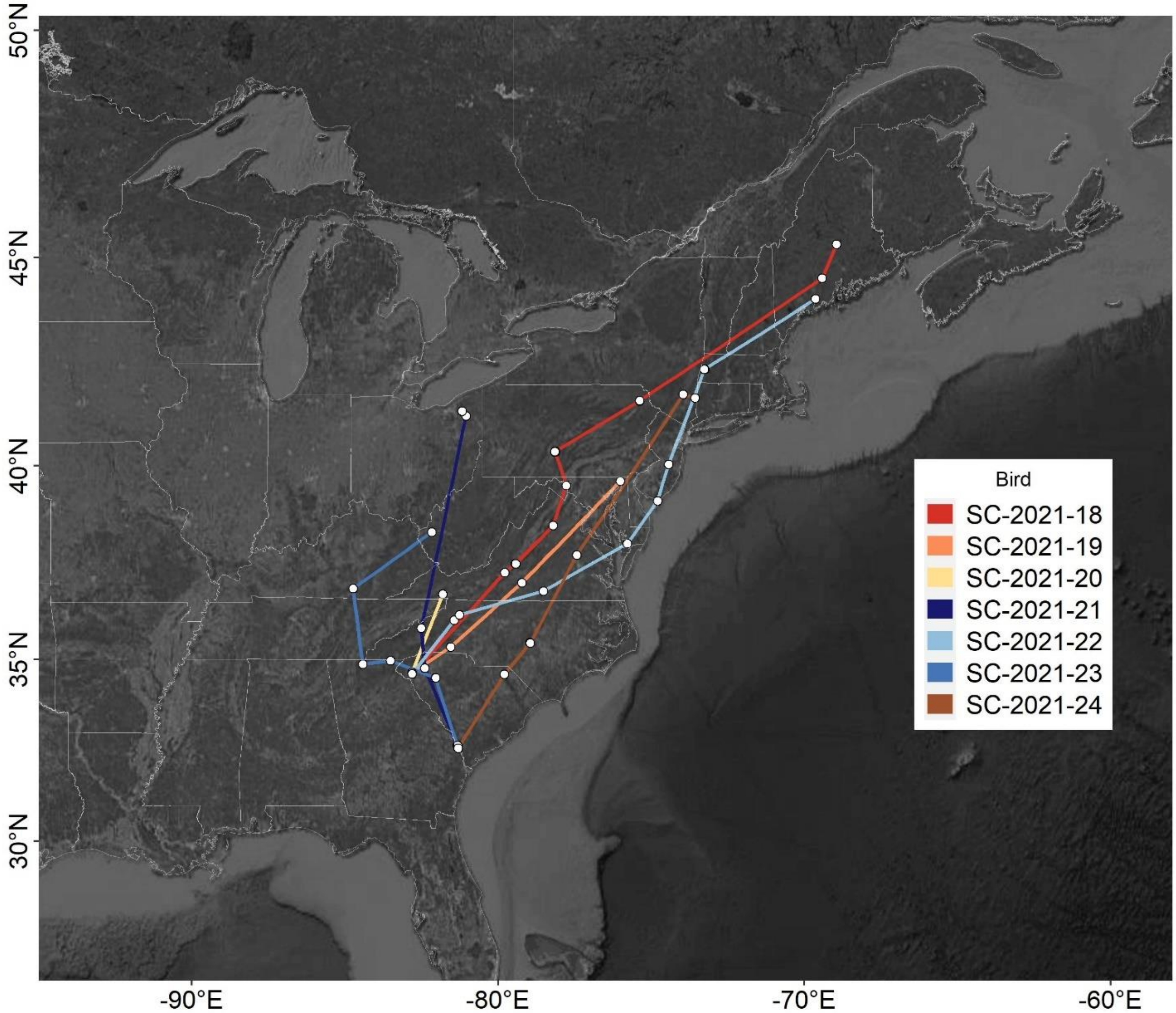

Figure A19. Spring migration of woodcock tagged in South Carolina in Spring 2021.

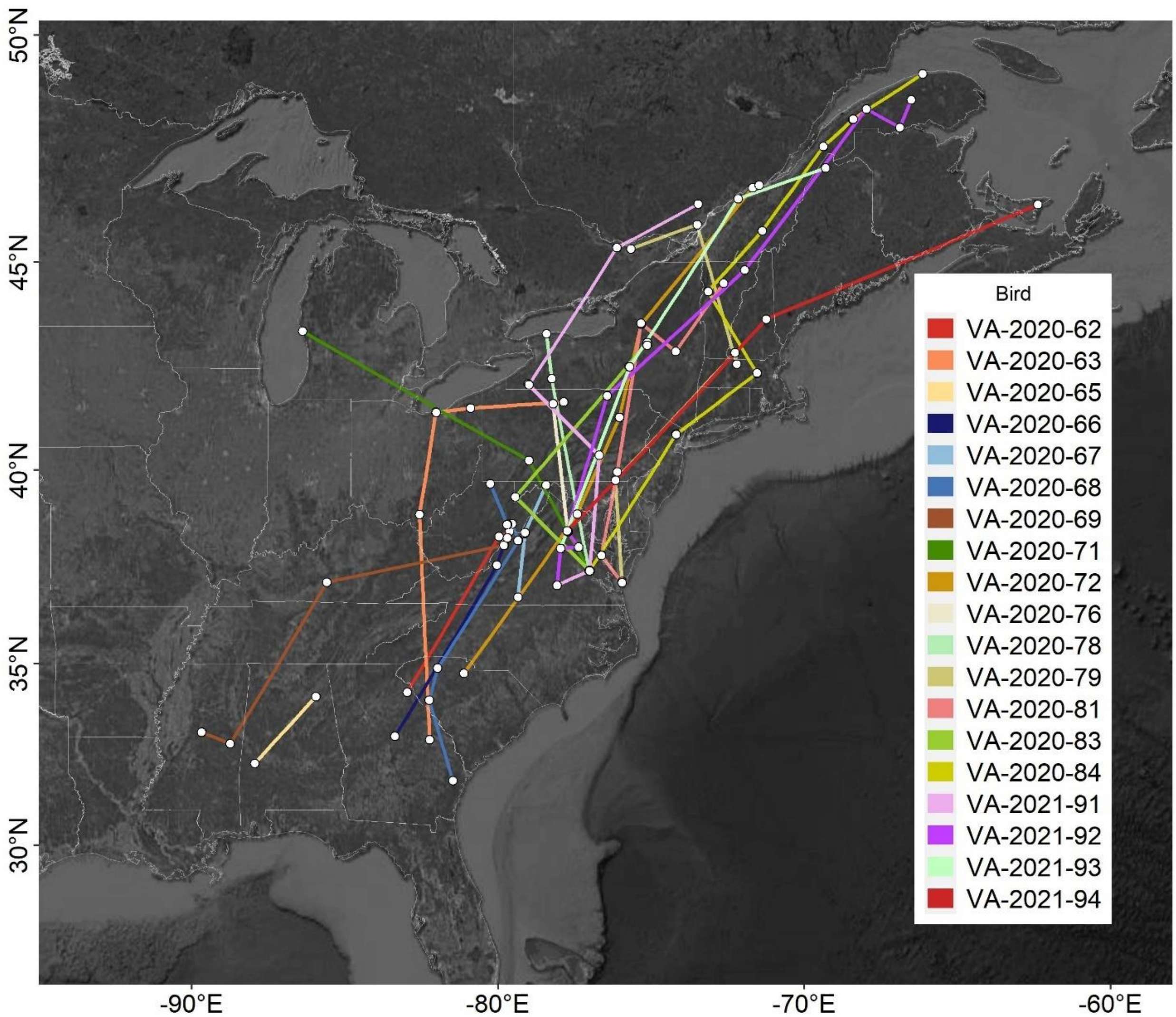

Figure A20. Spring migration of woodcock tagged in Virginia in Fall 2020 and Spring 2021.

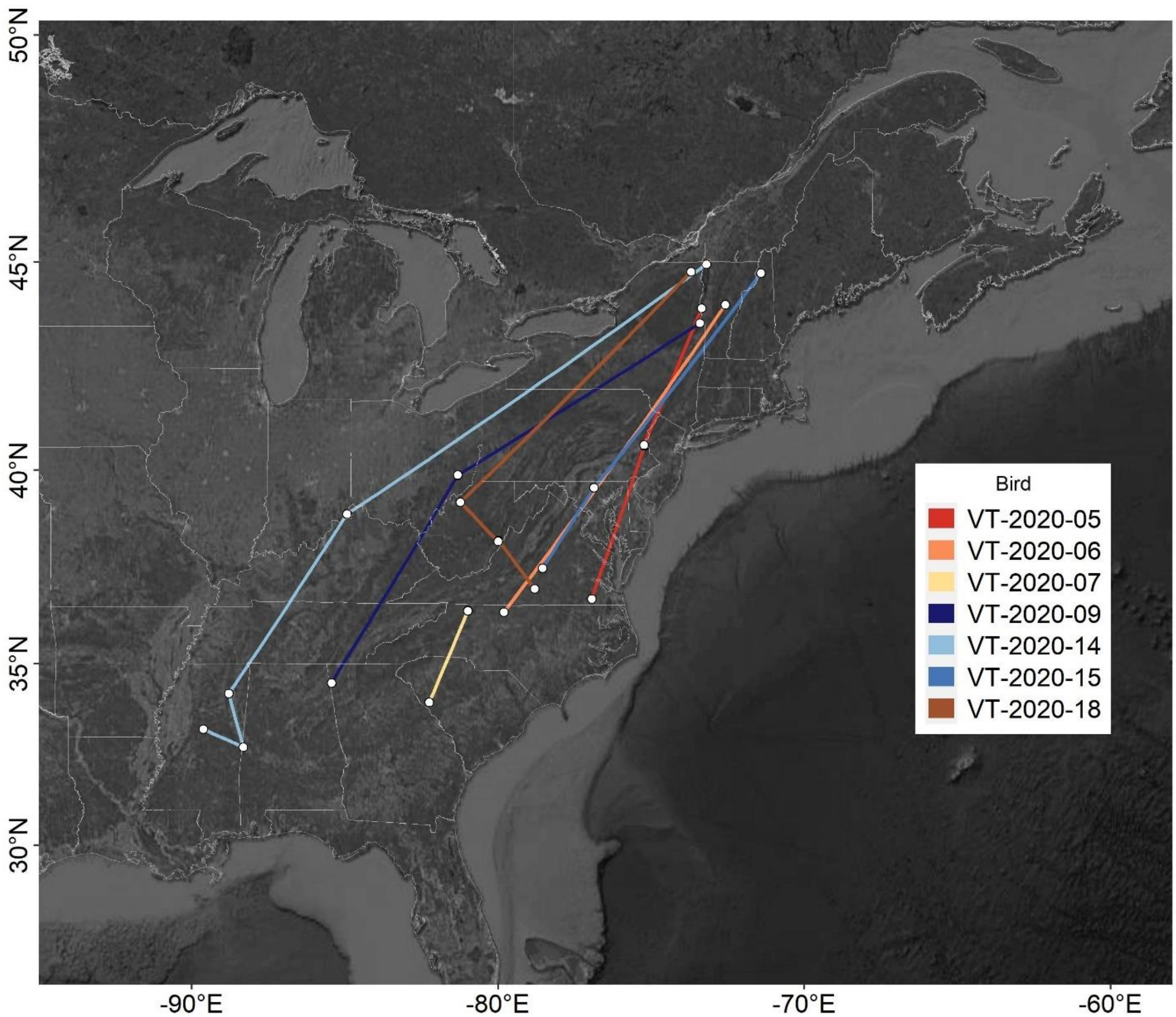

Figure A21. Spring migration of woodcock tagged in Vermont in Fall 2020.

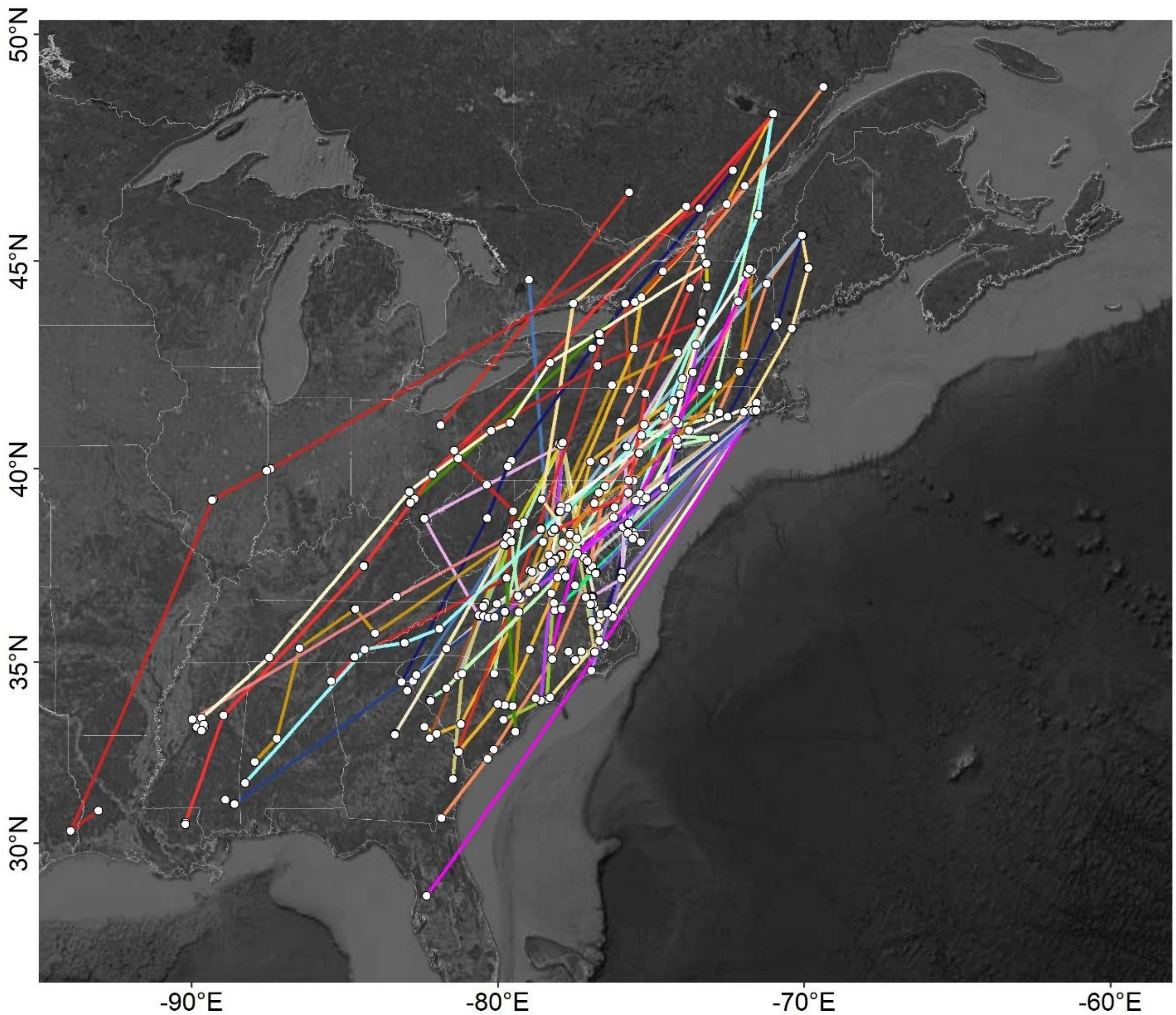

Figure A22. All American Woodcock migratory movements from Fall 2020.

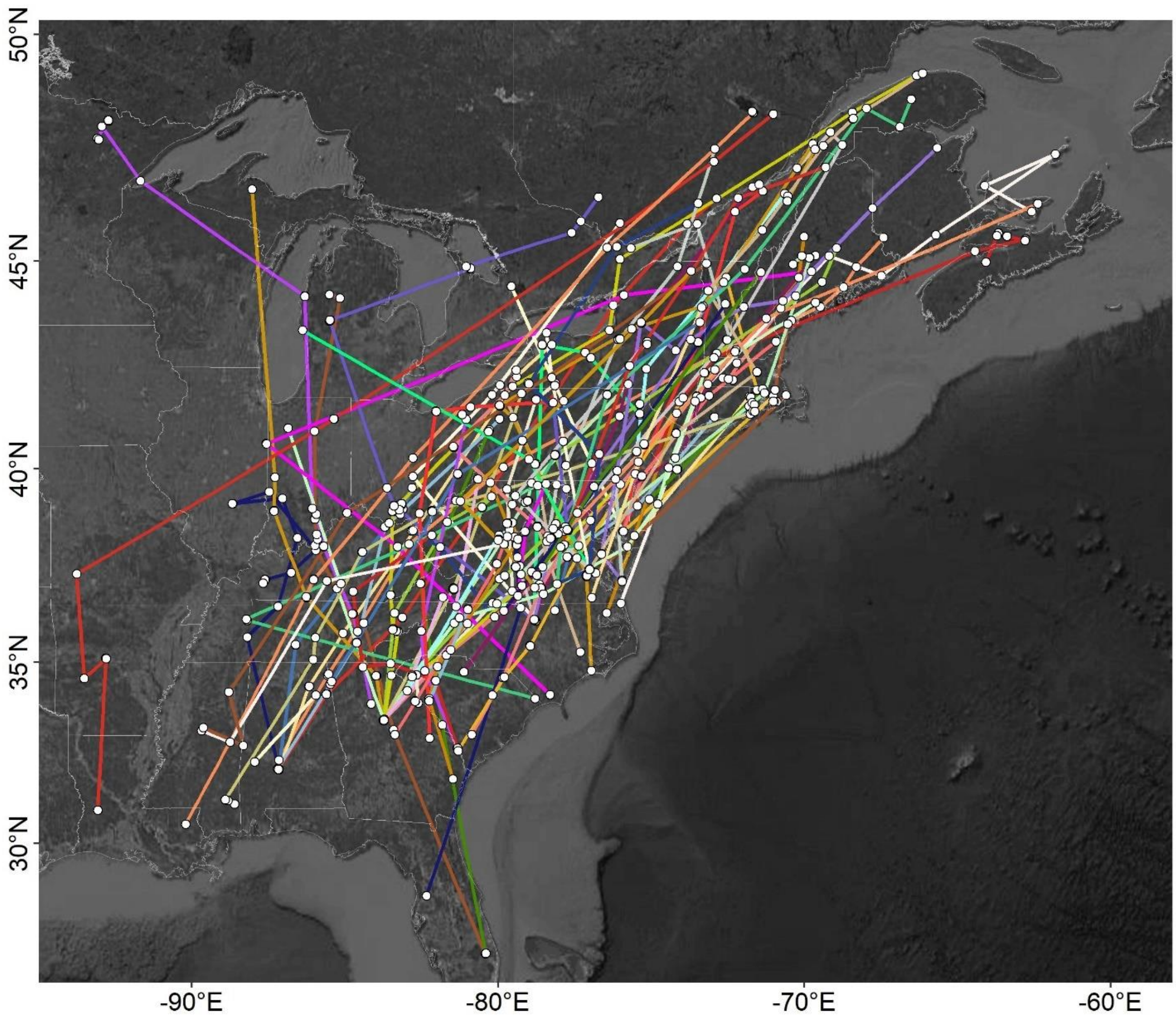

Figure A23. All American Woodcock migratory movements from Spring 2021.

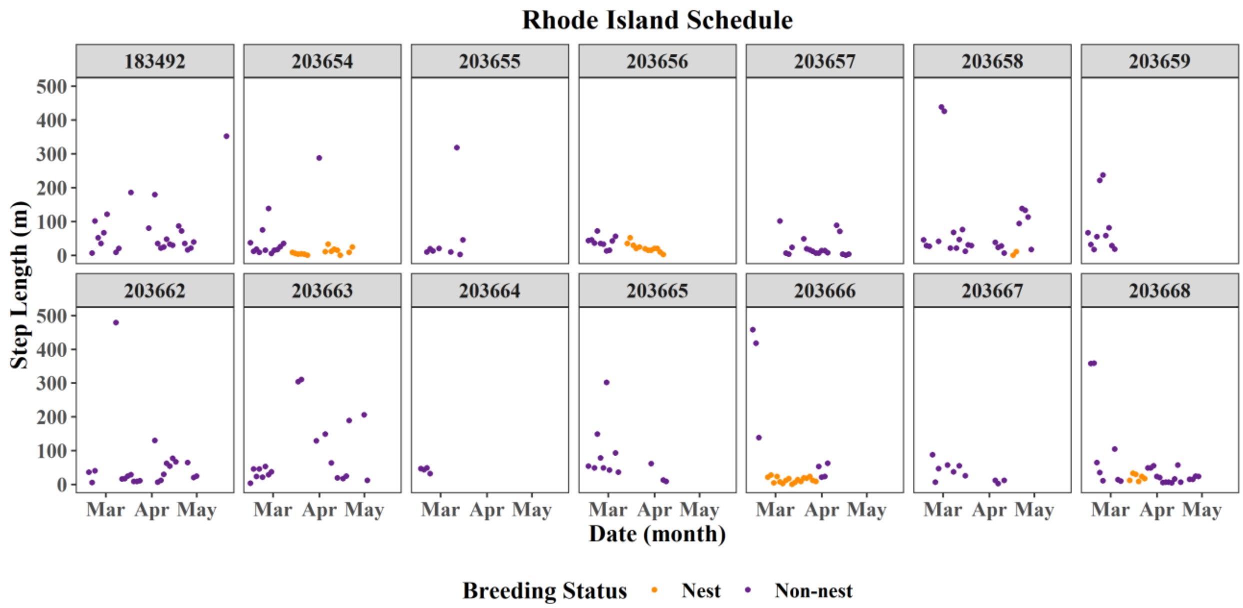

Figure A24. RI duty-cycle step-lengths for incubating and non-nesting periods during the 2021 spring breeding season. In total, there were 6 verified nests, and one with a renest (203654). 203664 had a confirmed breeding attempt, but the tag slipped and was identified using pointing dogs in RI rather than step lengths.

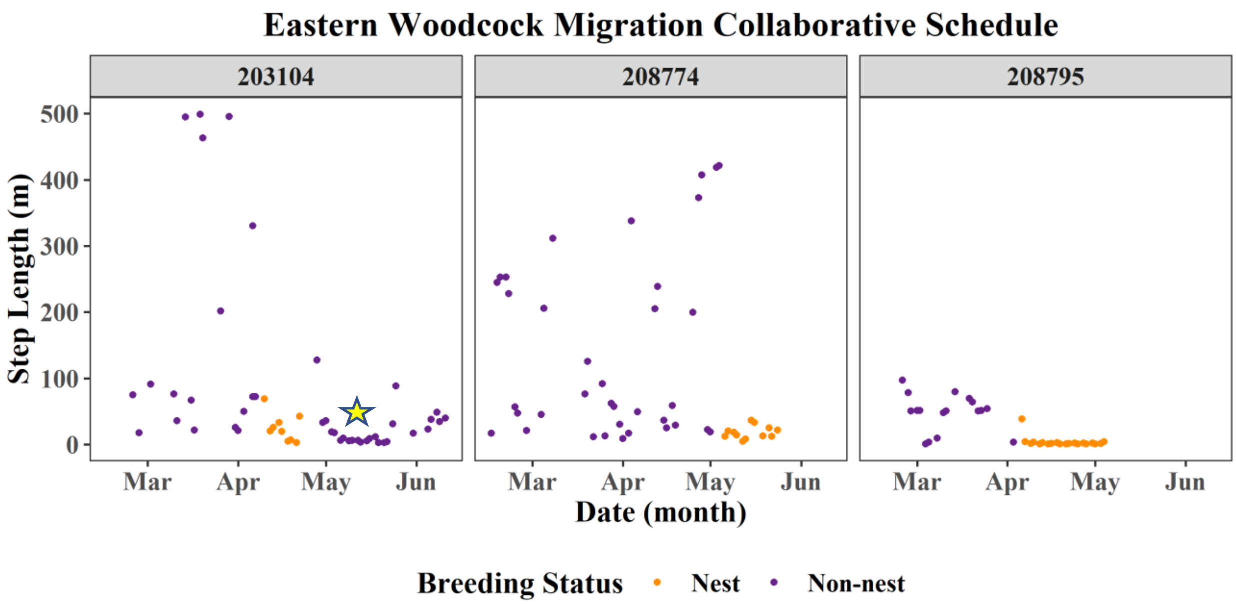

Figure A25. EWMRC duty-cycle step-lengths for incubating (orange) and non-nesting (dark blue) periods for the three verified, ground-truthed nesting hens found during the 2021 spring breeding season. Star on steps of Id (203104) denotes a renest that was unable to be verified by a collaborator.

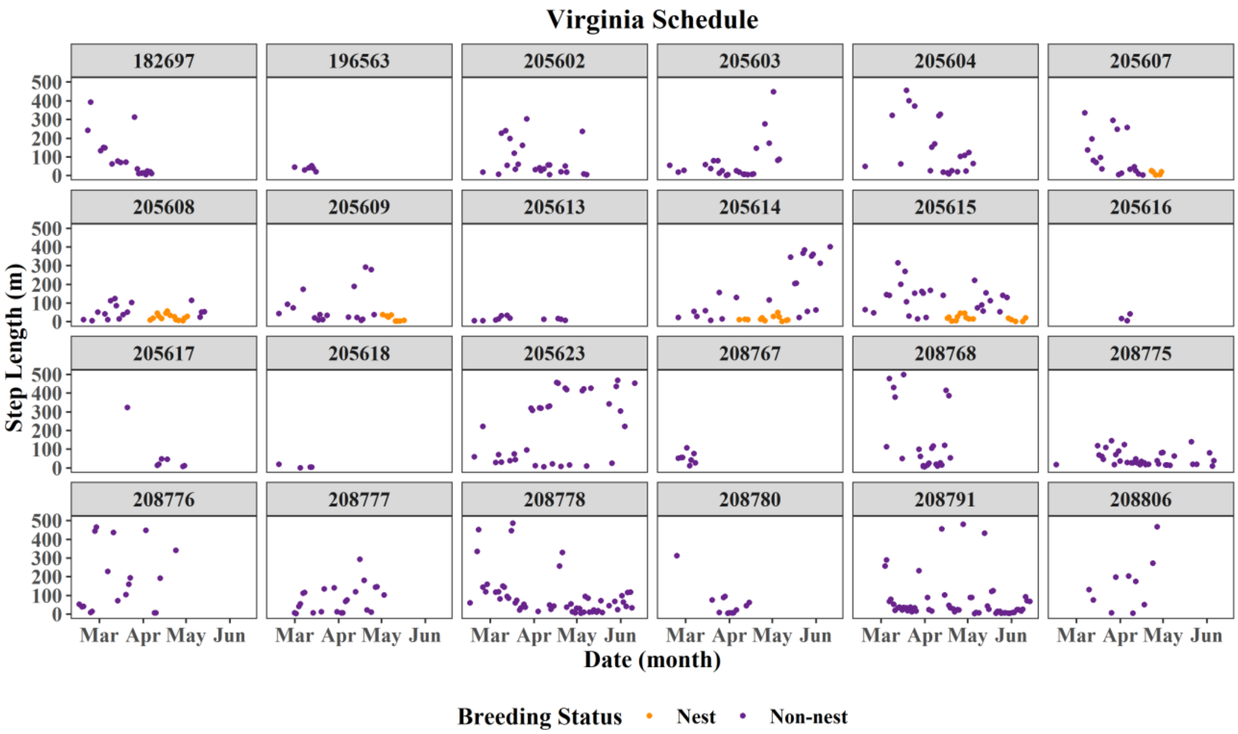

Figure A26. VA duty-cycle step-lengths for incubating (orange) and non-nesting periods (dark blue) during the 2021 spring breeding season; in total, there were 5 hens that had verified nests, two of these renested (205614 and 205615).