AMERICAN WOODCOCK (*SCOLOPAX MINOR*) MIGRATION ECOLOGY IN EASTERN NORTH AMERICA – 2022 Annual Report

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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. Any results or information reported herein should be cited as unpublished data; we anticipate interpretation may change as additional data are collected.*

Cover photo: Collaborators tagging a woodcock at The Nature Conservancy's Helen W. Buckner Natural Area in southwestern Vermont. Credit to Murray McHugh, The Nature Conservancy.

Executive Summary

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. This report documents data collection and preliminary findings from the past year, as well as describing future directions. Past achievements can be found in our previous year's reports by visiting woodcockmigration.org/research. Highlights from the report include:

- ***Data collected to date:*** From Fall 2017 – Spring 2022, we deployed 568 GPS transmitters on woodcock captured in 14 states and 3 Canadian provinces throughout eastern North America, which provided data on 494 migration attempts and 433 full migratory paths. We have also

collected feather or blood samples from the majority of marked woodcock, which we will use to assess woodcock population structure based on genomic and isotopic methods.

- Student Theses Produced: The past year saw the production of two student theses from EWMRC data, with Alex Fish completing his PhD Dissertation and Katie Trebilcock completing an undergraduate honors thesis, both at the University of Maine. Fish 2020 provides an assessment of woodcock migration phenology relative to harvest regulations, explores weather effects on woodcock migration timing, and gives a first look at survival of woodcock during periods of migration. Trebilcock 2021 explores the effects of winter and early spring severe weather on woodcock movements, asking how wintering and migrant birds cope with extreme events. Both documents are available to download through UMaine's Digital Commons, and we are working to advance the individual manuscripts through to peer-reviewed publications.

- ***Spring male migration and the signing ground survey:*** We have a manuscript in final stages pre-submission evaluating the phenology of spring migration by male woodcock and using these data to assess several assumptions of the American woodcock singing ground survey (SGS). Based on data from 133 males that migrated during spring over 4 years, we ask whether the SGS window (20-day period during which the survey may be conducted) occurred following completion of migration in each SGS zone, and whether males settled within the approximate spatial coverage of the SGS. We found SGS timing was relatively consistent with migration except in the northernmost zone (zone 5), and that 90% of males settled into breeding territories within SGS coverage.

- ***Female reproduction and migration:*** During spring 2021 and 2022, we documented nesting attempts of GPS-marked birds and confirmed 31 nests via field observation. In doing so, we documented unprecedented observations of females making long-distance migrations (> 500 kilometers) between successive nesting attempts. This suggests woodcock may possess an itinerant breeding strategy, where individuals reproduce in multiple regions connected via migration. We are currently working to mine the larger EWMRC dataset, using these field-observed nests as validation, to understand the degree to which female woodcock engage in migration between nesting attempts, and how this could play into woodcock reproductive ecology. This work is led by Colby Slezak at the University of Rhode Island.

- ***Future directions:*** We will continue to collect data at a subset of field sites during Fall 2022 and Spring 2023. We also plan to expand analyses in the coming year to address 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 structure, a description of flight altitudes in migrating woodcock, a more formal classification of woodcock migration strategies, and focal work on woodcock ecology in New York state.

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Introduction

The American Woodcock (*Scolopax minor*; woodcock hereafter) is a migratory forest-dwelling scolopacid 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 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 using satellite-enabled telemetry.

In this report, we document data collected during the project's first five years, summarize woodcock observations during Fall 2021-Summer 2022 (see appendices), highlight several noteworthy findings from the past year, and provide a description of future directions and outreach accomplishments. Previous years' reports describing past data and findings can be found by visiting woodcockmigration.org/research.

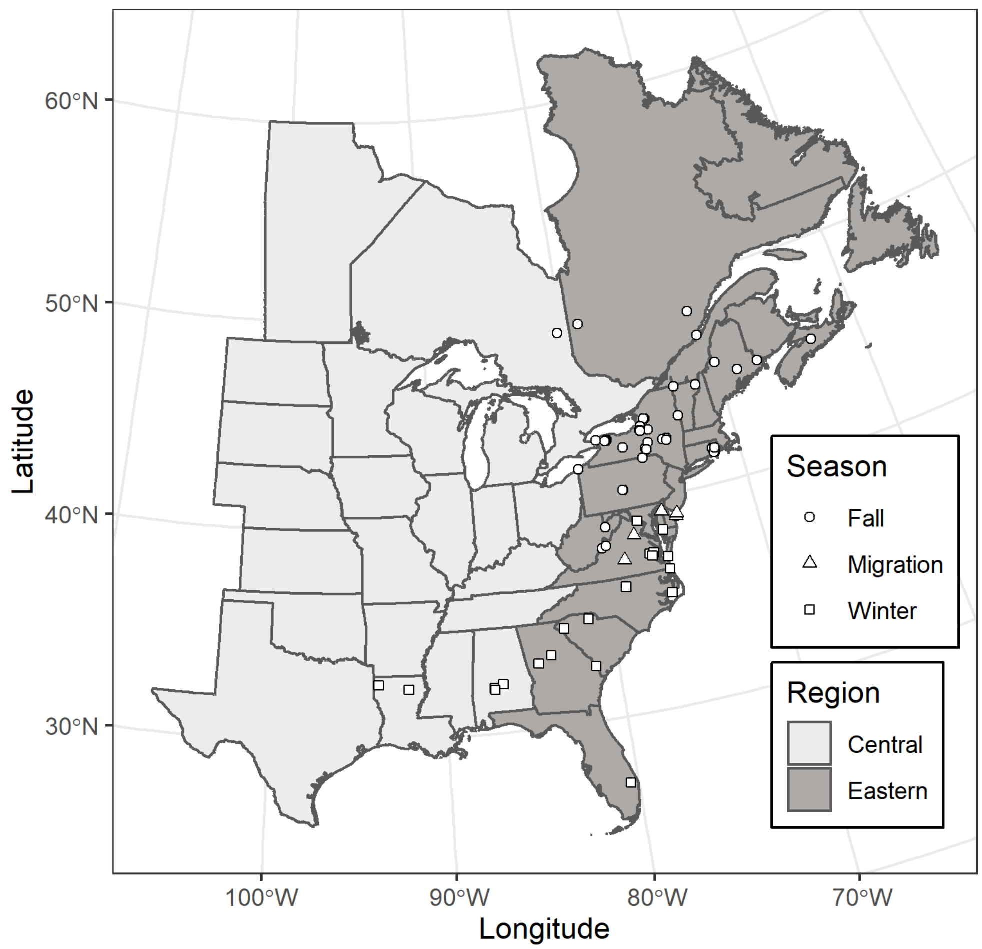

Figure 1. American Woodcock Central and Eastern Management Regions, with distribution of capture locations by season of capture.

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. During the fall (September – October), we focused capture efforts in ME, NY, PA, RI, VA, VT, and WV in the U.S., as well as NS, ON, and QU in Canada. During winter

(December-February), we focused captures in AL, FL, GA, LA, MD, NC, NJ, SC, and VA (Figure 1). 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

We captured woodcock 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 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 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 are useful to evaluate fine scale movement and provide the finest resolution (i.e., one day) to document stopover (resting periods during migration) ecology. Infrequent schedules allow 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 23 August 2022) 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 568 transmitters on birds in 18 states and provinces (Table A1). These transmitters have gathered over 32,000 locations (Figures 2, 3) since 2017, and during the Fall 2021 and Spring 2022 migration seasons alone, we recorded over 130,000 kilometers of migratory movements (Figure 4). In total, we have documented 494 migration attempts and 433 full migratory paths (Table A2). Since altitude capacity was introduced on PinPoint transmitters in Fall 2020, we have also recorded 139 presumed night flight locations that can be used to characterize woodcock flight altitudes during migration (Figure 5).

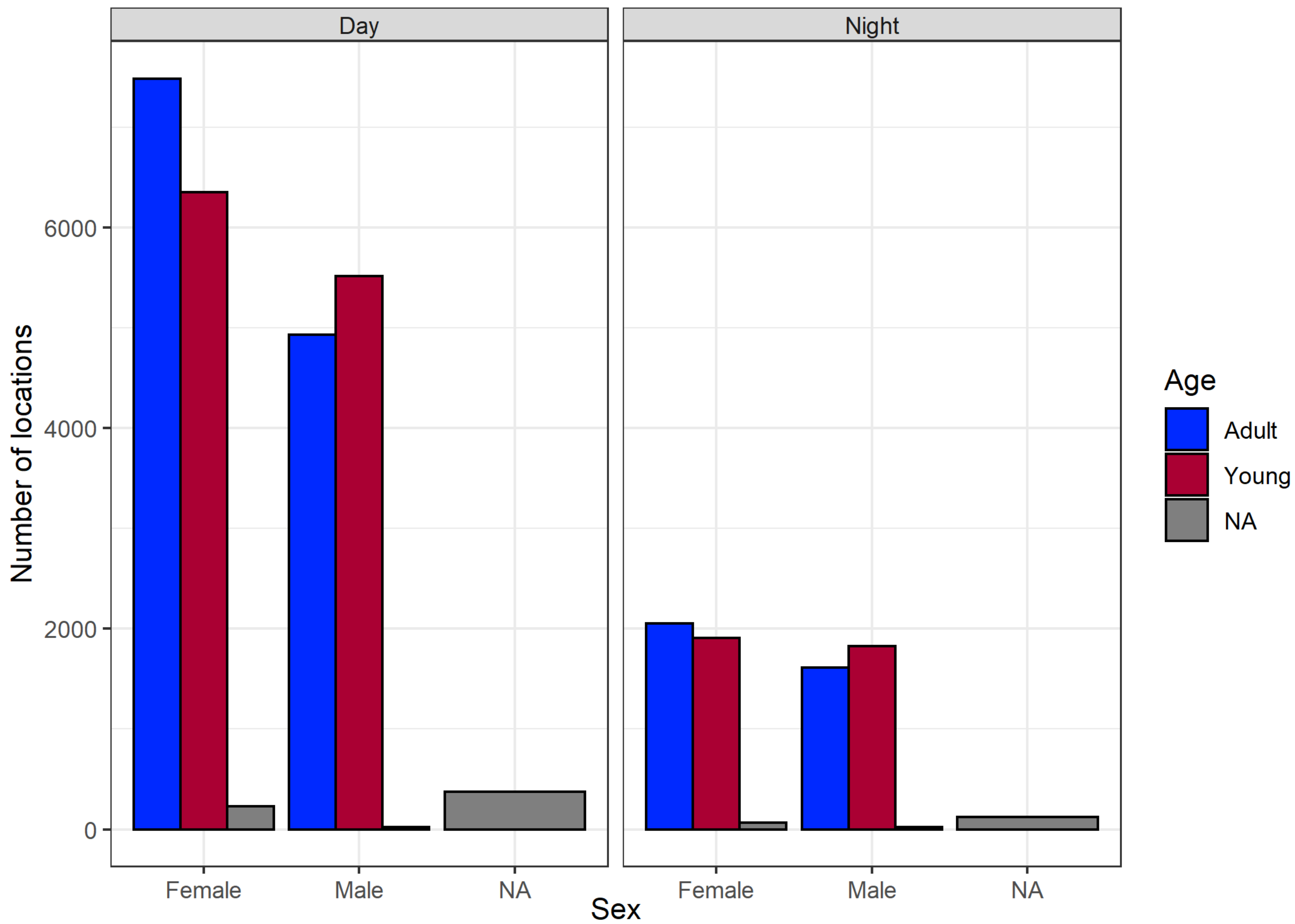

Figure 2. Counts of GPS locations recorded by tagged woodcock from Fall 2017 – Summer 2022. Over 32,000 locations have been gathered since the project began, including day and night locations and large sample sizes from each combination of sex and age classes. NA reflects birds not assigned a sex or age class at capture.

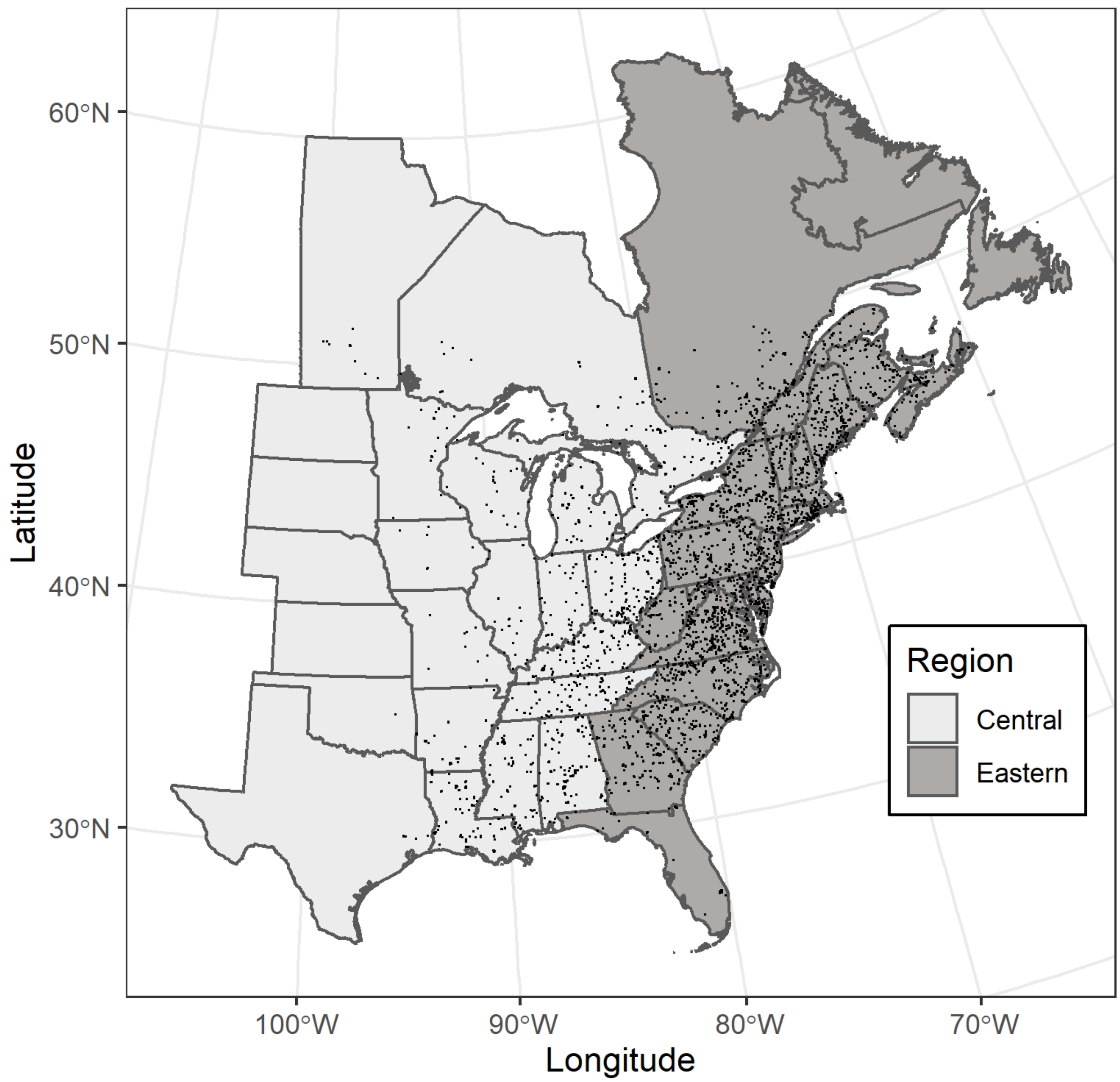

Figure 3. GPS locations collected by woodcock marked through the EWMRC from Fall 2017 – Summer 2022. Over 32,000 locations have been gathered since the project began. Location density is highest in the Eastern Management Region, but locations can be found throughout the entirety of the American Woodcock's range.

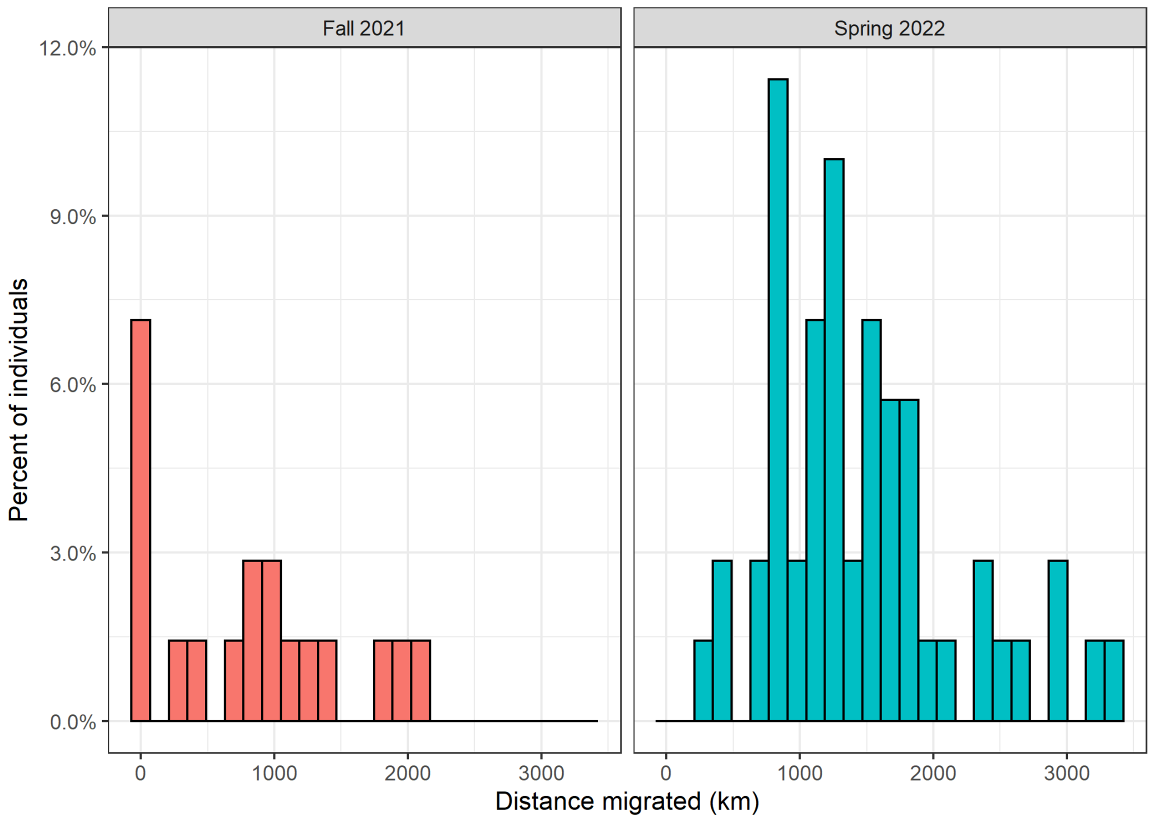

Figure 4. Distance migrated by GPS-tagged American Woodcock in Fall 2021 and Spring 2022. Distance migrated is the sum of all individual steps between the initiation and the termination of migratory movements. Woodcock moved slightly farther during Spring 2022 than Fall 2021, likely due to disproportionate sampling of woodcock at the southern extent of their range during winter captures.

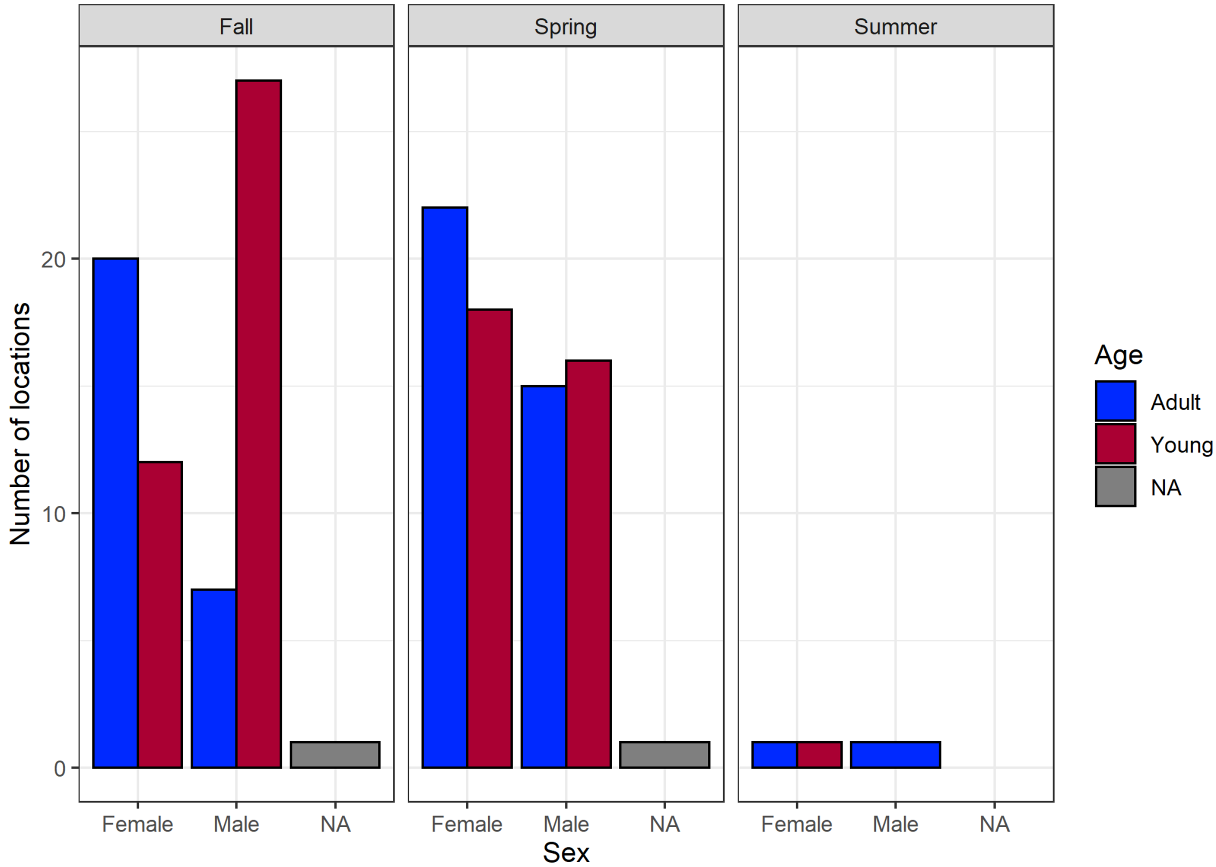

Figure 5. Counts of flight locations gathered by the EWMRC since the debut of transmitters with altitude capacity in Fall 2020. 139 presumed night flight locations have been collected to date, including fall and spring locations and samples from each combination of sex and age classes.

Recent Findings

1. Fish 2021. American Woodcock (Scolopax minor) Migration Ecology in Eastern North America

Dr. Alex Fish defended his PhD Dissertation in October 2021 (he went woodcock hunting after the defense). An abstract is provided below, and a full copy can be found via the UMaine Digital Commons.

https://digitalcommons.library.umaine.edu/cgi/viewcontent.cgi?article=4573&context=etd

Abstract: Across temperate regions of North America, migrating animals must contend with seasonally influenced thermal extremes, changing food abundance, and stochastic weather events. Migrating individuals must locate suitable areas, termed stopover locations, to rest and rebuild energy reserves needed to continue migration (Rodewald and Brittingham 2004, Taylor et al. 2011). The American Woodcock (*Scolopax minor*; woodcock hereinafter) is a migratory forest bird that has experienced long term population declines (Seamans and Rau 2019). We created the Eastern Woodcock Migration Research Cooperative, including 34 provincial, federal, state, and non-governmental partners, with the goal of describing the migration ecology of woodcock in the eastern portion of its range. We were primarily interested in understanding migration phenology, identifying weather conditions that were associated with migratory departure events, and quantifying survival during migration. Recent advances in transmitter design allowed the cooperative to remotely obtain high resolution locations of migrating woodcock. We deployed 304 satellite-gps transmitters in three provinces and 12 states and collected movement data from 1 October 2017 to 18 June 2020. We begin by describing the phenology associated with migration initiation, timing of stopovers, and termination of migration during fall migration, and the initiation of spring migration and describe the spatial, demographic, and body-conditions based variation in these events. We then built predictive models to estimate the dates associated with fall and spring migration and provide a framework for wildlife managers to evaluate the timing of hunting seasons under current and future harvest regulations. Next, we evaluate the environmental cues associated with migratory departure events and found that age influenced cue selection in the fall and sex in the spring. Furthermore, the specific conditions in which an individual initiated migration could influence the distance an individual traveled in a single migratory flight, but not the pace of migration which was more supported by spatial features. Lastly, we quantified survival of woodcock during migratory periods and found that survival varied by migratory behavioral state, through time, and depending on the season, but was not influenced by age or sex.

2. Trebilcock 2022. Riders on the Storm: Using Satellite Transmitters to Quantify American Woodcock Movement Behavior Following Extreme Weather Events

Katherine Trebilcock completed an undergraduate honors thesis at the University of Maine during spring 2022. An abstract is provided below, and a full copy can be found via the UMaine Digital Commons.

https://digitalcommons.library.umaine.edu/cgi/viewcontent.cgi?article=1730&context=honors

Abstract: The American Woodcock (Scolopax minor) has experienced steady declines in abundance over the past fifty years, which has raised questions as to why (Sauer et al. 1991). Migration for many birds, woodcock included, is energetically intensive, and may be the cause for greater mortality compared to other times of the year (Newton 2007). Despite this, there remains uncertainty in how conditions encountered during migration affect their movements and survival. One obstacle that birds must face is extreme weather, which has been increasing in intensity and occurrence due to climate change. How these events impact a migrating woodcock has been speculated but remains unknown. In my study I uncover different movement behaviors that woodcock exhibit when faced with extreme weather during both migration and winter pre-migration and explore variability in movement behavioral expression. Woodcock were tagged by the Eastern Woodcock Migration Research Cooperative, using GPS transmitters that provided fine-scale location data during the winter and spring migration period throughout eastern North America. I used a subset of this data and focused on winter pre-migration and spring migrations in 2019, 2020, and 2021. I also collected information on storm occurrence from the National Oceanic Atmospheric Administration's extreme weather database in order to identify birds that encountered extreme weather. I classified woodcock movement behaviors as either short movements, which included sheltering in place or moving a short distance to a local refuge, and long movements which were classified as a continued migration or a reverse migration. I found that very few woodcock experienced mortality as a result of

extreme weather. I also found that reverse migrations were prompted by snow and wind storms, and that birds in better body condition at time of capture were more likely to exhibit this behavior. Although reverse migrations are a normal part of nocturnal migrant phenology, previous research suggested birds would exhibit this behavior more if they were in poor body condition, counter to my results. I also found that male woodcock were more likely to move to a local refuge following extreme weather, regardless of time of the year, whereas females were more likely to shelter in place. This correlates with previous research which indicated that sex is a primary driver for cue selection in woodcock migration initiation. These results indicate that woodcock react to, and are affected by extreme weather, and have a number of strategies following these events that may help them to survive.

3. Female nesting and movements (Lead: Colby Slezak, URI)

During 2020-2022, we deployed GPS tags on females throughout the fall (by University of Rhode Island, URI) and winter (by other EWMRC collaborators) with the intent of finding nest attempts the following spring. From late January-June (2020-2022), Colby Slezak (PhD student, URI) closely monitored GPS points to detect nesting females based on consistent locations between consecutive points. We then relied on nearby collaborators who travelled to suspected nest sites and attempted to get a visual confirmation of the female on the nest. We verified 31 such nests, which will help us characterize the movement of pre-nesting, nesting, and post-nesting females, and allow us to auto-classify past and future nesting attempts. These data will contribute to our understanding of nesting phenology, nest success, and breeding season movements of female AMWO throughout the eastern range.

We captured and attached GPS units to 37 females during the 2020-2021 field season and 35 females during the 2021-2022 field season. During the first field season, female tags were programmed using one of 3 different schedules. Although our duty cycles varied (1-2 days) during 2020-2021, the movement patterns of nesting compared to non-nesting females from the three schedules were similar (Figures A16 & A17). We were able to find nests regardless of time of day since nesting females took such small step-lengths during the incubation period (2021: $\bar{x}$=15.1 ± 0.7 m; 2022: 21.9 ± 2.3 m) (Figures A18 & A19). In 2021-2022, we considered trade-offs related to battery life, seemingly high nest predation rates, and long-distance movements between nesting attempts that led us to choose a 2-day daytime only duty cycle in 2021-2022 that would allow us to track birds over a longer period while still being able to identify short nesting attempts.

Thanks to the EWMRC collaborators, we confirmed nesting for 23 (2021: n=14; 2022: n=9) tagged females and located a total of 31 nests from these females (2021: n=17; 2022: n=14). Nest locations ranged from North Carolina to Quebec. For four (2021: n=3; 2022: n=1) of the tagged females, we located a second nest attempt after failure of the first nest. Interestingly 6 of the 11 females that lost their initial nest made long-distance movements after nest failure (2021: n=4; 2022: n=2), and we were able to locate a second nest for 3 of these 6 females (2021: n=2; 2022: n=1). Thus, females nest and renest throughout spring migration, suggesting an itinerant breeding strategy for American Woodcock, with females sometimes migrating over large expanses between nest attempts (Figure 6). Moving forward, we will be using the NestR package (Picardi and Smith 2021) to identify nests retroactively for all females tagged 2019-2022. We will use parameter thresholds calculated from our set of verified nests to identify birds that appeared to have nested, renested, or moved considerable distance post-nest failure, and to validate the package predictions. This will help uncover how often females undertake migration between successive nesting attempts and uncover potential drivers of this unusual behavior. Colby will be presenting this work as a poster presentation at The Wildlife Society Conference in Spokane, WA during November 2022. We will also be working to submit our findings to an academic journal which should be available for collaborators to review sometime in late winter/early spring 2023.

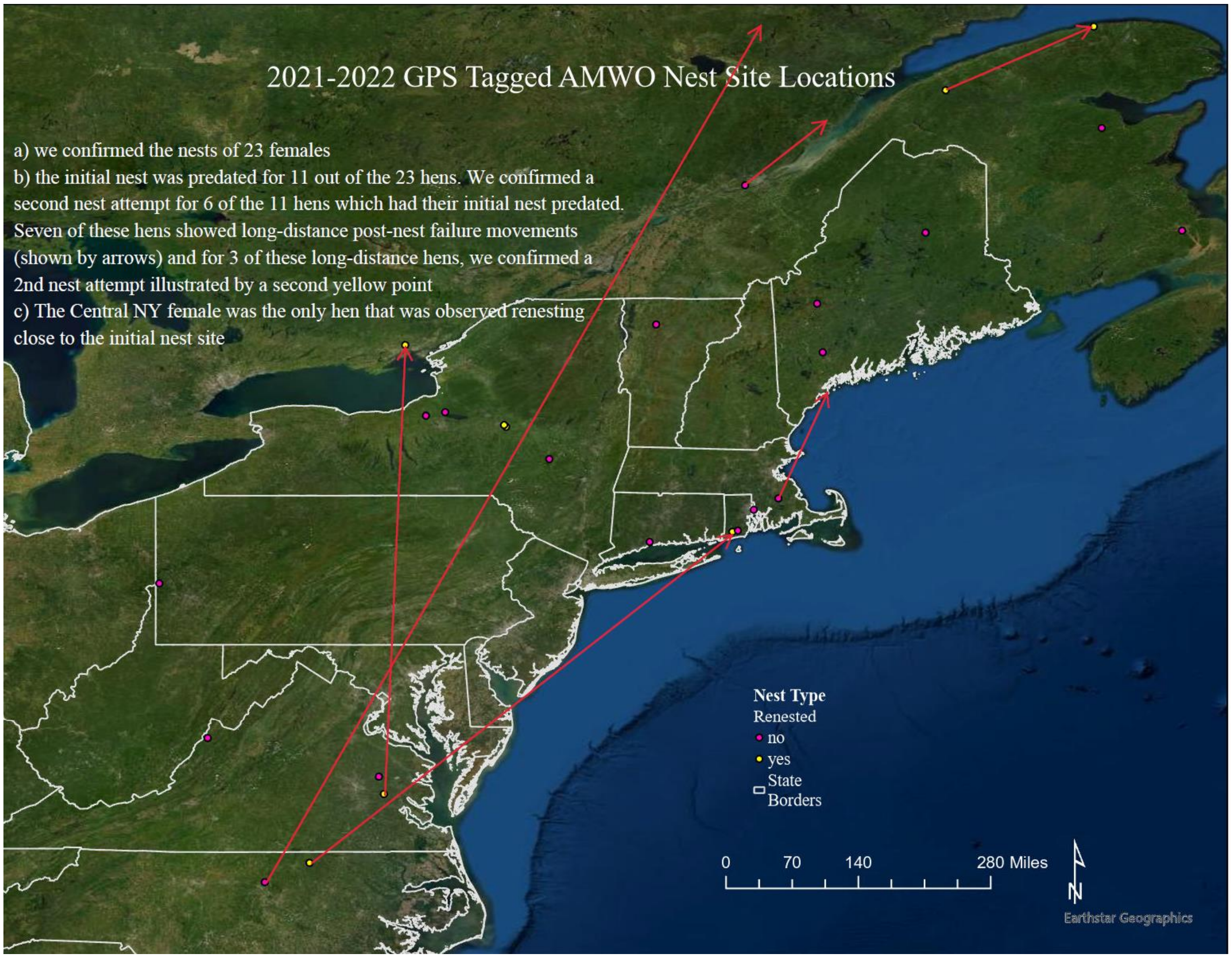

Figure 6. Confirmed nest site locations and post-nest failure movements of female AMWO tagged as part of the EWMRC nesting project during 2021-2022.

4. Evaluation of Singing Ground Survey timing in relation to male woodcock migration (Lead: Erik Blomberg)

The North American Woodcock Singing Ground Survey (SGS) plays a critical role in monitoring woodcock populations. Trends estimated from SGS data suggest persistent, range-wide declines, and SGS data have been used extensively in efforts to develop conservation plans, support management actions, and understand causes of decline. To avoid biased inference, the SGS should be appropriately timed to avoid periods of migration, and the distribution of survey routes should coincide with woodcock breeding distribution. We used data from 133 male woodcock captured during 2019 – 2022, classified the timing of their migration, and compared it with the spatiotemporal stratification of the SGS. A majority of woodcock (74 %) completed migration prior to the onset of the local SGS survey window. However, this general pattern was not uniform, and in the northern-most SGS zone, 34 % of males continued migration during the active survey window. Delayed migration during a survey window was more likely for young woodcock completing their first migration, which took 8.6 days longer to complete on average compared to adult birds. We found that 90% of male woodcock established breeding sites within the spatial coverage of the SGS and recorded only 1 male breeding south of the SGS coverage; thus, the existing SGS routes appear to cover the majority of male woodcock post-migratory breeding distribution (Figure 7). Stopovers recorded during active SGS windows were not distributed further south than post-migratory breeding sites, suggesting minimal spatial bias in SGS-derived density estimates at regional scales. We found little evidence for substantial annual variation in migration phenology among our 4 study years. Our results confirm the SGS likely detects migrant males, with the proportion relative to resident breeding males increasing in more northern survey strata. While available evidence suggests these errors are unlikely to produce substantial bias in trend estimates at large spatial or temporal scales (e.g., within woodcock management regions), there may be greater concern at more local scales (e.g., state or provincial density estimates). Simulations informed by our results could be useful to better-understand the implications for inferences drawn from SGS data. This manuscript is currently being prepared for submission to a journal.

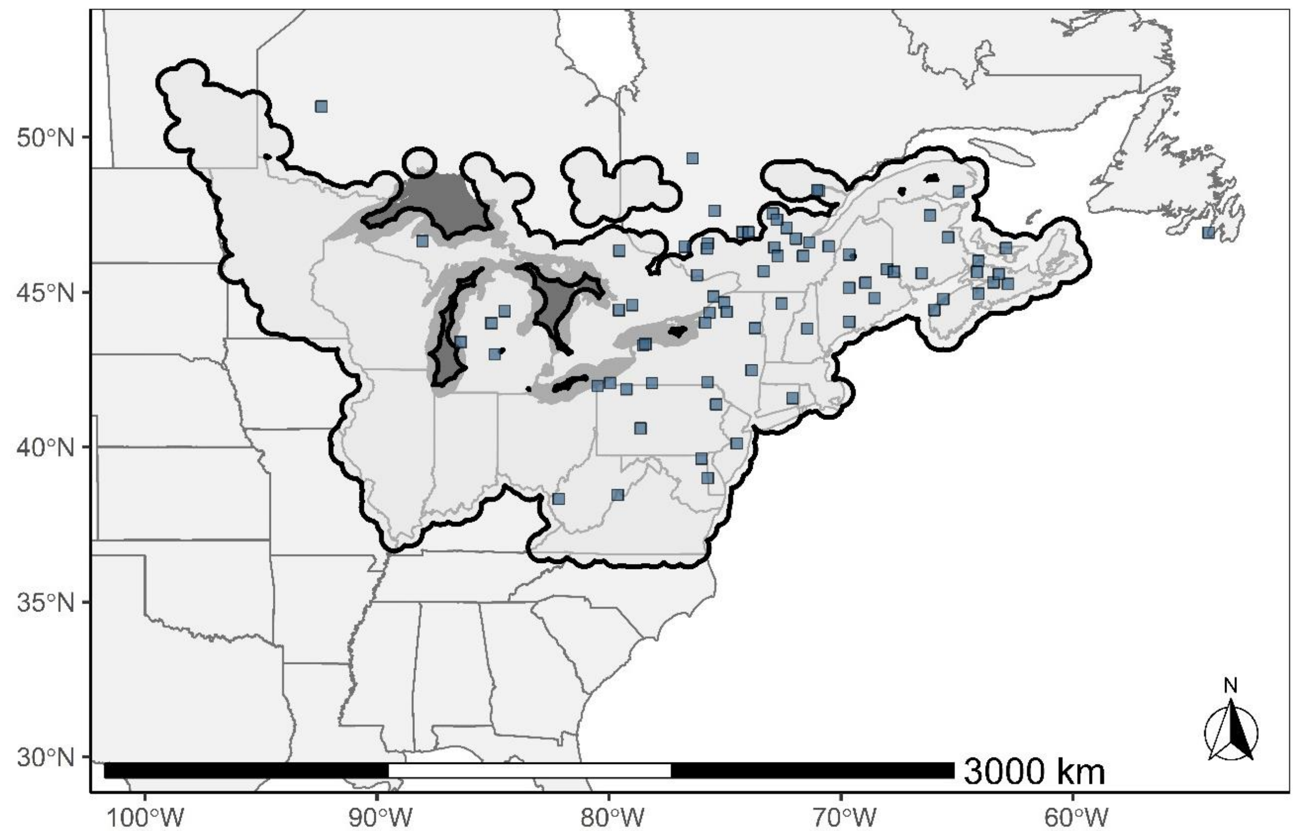

Figure 7. Ending (termination) points of migration paths for GPS-marked male American woodcock during spring migration, 2019 – 2022, compared to the approximate spatial coverage of the American woodcock singing ground survey (SGS). SGS distribution was estimated by Moore et al. (2019) using 50km buffers placed around 10-degree blocks containing SGS routes. Termination locations occurring outside the buffered area reflect instances of male woodcock breeding well outside the current coverage of the SGS.

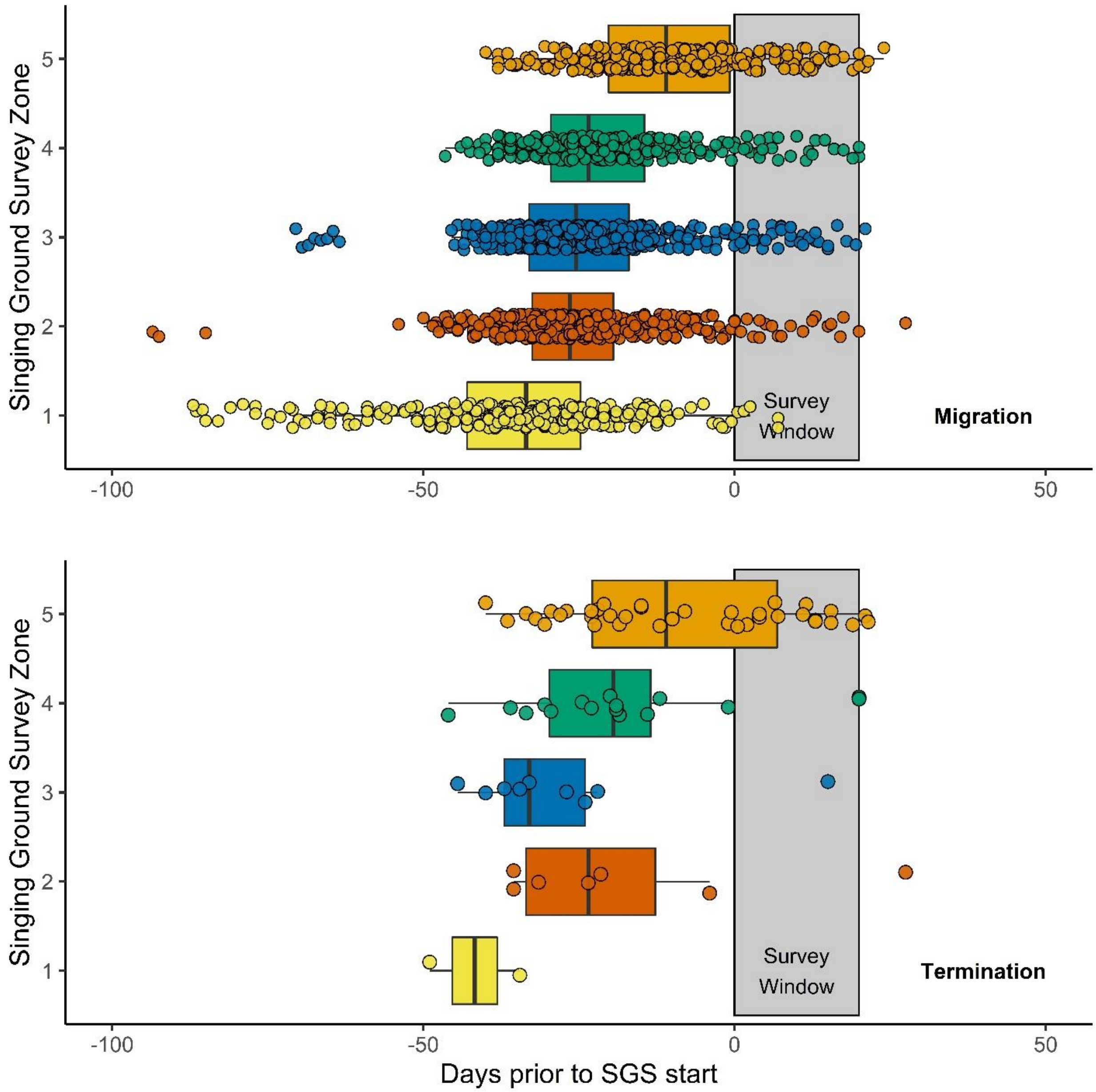

Figure 8. Distribution of migratory stopover and termination locations for GPS-marked American woodcock in eastern North America with respect to timing of the USFWS Woodcock Singing Ground Survey (SGS), 2019 – 2022. Data are stratified by American Woodcock Singing Ground Survey (SGS) zones, and location dates have been standardized to the start of the survey window (time period during which surveys may be conducted; gray box), where day 0 reflects the starting date of the survey for each zone.

Migration points falling within the SGS survey window indicate migrant male woodcock that have not yet settled into a final breeding territory but may be available for detection during an active survey. Termination indicates the first date that a male woodcock arrived at a permanent, post-migration territory, as defined by multivariate hidden Markov movement models.

Future Directions

1. Regional and seasonal differences in private and public land use (Lead: Liam Berigan)

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 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 full 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 will be a chapter in Liam Berigan's dissertation (anticipated graduation 2024).

2. Habitat selection throughout the full annual cycle (Lead: Liam Berigan)

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 breeding season 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 bird conservation 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 home range size and will investigate variation in habitat selection strategies within regional populations. This will be a chapter in Liam Berigan's dissertation (anticipated graduation 2024).

3. Response to light pollution during migration (Lead: Rachel Darling)

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 will be a chapter in Rachel Darling's dissertation (anticipated graduation 2026).

4. Genomic and isotopic analysis of population connectivity (Lead: Rachel Darling)

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. This will be a chapter in Rachel Darling's dissertation (anticipated graduation 2026).

5. Altitudinal distribution of woodcock flight locations during migration (Lead: Liam Berigan)

In Fall 2020, Lotek began to incorporate altitude recorders into all newly-built PinPoint Argos GPS transmitters. These altitude recorders provide fairly limited information when the bird is on the ground, but during migratory flights they can be used to determine the likely altitude that birds are flying at during migration. Flight altitudes are particularly relevant as low altitudes lead to increased exposure to certain hazards, such as wind turbines and building collisions. To date we've collected 139 suspected night flight locations from tagged woodcock. Our preliminary analysis has shown that flight altitudes are higher during the spring than the fall (Figure 9). During fall woodcock migrated at an average altitude of ~200 m, with most altitudes falling below 700 m. However, outlier points demonstrate fall migratory flights sometimes were as high as >1500 m. In the spring, mean altitude was ~ 250 m, and outliers fell beyond 2000 m. The most likely reason for a change in flight altitudes would be to shift exposure to prevailing winds, although we are still attempting to determine which weather patterns such a seasonal difference would be in response to. We plan to continue this study using a Bayesian analysis to compensate for GPS error and delineate flight and ground locations. We will also look for differences in flight altitudes between sex and age classes, in addition to tracking how flight altitude changes in response to weather events. This will be a chapter in Liam Berigan's dissertation (anticipated graduation 2024).

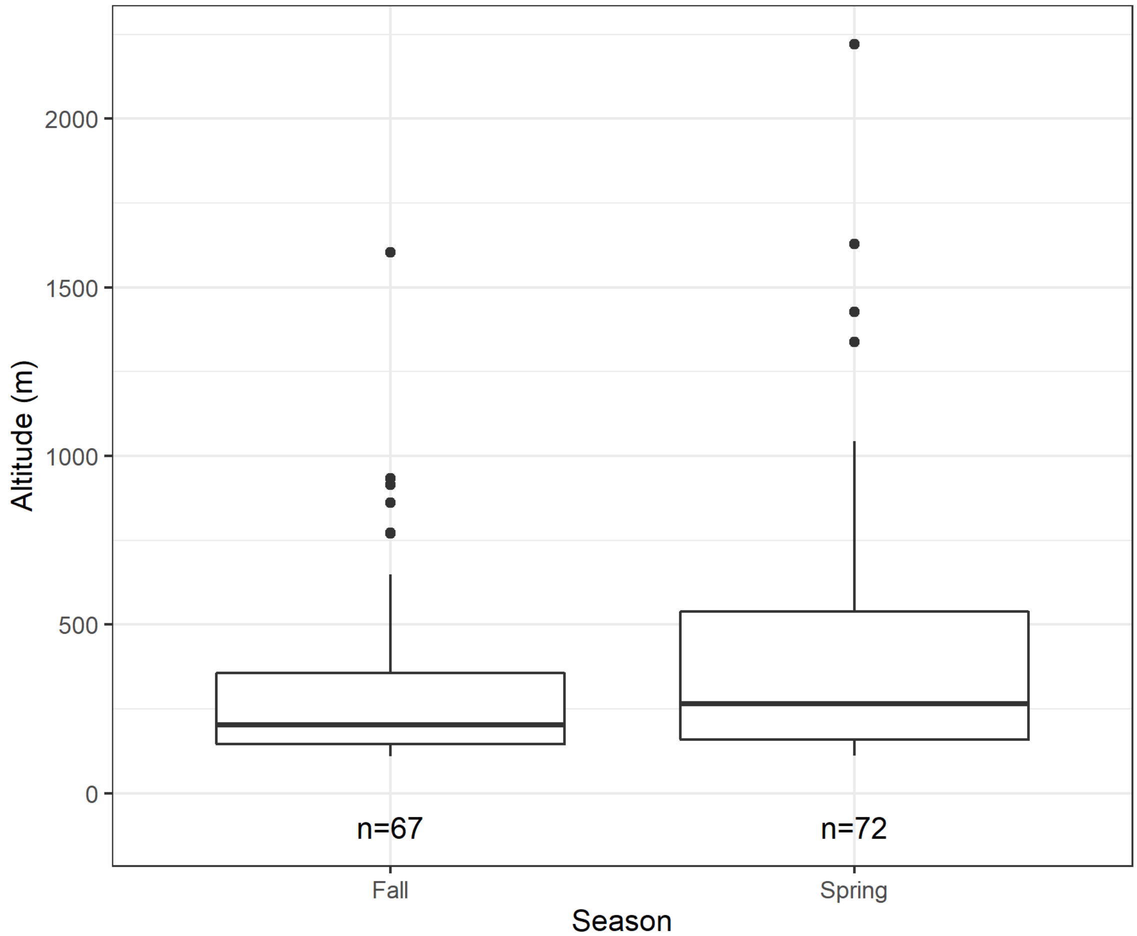

Figure 9. Flight altitude of American Woodcock shifts seasonally, with higher altitudes predominantly recorded during the spring.

6. Characterizing migration strategy and migratory corridors in American Woodcock (Lead: Sarah Clements)

High within-species diversity in migration behavior and route is associated with increased resilience to population decline in the face of climate and land use change (Gilroy et al. 2016). While some species show low variability in migration strategy, others exhibit substantial variation as a gradient across individuals or as group-specific strategies (Piersma 2007, Vardanis et al. 2011). Understanding migratory behavior and identifying key stopovers and migratory corridors could be useful for collaborative research and management efforts for migratory species. We aim to 1) characterize migration strategy in American Woodcock during fall and spring migrations, 2) identify key migratory routes and stopover areas, and 3) explore patterns in drivers of variation in migration strategy such as location, sex and age class, time, and environmental variables. To address objective 1, we will first quantify migration strategy by calculating metrics of migration and stopover behavior for each individual and using Principal Components Analysis (PCA; James et al. 2014) to identify key components determining migration strategy and identify any clustering of individuals into strategies. Preliminary results for fall migration show that variation in migration strategy results from metrics related to migration distance, stopover behavior, and distance of the migratory path from the coast, and this variation presents across a gradient of all individuals rather than discrete clusters. To address objective 2, we plan to calculate utilization distributions for spring and fall migration using Brownian Bridge movement models (e.g., Kranstauber et al. 2012) or similar analyses to identify stopover areas and or migration corridors with high probabilities of use by woodcock. To meet objective 3, we will quantify drivers of migration strategy by modelling migration characteristics as a function of individual characteristics and environmental variables of interest. This will be a component of Sarah Clements' research, with an anticipated completion date sometime in 2024.

7. American Woodcock resource selection in New York State during breeding season (Lead: Kayleigh Filkins)

SUNY Brockport is partnering with New York State Department of Environmental Conservation (NYSDEC) to expand our understanding of woodcock resource selection in New York. The focus of this work will be primarily during the breeding season with consideration also given to migratory stopover sites. We will be using all current EWMRC data from birds that spent time in New York and supplementing that data with 20 additional transmitters deployed over the course of 2 years (2022-2023). We will also incorporate additional data from avian databases such as eBird, MAPS, and GPAST. We will be utilizing Program R and ArcMap to build and depict habitat selection models in relation to land cover types and landscape characteristics. This model will be the basis for a woodcock habitat selection and management tool designed to help NYSDEC with habitat prioritization. This work will be the basis for Kayleigh Filkins' master's thesis (anticipated graduation 2024).

Outreach

As our analyses could potentially be valuable to a wide range of interested parties engaged in woodcock management, we devote considerable time and energy to disseminating our results to a broad audience. 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 (>58,000 unique visitors, > 170,000 page views), and we have 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 include our results on the website, as well as links to our published studies. Our data have also been incorporated into the National Audubon Society's Bird Migration Explorer (explorer.audubon.org), which is an educational resource for learning about North American bird migration, connectivity, and conservation. Finally, we continue to present our results at wildlife and ornithology conferences, including recent presentations at the American Ornithological Society's annual meeting in July 2022 and The Wildlife Society's upcoming Annual Conference in November 2022.

Project Partners

- Alabama Department of Conservation and Natural Resources
- American Woodcock Society
- Association des Savaginiers du Saguenay-Lac-St-Jean
- Atlantic Flyway Council
- Audubon Vermont
- 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
- Louisiana Department of Wildlife and Fisheries
- Maine Department of Inland Fisheries and Wildlife
- Maryland Department of Natural Resources
- Missisquoi National Wildlife Refuge
- Moosehorn National Wildlife Refuge
- The Nature Conservancy in Vermont
- 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
- Silvio O. Conte National Wildlife Refuge
- State University of New York - Brockport
- 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**	
State	**Year**	**Young**	**Adult**	**Unk**	**Young**	**Adult**	**Unk**	**Unk**	**Total**
Alabama	*2020*	1	2		2	2			7
	2021		2		2	2			6
	2022	5	2	1	1	1			10
Florida	*2021*	1	3		1				5
	2022	2	4						6
Georgia	*2020*	3	3		1	5			12
	2021	1	3		2	5			11
Louisiana	*2022*	4	4		3	5			16
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

		Male			Female			Unknown	
State	Year	Young	Adult	Unk	Young	Adult	Unk	Unk	Total
	2019	8			9				17
New York	*2018*	4	1		1	3			9
	2019	4	6		11	9			30
	2022				5	5			10
North Carolina	*2019*	2	2			2			6
	2020	7	1		4	3			15
	2021	6	1		1	2			10
	2022	5	2		1	7			15
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
	2021	5	2		2	3			12
Quebec	*2018*	2			2	1			5
	2019	5			2	3			10
	2020	2	1		1	3			7
	2021				2	2			4
Rhode Island	*2018*		12			3			15
	2019		12			3			15
	2020				7	7	3		17

		Male			Female			Unknown	
State	**Year**	**Young**	**Adult**	**Unk**	**Young**	**Adult**	**Unk**	**Unk**	**Total**
	2021				3	12			15
South Carolina	*2019*	2	1		4	2			9
	2020	2	3		2	1			8
	2021	2	4		1				7
	2022						1		1
Virginia	*2018*		6		2	1			9
	2019	11	10		11	13		2	47
	2020	15	5	1	7	16			44
	2021			1	1	2	1	4	9
	2022						2		2
Vermont	*2020*	8	5		3	2			18
	2021	3	1		2	4			10
West Virginia	*2019*	2	1		1				4
	2020				1				1
Total		**140**	**120**	**3**	**132**	**160**	**7**	**6**	**568**

Table A2. Number of attempted and complete migratory movements by GPS-tagged American Woodcock by season from Fall 2017 through Spring 2022.

	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
Summer 2021	2	2
Fall 2021	17	17
Spring 2022	76	53

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 2022.

	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	12/3/2018	10/28/2018	2/3/2019
2019	74	11/11/2019	10/12/2019	12/13/2019	12/2/2019	10/20/2019	1/29/2020
2020	59	10/28/2020	8/3/2020	12/15/2020	11/30/2020	10/30/2020	1/12/2021
2021	17	10/31/2021	8/31/2021	11/22/2021	11/16/2021	10/25/2021	12/10/2021
Spring							
2019	42	3/10/2019	1/26/2019	3/29/2019	4/19/2019	2/8/2019	7/14/2019
2020	55	3/6/2020	2/3/2020	5/4/2020	4/14/2020	2/11/2020	7/28/2020
2021	76	2/28/2021	1/14/2021	4/23/2021	4/2/2021	3/2/2021	5/18/2021
2022	53	2/26/2022	1/19/2022	4/26/2022	4/18/2022	2/21/2022	6/7/2022

Table A4. Migration records of GPS-tagged American Woodcock from the migratory seasons of Fall 2021 (September 1st, 2021 – January 31st, 2022) and Spring 2021 (February 1st, 2022 - May 31st, 2022). [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 2021										
Pennsylvania										
PA-2021-34	10/4/2021	M	HY	80	11/2/2021	11/6/2021	4	PA	AL	1169
PA-2021-35	10/4/2021	M	AHY	50	11/4/2021	11/7/2021	3	PA	KY	726
PA-2021-37	10/5/2021	M	HY	67	11/18/2021	11/24/2021	6	PA	AL	1138
PA-2021-38	10/5/2021	M	AHY	68	11/18/2021	11/24/2021	6	PA	SC	860
PA-2021-40	10/8/2021	F	HY	74	11/22/2021	11/24/2021	2	PA	NC	757
PA-2021-41	10/7/2021	M	HY	71	11/02/2021	11/06/2021	4	PA	GA	1171
PA-2021-42	10/7/2021	F	AHY	74	11/19/2021	12/24/2021	35	PA	LA	2059
PA-2021-44	10/8/2021	M	HY	32	11/13/2021	11/25/2021	12	PA	GA	1249

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]
Quebec										
QUE-2021-23	9/22/2021	F	AHY	77	10/17/2021	10/25/2021	8	QUE	VA	1316
QUE-2021-24	9/21/2021	F	HY	82	10/18/2021	10/29/2021	11	QUE	NC	1472
QUE-2021-25	9/22/2021	F	HY	49	10/23/2021	11/4/2021	12	QUE	AL	2078
QUE-2021-26	9/20/2021	F	AHY	82	10/23/2021	11/30/2021	38	QUE	GA	2285
Rhode Island										
RI-2021-48	8/30/2021	F	AHY	5	8/31/2021	11/10/2021	71	RI	NC	1004
Vermont										
VT-2021-21	10/4/2021	M	HY	39	11/13/2021	11/21/2021	8	VT	SC	1501
VT-2021-23	10/6/2021	F	AHY	64	10/15/2021	12/15/2021	61	VT	FL	1921
VT-2021-25	10/5/2021	F	HY	60	11/16/2021	12/10/2021	24	VT	AL	1923
VT-2021-26	10/4/2021	F	AHY	82	10/27/2021	11/24/2021	28	VT	GA	1914
Spring 2022										
Alabama										
AL-2022-14	2/9/2022	F	ASY	6	-	-	-	AL	-	-
AL-2022-15	2/9/2022	F	SY	48	3/03/2022	5/08/2022	66	AL	QUE	3263
AL-2022-16	2/7/2022	M	AHY	33	2/15/2022	5/18/2022	92	AL	ON	2521

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]
AL-2022-17	2/7/2022	M	SY	43	2/15/2022	5/20/2022	94	AL	MB	2781
AL-2022-18	2/7/2021	M	SY	16	2/15/2022	4/04/2022	48	AL	NY	1823
AL-2022-19	2/10/2022	M	ASY	47	2/15/2022	4/02/2022	46	AL	QUE	2044
AL-2022-20	2/7/2022	M	SY	37	2/13/2022	4/22/2022	68	AL	NY	1977
AL-2022-21	2/7/2022	M	ASY	42	2/21/2022	3/19/2022	26	AL	NY	1913
Florida										
FL-2022-05	1/24/2022	M	ASY	43	2/19/2022	4/24/2022	64	FL	ON	2751
FL-2022-06	1/26/2022	M	SY	48	2/15/2022	4/18/2022	62	FL	PEI	3022
FL-2022-07	1/28/2022	M	SY	46	3/05/2022	5/14/2022	70	FL	QUE	3353
FL-2022-08	1/27/2022	M	ASY	27	2/15/2022	2/23/2022	8	FL	VA	1167
FL-2022-09	1/30/2022	M	ASY	32	2/17/2022	2/21/2022	4	FL	NC	1034
Louisiana										
LA-2022-05	1/18/2022	M	SY	29	3/02/2022	-	-	LA	-	-
LA-2022-06	1/19/2022	M	ASY	24	2/20/2022	-	-	LA	-	-
LA-2022-10	1/18/2022	F	SY	25	-	-	-	LA	-	-
LA-2022-11	1/19/2022	F	ASY	63	2/27/2022	-	-	LA	-	-
LA-2022-12	1/19/2022	F	ASY	52	2/21/2022	-	-	LA	-	-

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]
LA-2022-13	1/19/2022	F	ASY	15	-	-	-	LA	-	-
LA-2022-14	1/18/2022	F	SY	48	1/19/2022	-	-	LA	-	-
LA-2022-15	1/10/2022	F	SY	11	-	-	-	LA	-	-
LA-2022-16	1/19/2022	F	ASY	47	-	-	-	LA	-	-
N. Carolina										
NC-2022-31	2/3/2022	F	ASY	48	3/05/2022	5/04/2022	60	NC	ON	1933
NC-2022-32	2/3/2022	M	SY	29	2/17/2022	2/21/2022	4	NC	MD	522
NC-2022-33	2/3/2022	M	SY	47	3/01/2022	6/03/2022	94	NC	ME	1223
NC-2022-34	2/3/2022	F	ASY	37	3/15/2022	4/28/2022	44	NC	NB	1478
NC-2022-35	2/3/2022	F	ASY	48	3/17/2022	4/14/2022	28	NC	NS	1494
NC-2022-36	2/3/2022	M	ASY	42	3/03/2022	5/06/2022	64	NC	NS	1602
NC-2022-37	2/21/2022	F	ASY	43	4/06/2022	6/07/2022	62	NC	QUE	1923
NC-2022-38	2/21/2022	F	ASY	38	3/15/2022	4/26/2022	42	NC	QUE	1655
NC-2022-39	2/21/2022	F	ASY	48	3/05/2022	5/22/2022	78	NC	NY	1073
NC-2022-40	2/22/2022	F	SY	26	3/11/2022	4/16/2022	36	NC	NH	1237
NC-2022-41	2/21/2022	M	ASY	36	3/13/2022	4/06/2022	24	NC	NB	1688
NC-2022-42	2/21/2022	M	SY	36	3/05/2022	4/04/2022	30	NC	NS	1766

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]
NC-2022-43	2/21/2022	M	SY	12	3/09/2022	-	-	NC	-	-
NC-2022-44	2/21/2022	M	SY	20	3/17/2022	-	-	NC	-	-
NC-2022-45	2/21/2022	F	ASY	44	3/15/2022	5/26/2022	72	NC	NH	1510
Pennsylvania										
PA-2021-37	10/5/2021	M	HY	6	2/05/2022	-	-	PA	-	-
PA-2021-38	10/5/2021	M	AHY	8	1/29/2022	-	-	PA	-	-
PA-2021-39	10/4/2021	F	HY	11	2/12/2022	-	-	PA	-	-
PA-2021-41	10/7/2021	M	HY	11	2/12/2022	3/19/2022	35	PA	NY	1224
PA-2021-42	10/7/2021	F	AHY	6	2/19/2022	-	-	PA	-	-
PA-2021-45	10/7/2021	M	HY	17	2/10/2022	3/22/2022	40	PA	PA	1577
Quebec										
QUE-2021-25	9/22/2021	F	HY	13	-	-	-	QUE	-	-
Rhode Island										
RI-2021-46	8/25/2021	F	AHY	28	2/10/2022	-	-	RI	-	-
RI-2021-47	8/31/2021	F	AHY	6	-	-	-	RI	-	-
RI-2021-49	9/4/2021	F	AHY	2	-	-	-	RI	-	-
RI-2021-50	8/31/2021	F	AHY	12	3/04/2022	-	-	RI	-	-

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-2021-52	9/10/2021	F	HY	14	-	-	-	RI	-	-
RI-2021-53	9/10/2021	F	AHY	22	-	-	-	RI	-	-
RI-2021-57	8/27/2021	F	AHY	38	2/08/2022	4/01/2022	52	RI	RI	745
RI-2021-58	8/23/2021	F	AHY	8	-	-	-	RI	-	-
RI-2021-59	8/23/2021	F	HY	40	2/06/2022	3/22/2022	44	RI	RI	1480
South Carolina										
SC-2022-25	3/30/2022	F	-	24	4/04/2022	4/16/2022	12	SC	NY	1142
Virginia										
VA-2021-96	12/13/2021	F	AHY	42	3/18/2022	3/21/2022	3	VA	VT	781
VA-2021-97	12/13/2021	F	AHY	43	3/14/2022	5/28/2022	75	VA	ME	1820
VA-2021-98	-	F	-	47	3/18/2022	4/26/2022	39	VA	NB	1643
VA-2021-99	12/15/2021	F	HY	2	-	-	-	VA	-	-
VA-2022-100	-	F	-	42	4/26/2022	5/04/2022	8	VA	ON	904

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-2021-21	10/4/2021	M	HY	8	3/12/2022	-	-	VT	-	-
VT-2021-22	10/4/2021	F	HY	10	2/12/2022	-	-	VT	-	-
VT-2021-23	10/6/2021	F	AHY	3	-	-	-	VT	-	-
VT-2021-25	10/5/2021	F	HY	5	2/26/2022	-	-	VT	-	-
VT-2021-26	10/4/2021	F	AHY	8	2/19/2022	-	-	VT	-	-
VT-2021-27	10/6/2021	M	HY	7	2/06/2022	-	-	VT	-	-
VT-2021-28	10/6/2021	M	HY	15	2/10/2022	4/27/2022	76	VT	QUE	2985

Additional Figures

Figures A1 – A15. Maps showing American Woodcock migratory movements in Fall 2021 and Spring 2022, broken out by the state or province in which each bird was originally captured.

Fall 2021

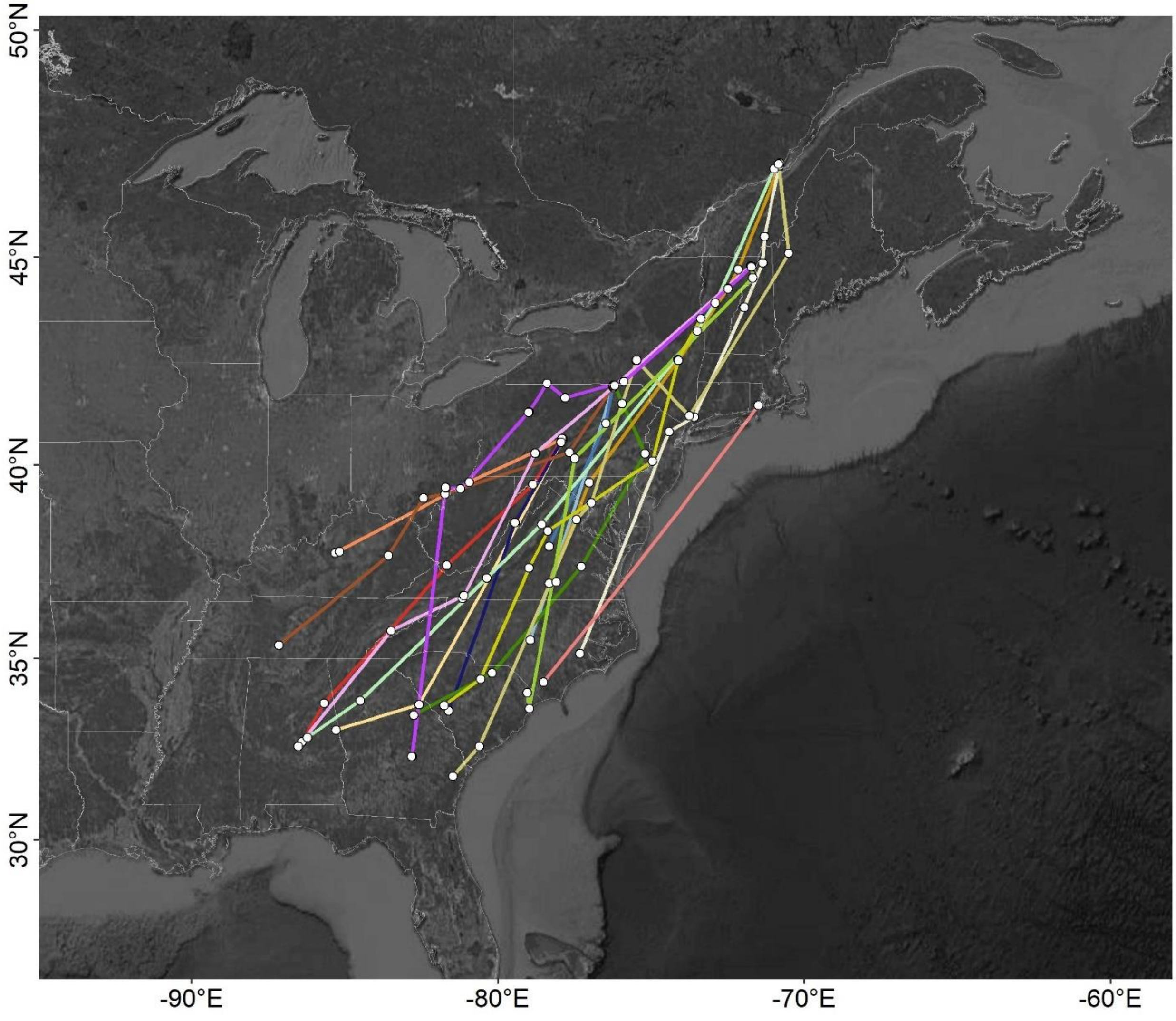

Figure A1. All migratory movements from tagged woodcock in Fall 2021.

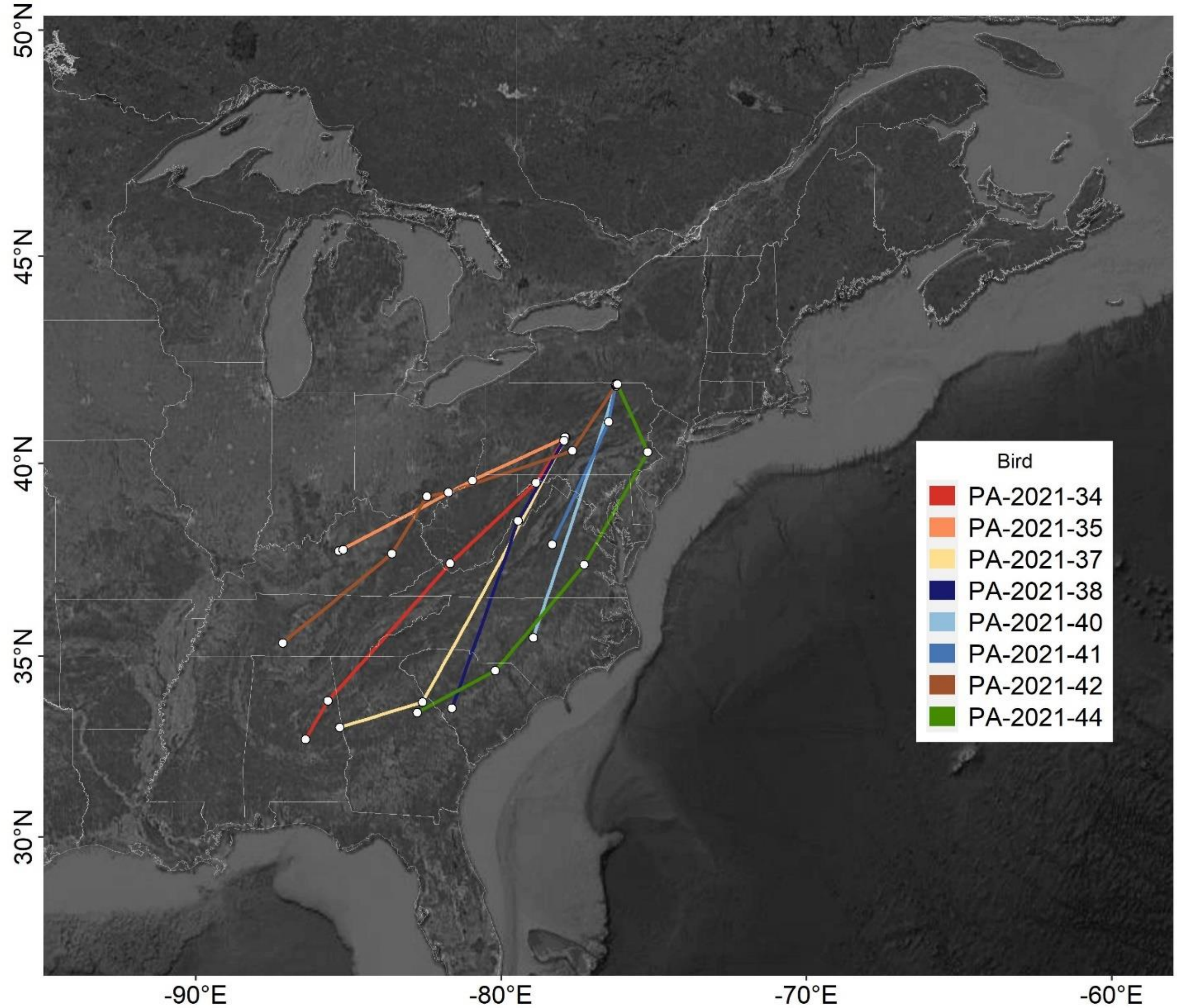

Figure A2. Fall migration of woodcock tagged in Pennsylvania in Fall 2021.

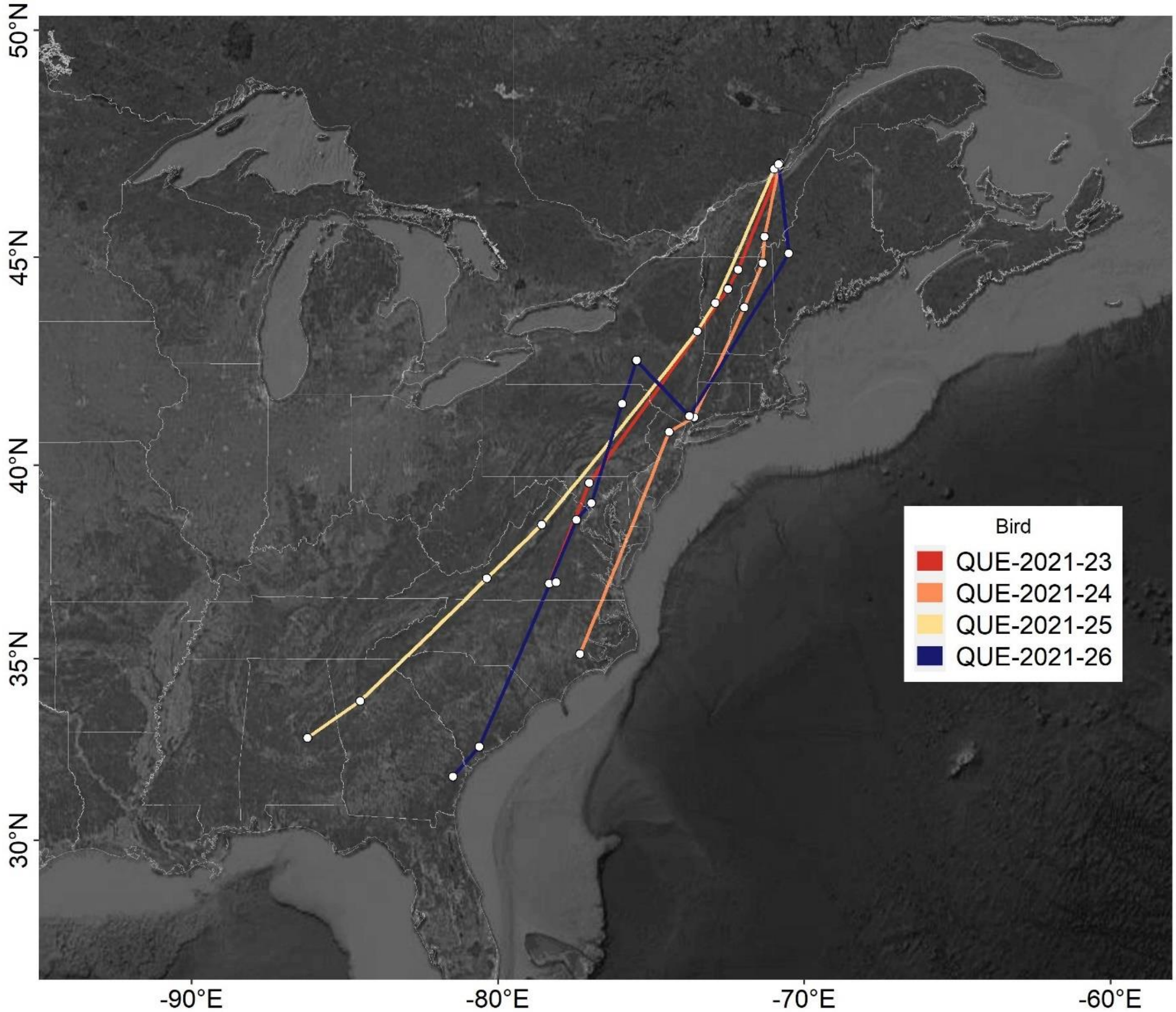

Figure A3. Fall migration of woodcock tagged in Quebec in Fall 2021.

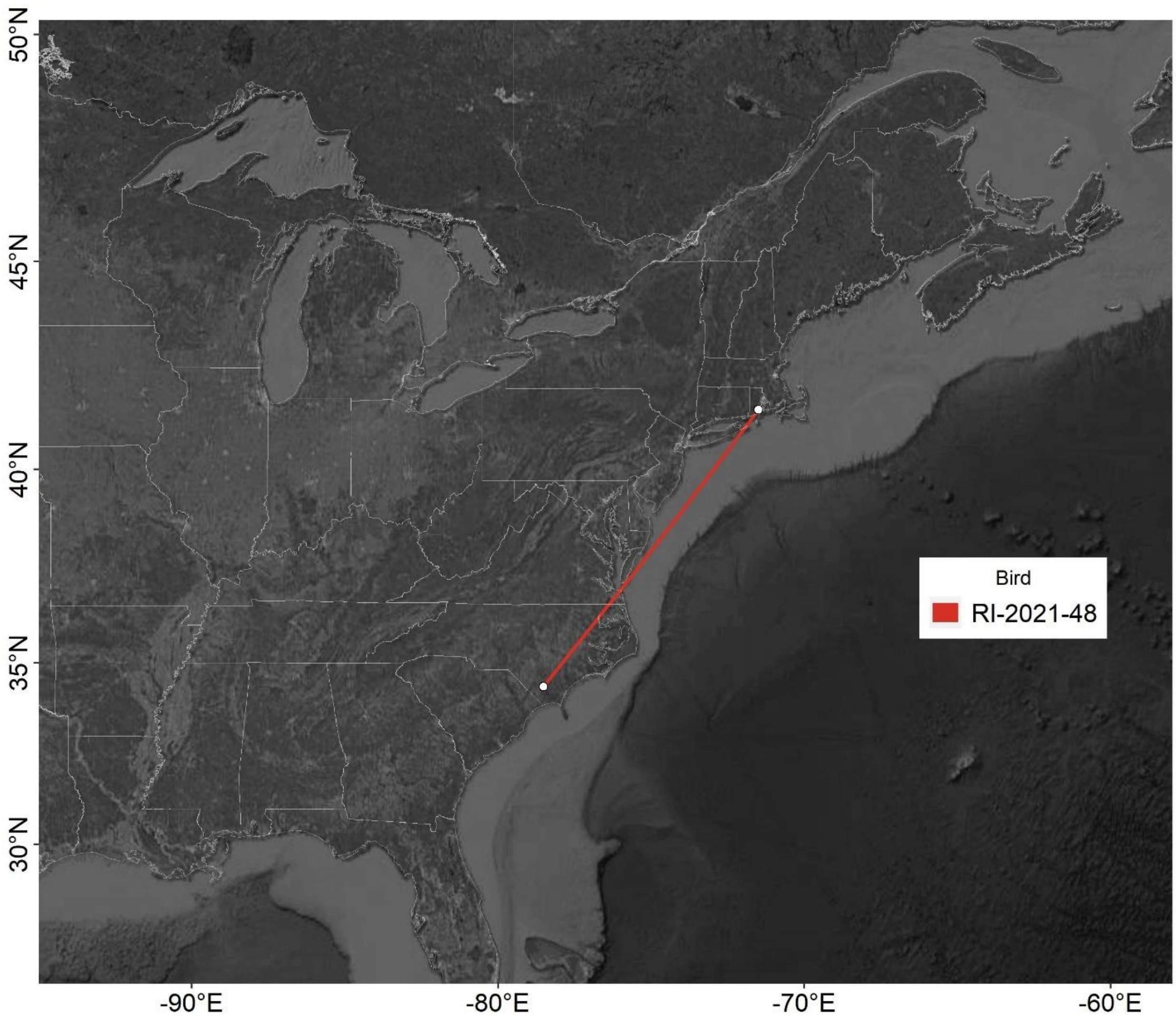

Figure A4. Fall migration of woodcock tagged in Rhode Island in Fall 2021.

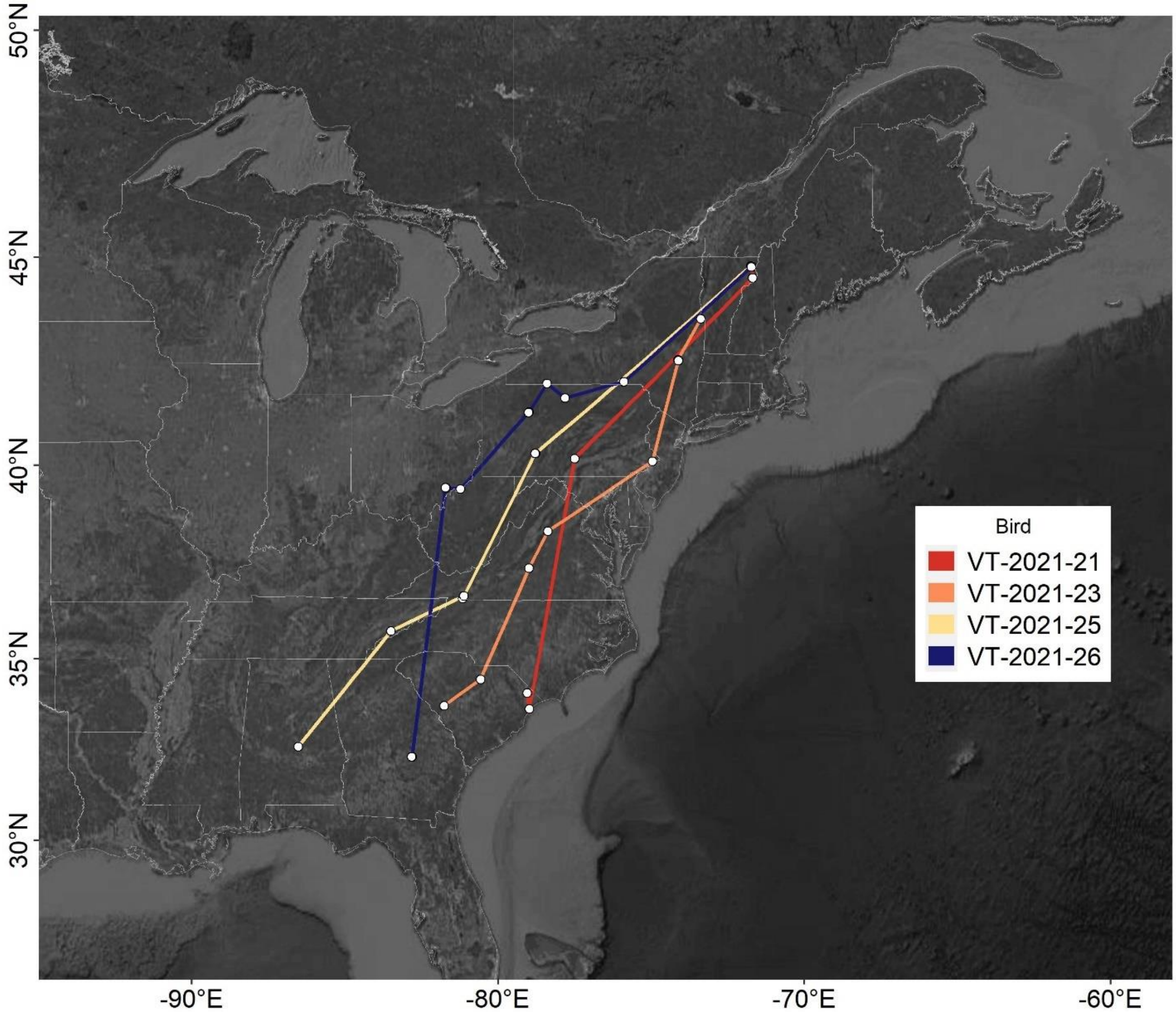

Figure A5. Fall migration of woodcock tagged in Vermont in Fall 2021.

Spring 2022

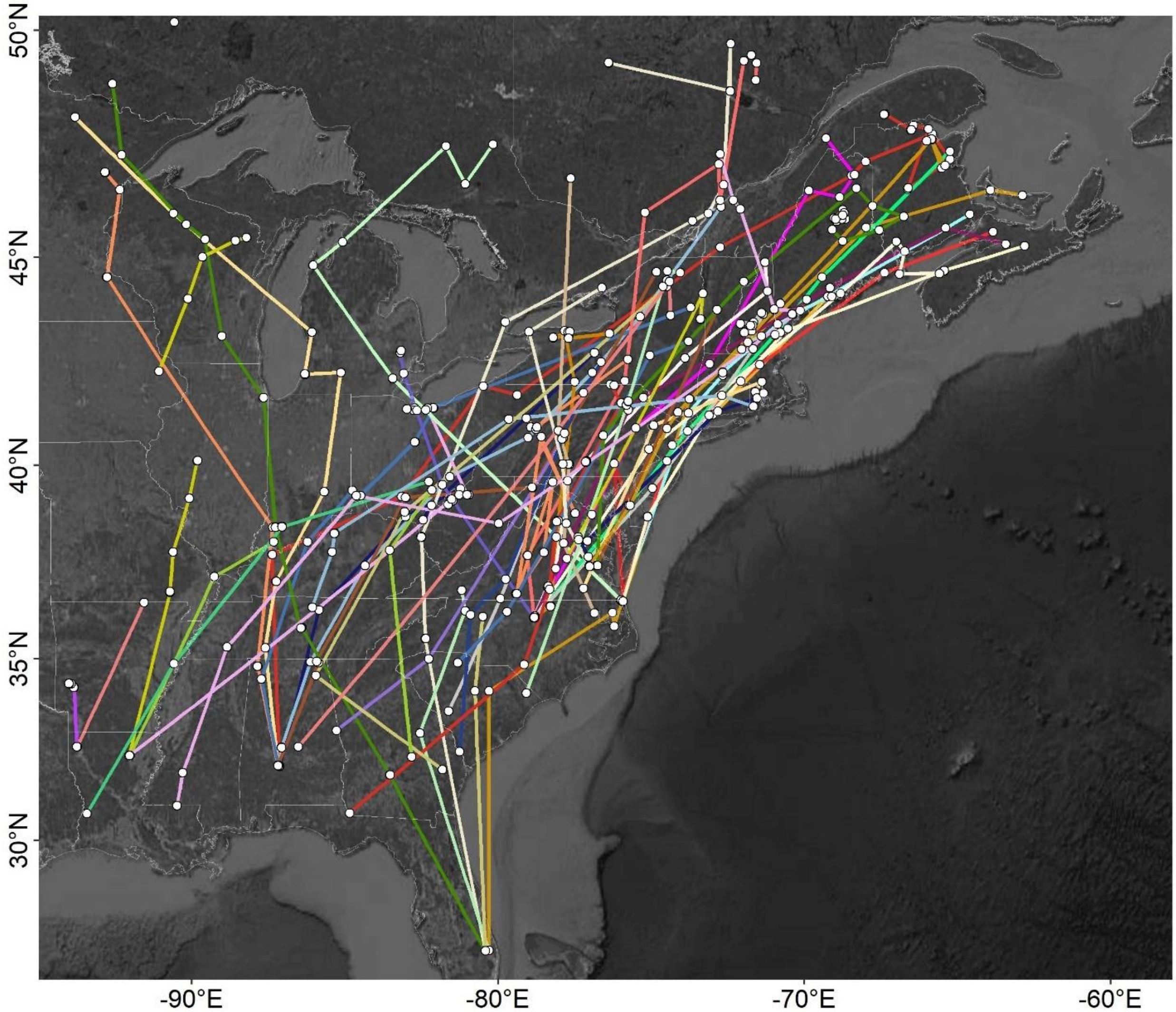

Figure A6. All migratory movements from tagged woodcock in Spring 2022.

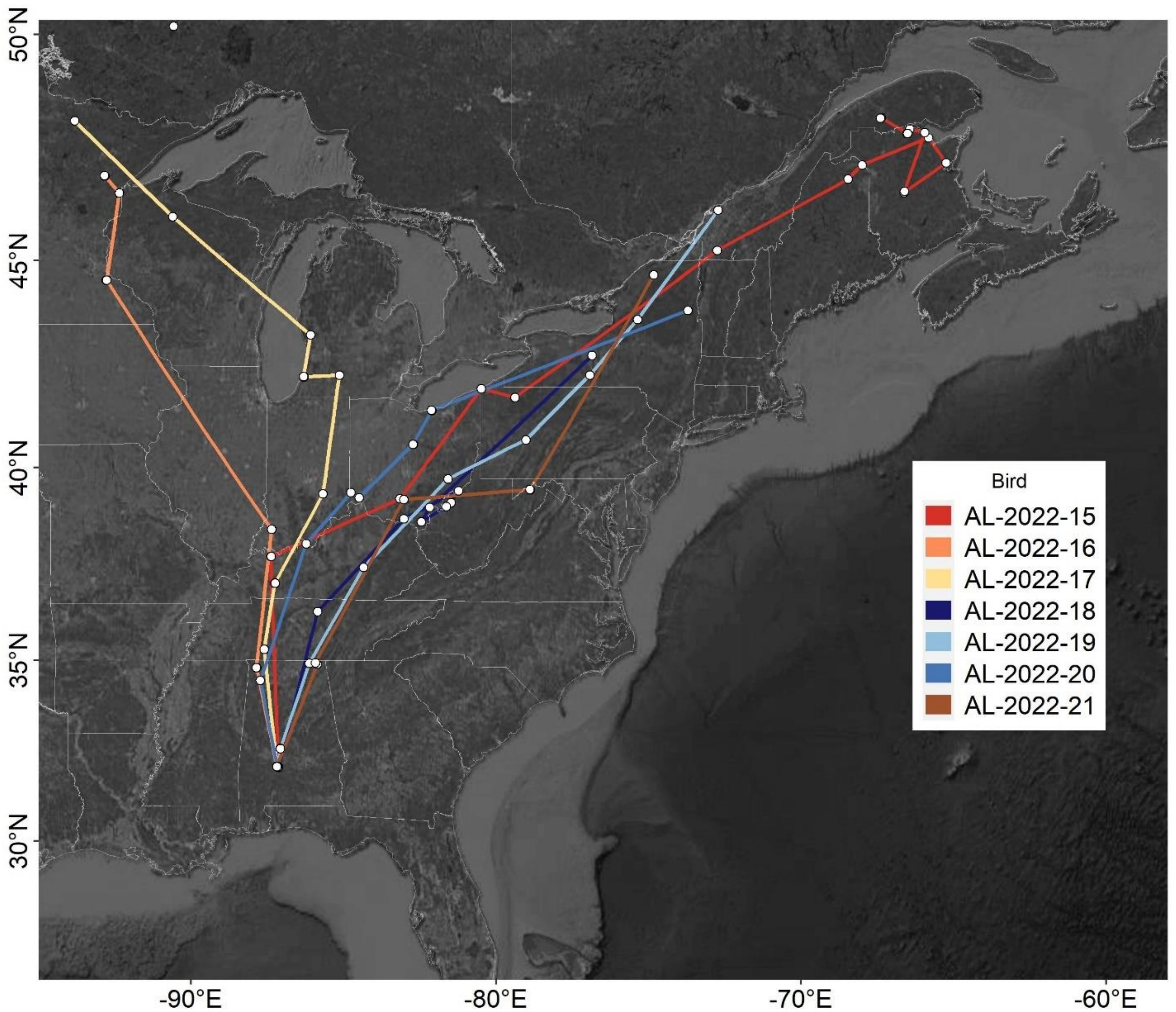

Figure A7. Spring migration of woodcock tagged in Alabama in Spring 2022.

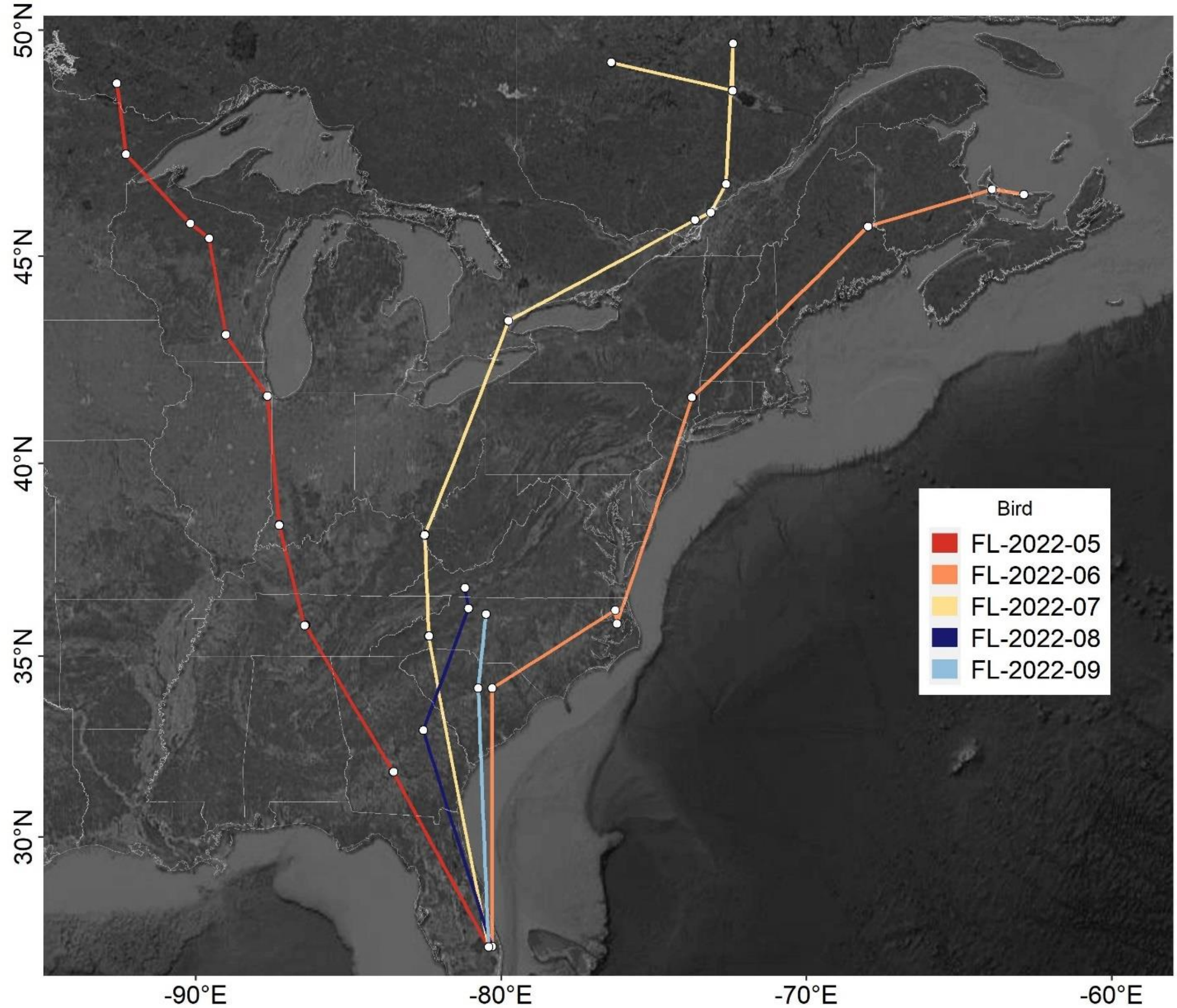

Figure A8. Spring migration of woodcock tagged in Florida in Spring 2022.

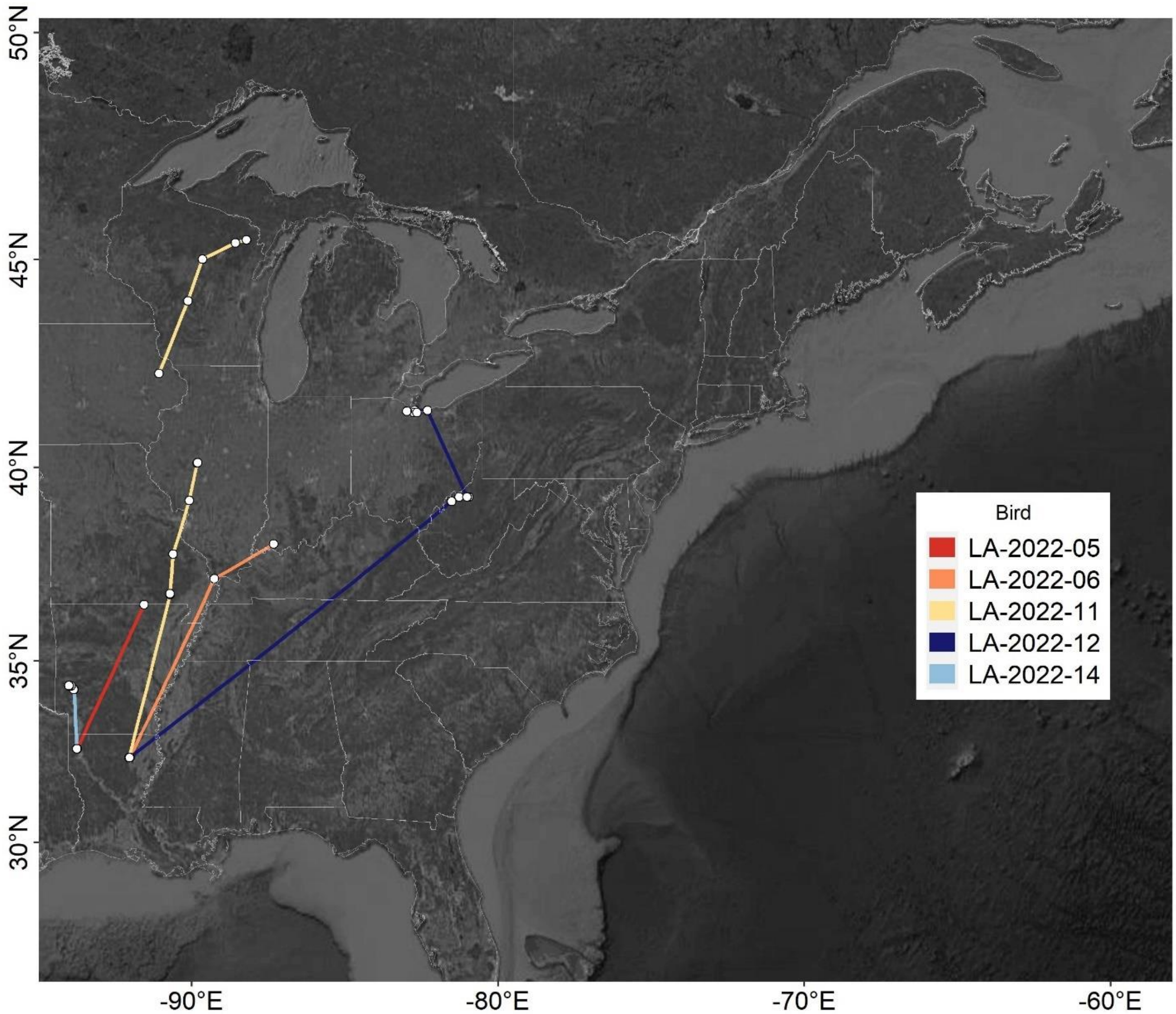

Figure A9. Spring migration of woodcock tagged in Louisiana in Spring 2022.

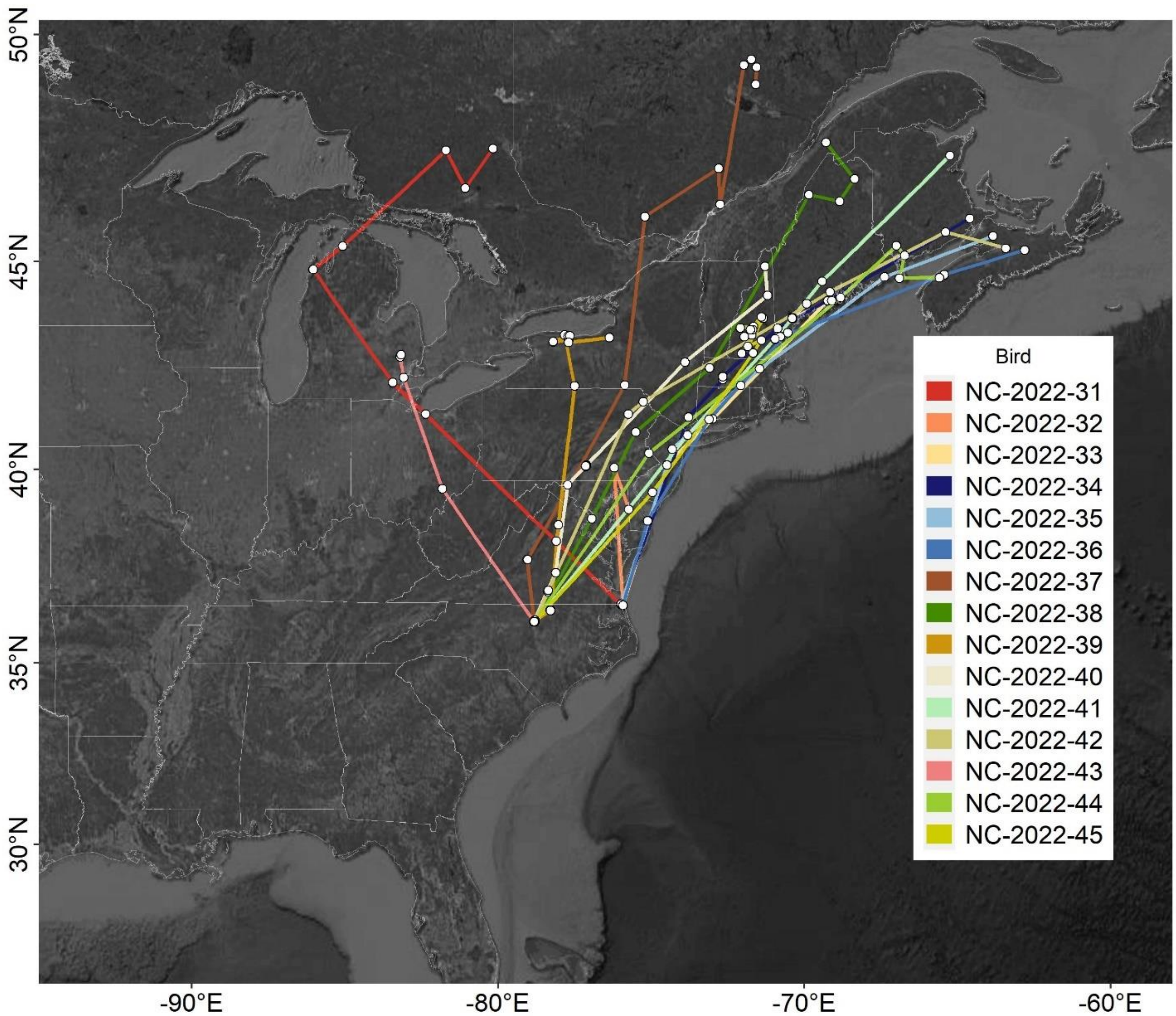

Figure A10. Spring migration of woodcock tagged in North Carolina in Spring 2022.

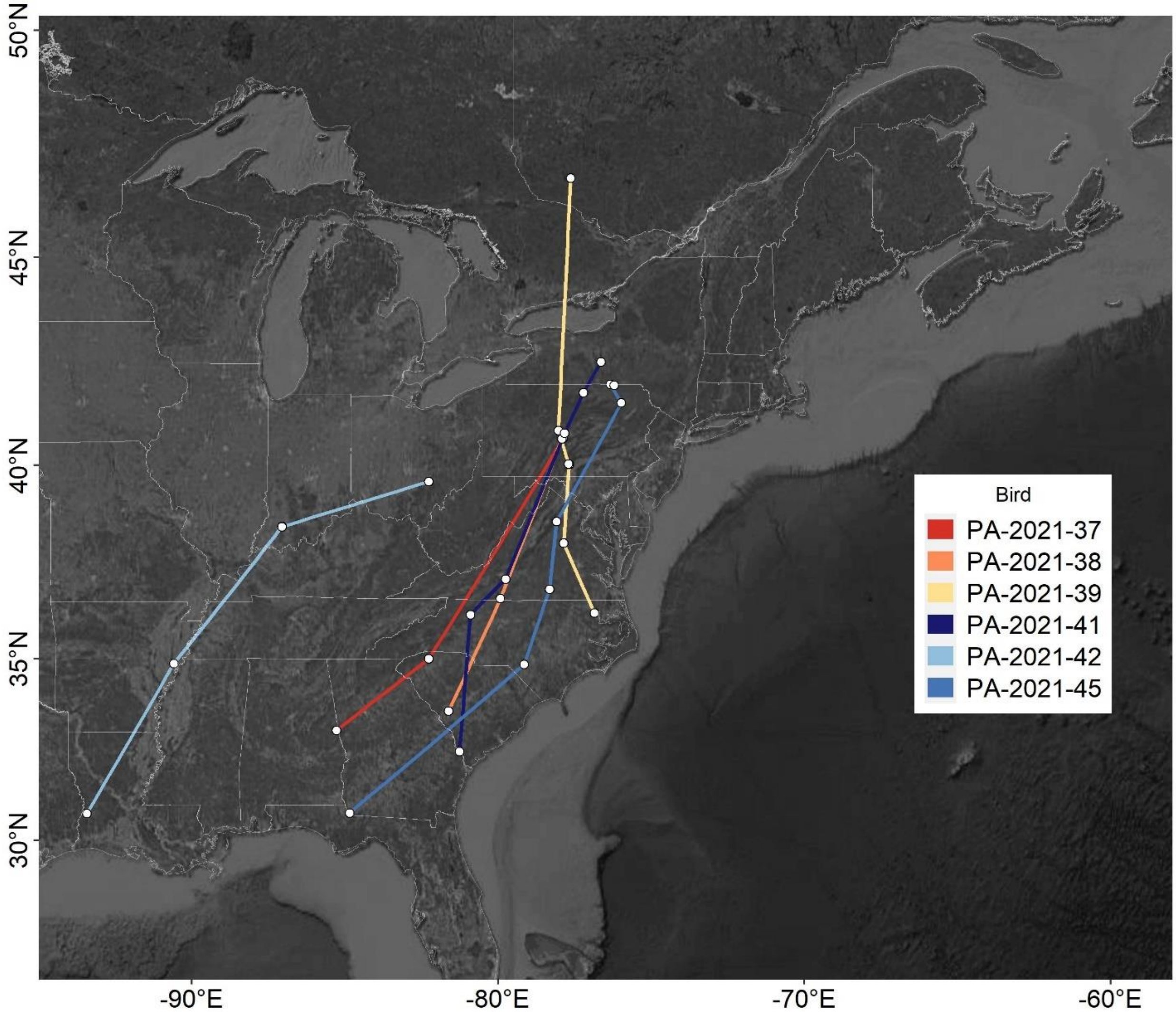

Figure A11. Spring migration of woodcock tagged in Pennsylvania in Fall 2021.

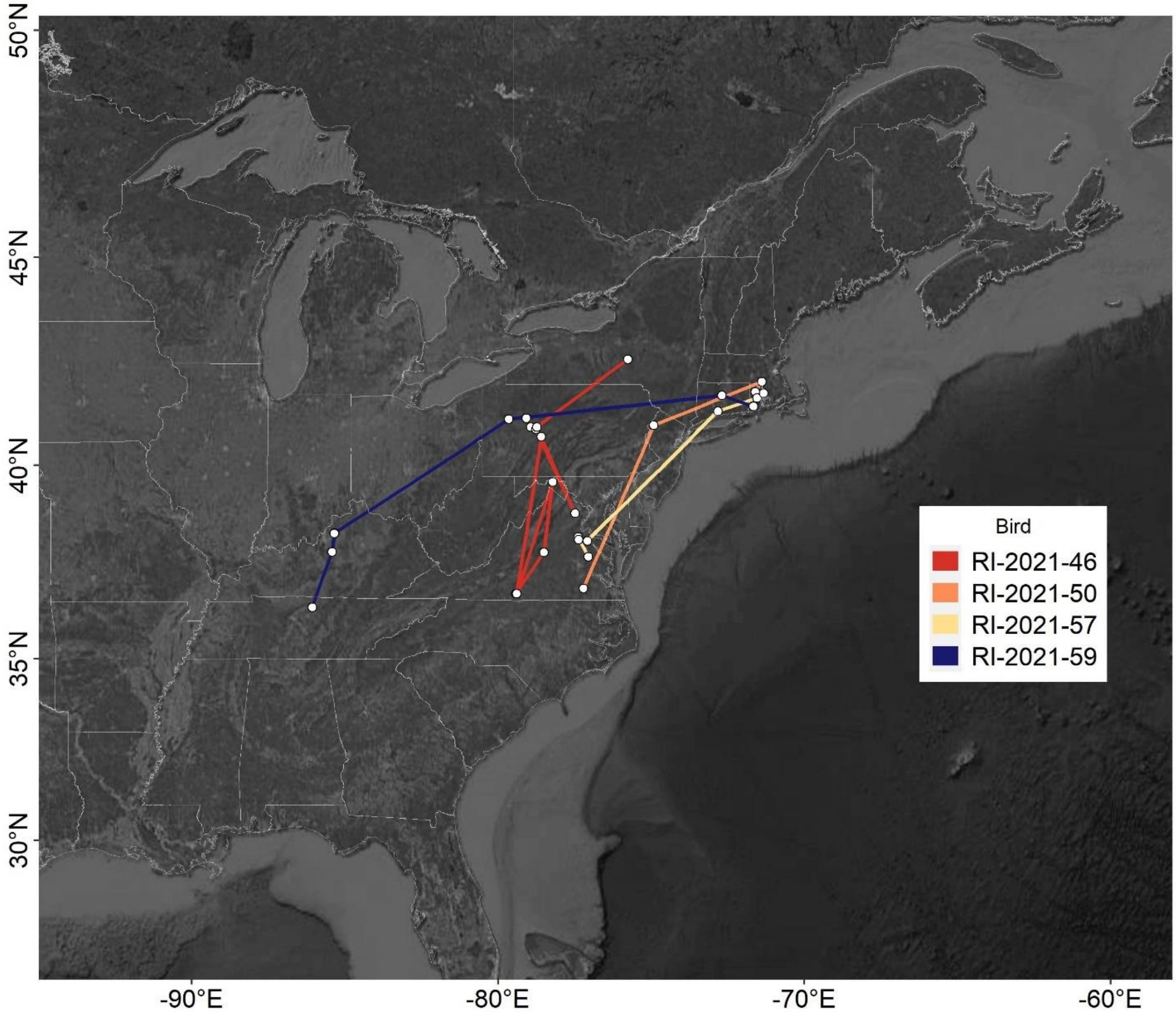

Figure A12. Spring migration of woodcock tagged in Rhode Island in Fall 2021.

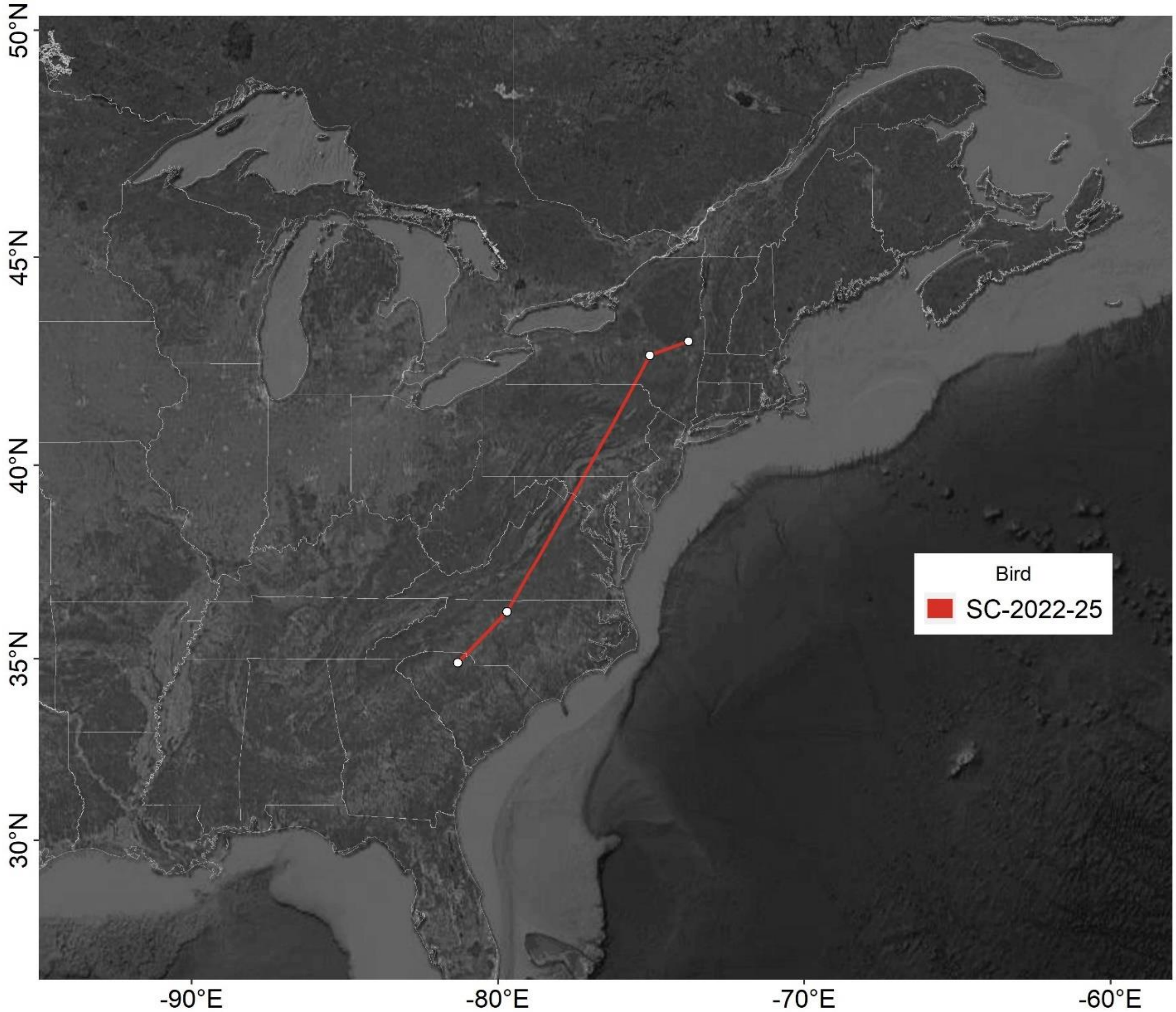

Figure A13. Spring migration of woodcock tagged in South Carolina in Spring 2022.

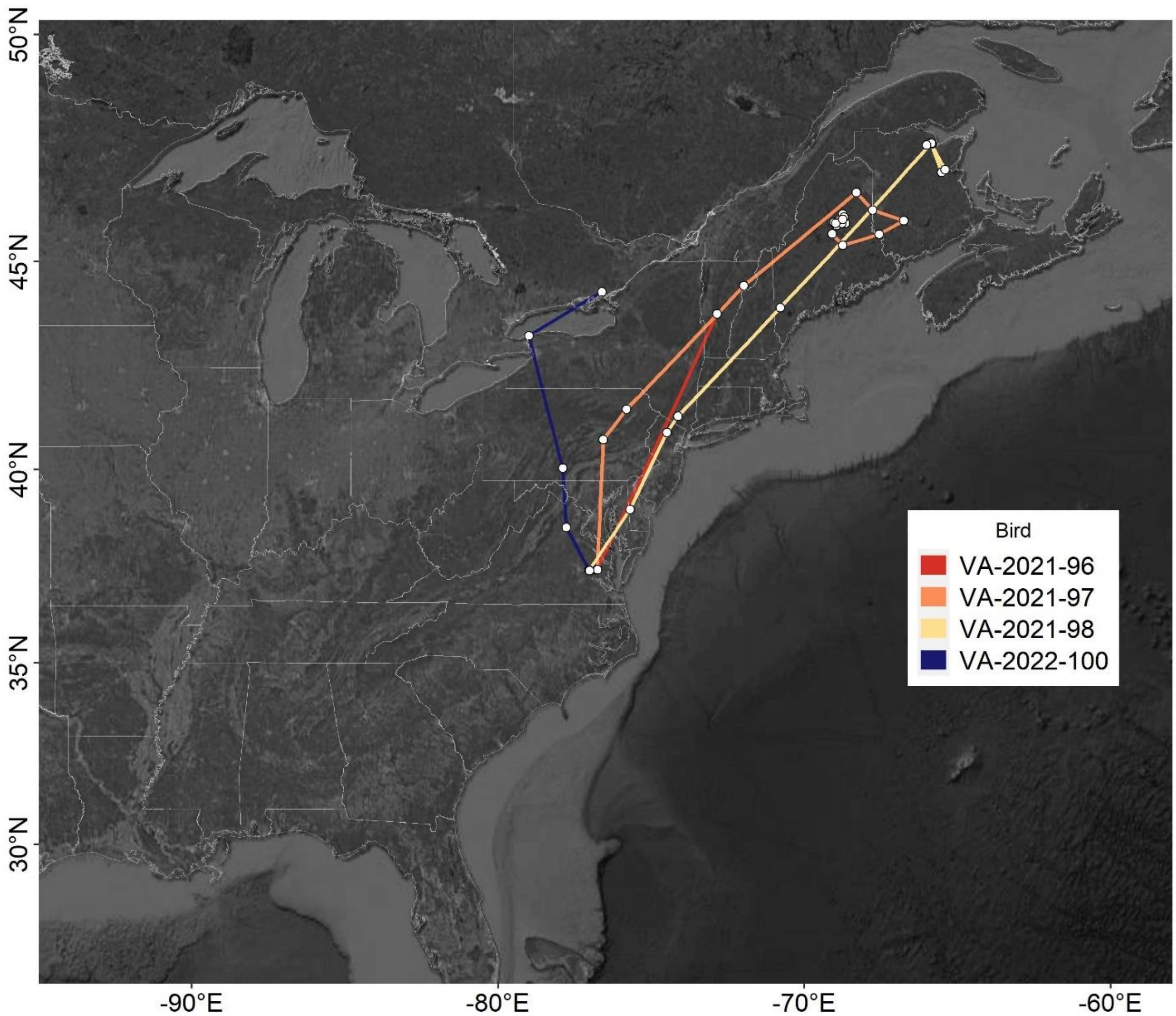

Figure A14. Spring migration of woodcock tagged in Virginia in Fall 2021 and Spring 2022.

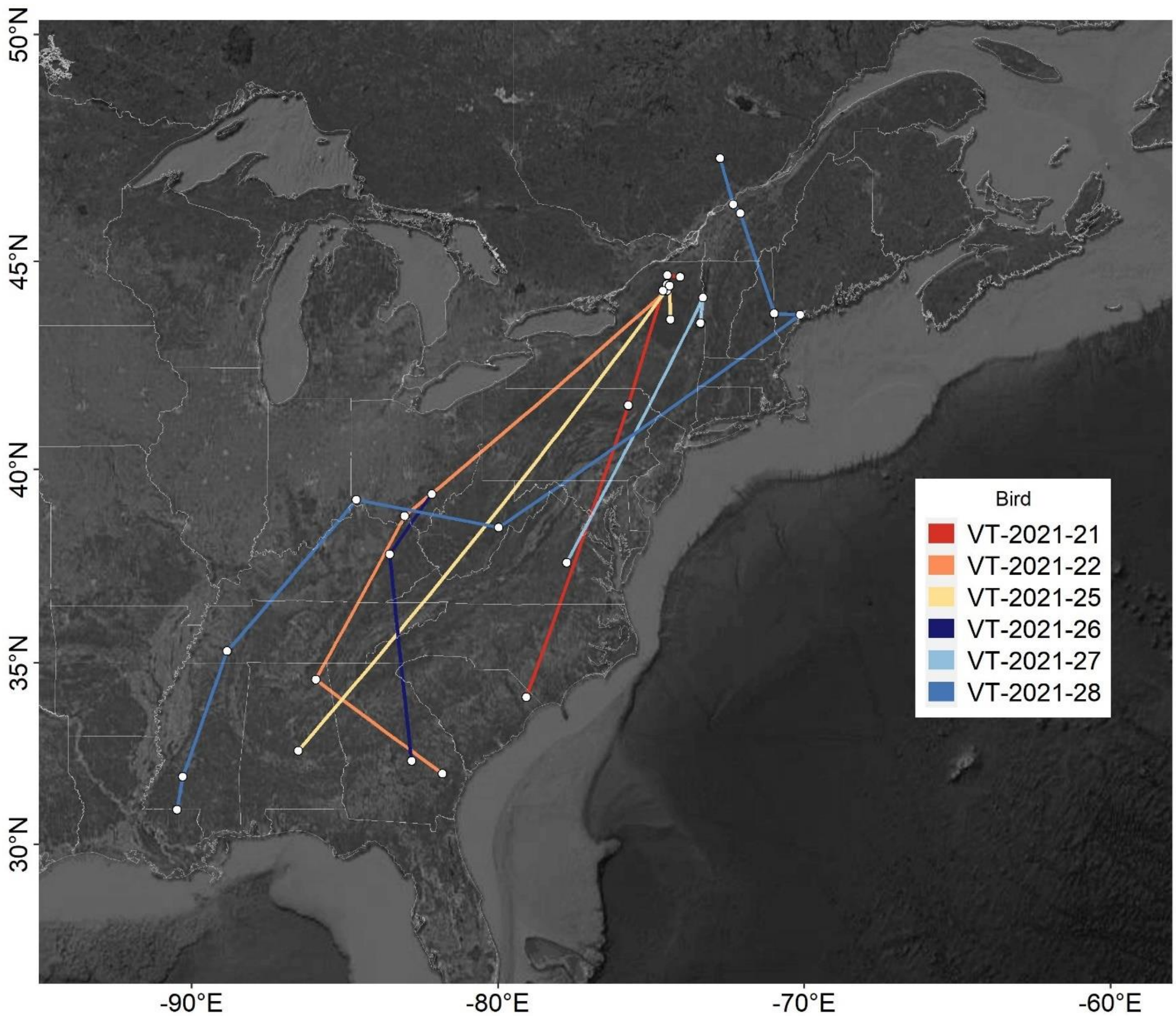

Figure A15. Spring migration of woodcock tagged in Vermont in Fall 2021.

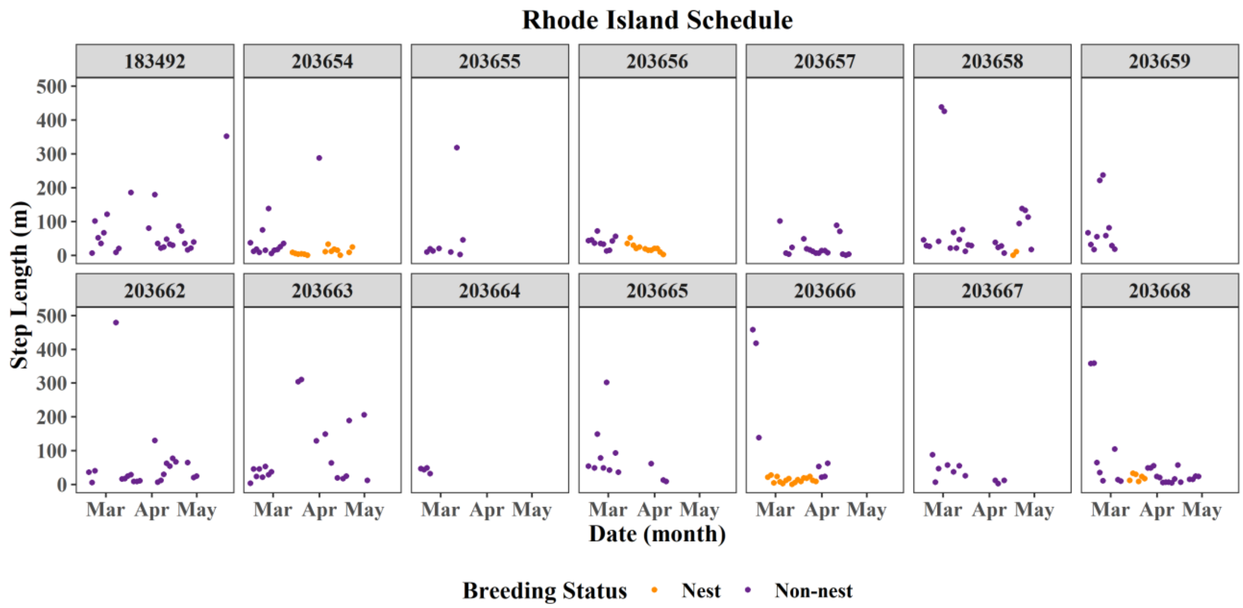

Figure A16. RI duty-cycle step-lengths for incubating and non-nesting periods during the 2021 spring breeding season. In total, there were 6 verified nests, and one with a renest (RI-2020-35). RI-2020-42 had a confirmed breeding attempt, but the tag slipped and was identified using pointing dogs in RI rather than step lengths.

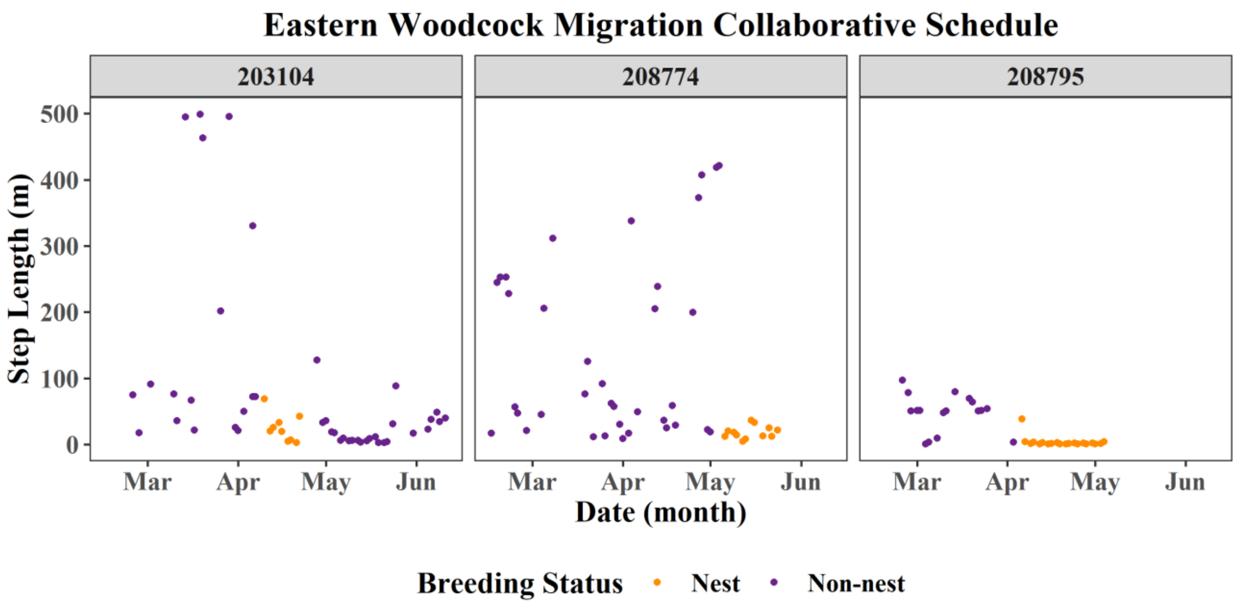

Figure A17. EWMRC duty-cycle step-lengths for incubating (orange) and non-nesting (dark blue) periods for the three verified, ground-truthed nesting hens found during the 2021 spring breeding season.

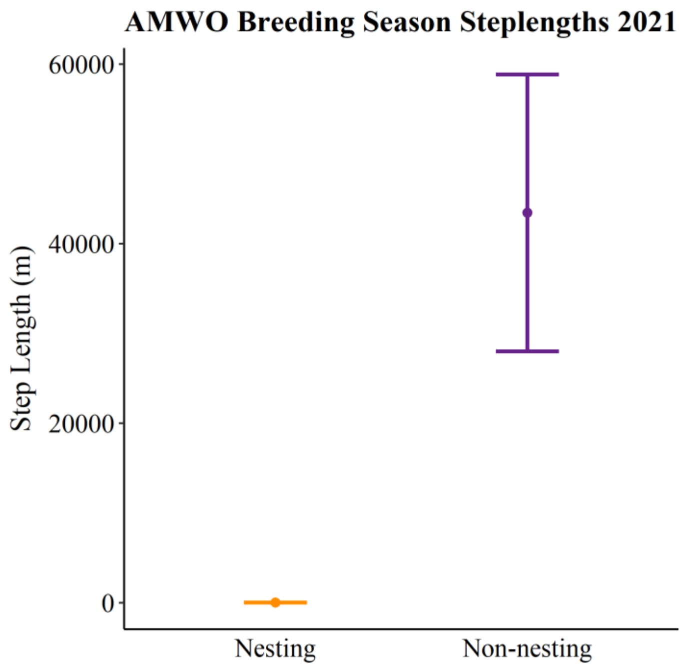

Figure A18. Mean step-lengths with 95% CI for all nesting and non-nesting steps taken for all GPS tagged birds during spring 2021. The non-nesting step length average include GPS tagged birds that did not have a verified nesting attempt.

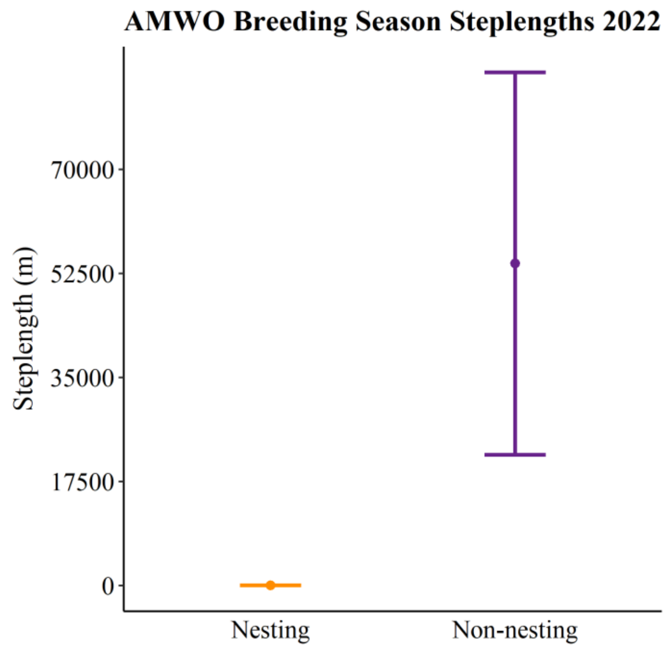

Figure A19. Mean step-lengths with 95% CI for all nesting and non-nesting steps taken for all GPS tagged birds during spring 2022. The non-nesting step length average include GPS tagged birds that did not have a verified nesting attempt.