# Eleventh American Woodcock Symposium

*Proceedings of the*

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**CONSERVATION STRATEGIES:** Mark Seamans and Rebecca Rau, "American Woodcock Status." **POPULATION ASSESSMENT:** Kyle O. Daly, David E. Andersen, Wayne L. Brininger, and Thomas R. Cooper, "Evaluating Techniques for Estimating Post-Breeding-Season Age Ratios for American Woodcock." Kyle O. Daly, David E. Andersen, Wayne L. Brininger, and Thomas R. Cooper, "Breeding Season Survival of American Woodcock at a Habitat Demonstration Area in Minnesota." **HABITAT DYNAMICS:** David G. McAuley, Guthrie Zimmerman, Brian B. Allen, Chris Dwyer, and Thomas R. Cooper, "Survival Rates and Stopover Persistence of American Woodcock Using Cape May, New Jersey, during Fall Migration." **SINGING-GROUND SURVEY EVALUATION:** Rebecca D. Rau, Thomas R. Cooper, and Matthew R. Nelson, "American Woodcock Singing-ground Survey: The Logistical Challenges Associated with Route Consistency through Time." **MANAGEMENT TECHNIQUES:** Tom R. Cooper, "Assessment of the American Woodcock Wing-Collection Survey." D. G. McAuley and R. E. Brown, "Detecting Passage of Migrating Woodcock Using Nano Tag Technology." Daniel G. McAuley, David A. Clugston, Jerry R. Longcore, and William A. Halteman, "Behavior of Incubating American Woodcock (*Scolopax minor*) in Maine."

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# Eleventh American Woodcock Symposium

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# Eleventh American Woodcock Symposium

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# Preface

It is hard to believe that it has been 11 years since the 10th American Woodcock Symposium took place in October 2006! Since that time, stakeholders have completed several significant activities: 1) the Woodcock Task Force, formed by the Association of Fish and Wildlife Agencies (AFWA), finalized the American Woodcock Conservation Plan in 2008; 2) AFWA's Migratory Shore and Upland Game Bird Support Task Force convened a workshop in 2010 to identify priority information for the American woodcock, with partners completing considerable work on the identified priorities; and 3) the Wildlife Management Institute stepped up to coordinate the implementation of the American Woodcock Initiative by forming regional Young Forest Initiatives working with numerous partners. Based on the volume of work completed since the 2006 symposium, woodcock researchers and managers felt it was timely to hold the 11th American Woodcock Symposium.

The 11th American Woodcock Symposium Planning Committee held their first organizing meeting in April 2016. Early in the planning process, the Committee made the decision to format the symposium sessions following the priority information needs identified for woodcock by AFWA's Migratory Shore and Upland Game Bird Support Task Force. As such, you will find the papers presented at the symposium organized by those four priorities in this volume. In addition, you will find a summary of work completed by partners to implement the American Woodcock Conservation under the leadership of the Wildlife Management Institute. Often plans go on a shelf and collect dust when completed, but partners truly stepped up to implement the American Woodcock Conservation Plan through the regional Young Forest Initiatives, demonstrating how science, policy, and management can influence conservation.

We would like to recognize a couple of key people that made the 11th American Woodcock Symposium memorable. Al Stewart, with the Michigan Department of Natural Resources, took the lead on organizing symposium logistics at the Ralph A. MacMullan Convention Center. The staff at the Center did a wonderful job hosting the symposium and Al went out of his way to make sure all participants had a great time! Who can forget the banquet dessert of chocolate pudding and Oreos with gummy worms in it? Andy Weik, with the Ruffed Grouse and American Woodcock Society, coordinated the financial logistics for the symposium. This included setting up online registration, paying invoices, and handling the registration process at the symposium. These are often thankless tasks and we appreciate the Ruffed Grouse and American Woodcock Society stepping up to manage the Symposium finances!

We are also appreciative of the many contributions made by authors, associate editors, manuscript reviewers, and planning committee members. It was a great team to work with over the past two years as we planned the symposium and worked to complete this volume. University of Minnesota Libraries Publishing produced this volume, and Emma Molls spearheaded that effort. Emma pushed all the pieces of this together, including the copyediting, formatting, and typesetting. She secured DOI numbers, provided electronic access, and worked with a printer to produce hard copies of the volume. We also thank Ross Hier, who eagerly agreed to illustrate this volume with his original artwork, which we hope you find to be a noteworthy addition.

The American Woodcock has a small, but faithful fan club. Our best data indicate that the number of hunters pursing the timberdoodle has been declining over the past several decades. However, those that remain are a dedicated group who care passionately about their conservation, which is why we periodically get together to share the latest information about the American Woodcock and how that can inform their conservation. We are hopeful that researchers, managers, and conservationists will continue to come together well into the future as new information about the American Woodcock becomes available. Until next time, enjoy!

Sincerely,
David Krementz
David Andersen
Thomas Cooper

***Past Woodcock Symposia***

1. 1966, Minnesota
2. 1968, Louisiana
3. 1969, Maine
4. 1971, Michigan
5. 1974, Georgia
6. 1977, New Brunswick
7. 1980, Pennsylvania
8. 1990, Indiana
9. 1997, Louisiana
10. 2006, Michigan
11. 2017, Michigan

# Welcome to Michigan and the 11th American Woodcock Symposium

The scientific woodcock community has hosted American woodcock symposia and workshops periodically since 1966. These symposia have provided the opportunity for researchers, land managers, biologists, law makers, hunters, and woodcock enthusiasts to discuss and report current information on woodcock ecology and management. Attendees have shared ideas on the future needs of woodcock research and management efforts, and addressed "hot topics" in the woodcock world. The 11th American Woodcock Symposium focuses on accomplishments during the last decade. Woodcock research over the past 10 years has been concentrated on the "Priority Needs for American Woodcock: A Funding Strategy" that was developed by woodcock authorities. This symposium highlights these priority needs related to conservation stewardship, population assessment, communication strategies, habitat dynamics, singing-ground survey evaluation, and management techniques.

Previous woodcock symposia have effectively fostered communication on woodcock research and have been the basis for successful woodcock management internationally. With each symposium, the quality of data, sophistication of statistical analysis, and originality of methods have advanced our understanding about this bird. Symposia have been held across the range of the species. This meeting is designed to stimulate thought, expand ideas, and increase our knowledge about woodcock management and ecology. This binder contains the meeting abstracts. Hard-bound symposium proceedings and e-documents will be available in the future. I hope this meeting serves as a catalyst to highlight the necessity for expanded work on woodcock population and habitat monitoring, broadened educational efforts to encourage the public to give "social value" to young forest habitats needed for woodcock survival, and increased funding for further study.

Many people have helped in the planning stages for the 11th American Woodcock Symposium. It is through their dedication and attention to detail that this meeting has come to fruition.

Enjoy your visit to Michigan and take time to deliberate with your peers.

Al Stewa

Al Stewart, Symposium Co-Chair

***Symposium Committee Members***

Andersen, David E.
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## CHAPTER ONE
## *Conservation Strategies*

## CHAPTER TWO
## *Population Assessment*

## CHAPTER THREE
## *Communication Strategies*

CHAPTER FOUR

## *Habitat Dynamics*

CHAPTER FIVE

## *Singing-ground Survey Evaluation*

CHAPTER SIX

## *Management Techniques*

## CHAPTER ONE

# Conservation Strategies

# American Woodcock Priority Information Needs – A Shared Vision

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In 2006, the Association of Fish and Wildlife Agencies' Migratory Shore and Upland Game Bird Working Group established a Migratory Shore and Upland Game Bird Support Task Force (Task Force). The Task Force was composed of nine representatives of state, federal, and non-governmental organizations. The Task Force was directed to update the research and management needs of the 16 species of migratory shore and upland game birds (Table 1), including the American woodcock (*Scolopax minor*), and to develop a strategy for funding priority research and management needs for these species. The Strategies included priorities that stakeholders believed would significantly improve the management of Migratory Shore and Upland Game Birds and, thus, represent a significant winnowing of hundreds of potential research and management needs, identified in earlier planning efforts (e.g., Tacha and Braun 1994), to 26. In a time of increased budget scrutiny and justification, these Strategies represent a significant accomplishment by focusing efforts on the most important actions.

## Strategy Purpose

The six Strategies each contain recommendations for obtaining priority information needed to improve habitat and harvest management decisions for the 16 species of North American migratory shore and upland game birds. The Strategies focused on evaluating and improving monitoring efforts, measuring vital rates (survival, reproduction, and recruitment), and evaluating habitat needs during the annual life cycle of these birds. The Strategies were intended to provide guidance for research and management activities, and to increase financial support for the program during the next 5–10 years.

## Strategy Development Process

The Task Force determined that convening groups of species experts would be the most efficient and effective process for developing Strategies. Experts from academia and from state and federal agencies in the United States (U.S.) and Canada participated in the process. More than 90 experts, collectively, collaborated on one or more of the Strategies. Many of these experts were intimately involved with the North American Flyway system of managing migratory game birds. Strategy development included a combination of in-person and online meetings, followed by additional work via email, online meetings, and conference calls. The first Strategy was completed in June 2008 and the final Strategy was completed in February 2011. Twenty-nine American woodcock experts (Appendix A) convened at a workshop held in Bloomington, Minnesota, in August 2009 to begin work on the strategy. The team completed "A Priority Information Needs for American Woodcock: A Funding Strategy" in March 2010 (D.J. Case and Associates 2010).

## Priority Information Needs For American Woodcock

The workshop resulted in the identification of four priority information needs for American woodcock (in priority order):

1. Develop a demographic-based model for assessing American woodcock population response to harvest and habitat management.
2. Develop communication strategies to increase support for policies and practices that benefit American woodcock and other wildlife of young forests.
3. Improve understanding of migration, breeding, and wintering habitat quality for American woodcock.
4. Improve the American Woodcock Singing-ground Survey.

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A full description of the four priorities, including background justifications and estimated costs, is available in D.J. Case and Associates (2010).

The planning team for the 11th American Woodcock Symposium (Symposium) used these priorities to organize the program. They believed that the Symposium offered a convenient and worthwhile forum for stakeholders to share the work they have completed to date on the four priorities identified in 2010. The manuscripts shared in this volume will help inform management efforts for American woodcock for years to come.

## Literature Cited

D.J. Case and Associates (editors). 2010. Priority information needs for American woodcock: a funding strategy. Developed for the Association of Fish and Wildlife Agencies by the Migratory Shore and Upland Game Bird Support Task Force. 15pp. https://www.fws.gov/birds/surveys-and-data/webless-migratory-game-birds/priority-information-needs.php.

Tacha, T.C. and C.E. Braun (editors). 1994. Migratory shore and upland game bird management in North America. International Association of Fish and Game Agencies, Washington, D.C., USA. 223pp.

**Table 1.** The 16 species of migratory shore and upland game birds for which priority information needs were identified through convening species-specific task forces to develop a strategy for funding priority research and management needs.

| Common Name | Scientific Name |
|---|---|
| King rail | *Rallus elegans* |
| Clapper rail | *Rallus longirostris* |
| Virginia rail | *Rallus limicola* |
| Sora | *Porzana carolina* |
| Purple gallinule | *Porphyrio martinica* |
| Common moorhen | *Gallinula chloropus* |
| American coot | *Fulica americana* |
| Sandhill crane | *Antigone canadensis* |
| Wilson's snipe | *Gallinago delicata* |
| American woodcock | *Scolopax minor* |
| Band-tailed pigeon | *Patagioenas fasciata* |
| Scaly-naped pigeon | *Patagioenas squamosa* |
| Zenaida dove | *Zenaida aurita* |
| Mourning dove | *Zenaida macroura* |
| White-winged dove | *Zenaida asiatica* |

## Appendix A. 2009 American Woodcock Priority Information Needs Workshop participants

- D.E. Andersen, *U.S. Geological Survey*
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- R.J. Blohm, *U.S. Fish and Wildlife Service/Migratory Shore and Upland Game Bird Task Force*
- D.J. Case, *MSUGB Task Force*
- T.R. Cooper, *U.S. Fish and Wildlife Service*
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- J.H. Schulz, *Migratory Shore and Upland Game Bird Task Force*
- C.A. Stewart, *Michigan Department of Natural Resources*
- W.E. Thogmartin, *U.S. Geological Survey*
- K.Van Horn, *Wisconsin Department of Natural Resources*
- S.D. Wilds, *Retired FWS/Wildlife Management Institute Young Forest Initiative Contractor*
- K.A. Wilkins, *U.S. Fish and Wildlife Service*
- G.S. Zimmerman, *U.S. Fish and Wildlife Service*

# Implementing the American Woodcock Conservation Plan: Wildlife Management Institute's Young Forest Initiative

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***Proceedings of the American Woodcock Symposium 11: 5–8***

The Woodcock Task Force, under the direction of the Association of Fish and Wildlife Agencies, completed the American Woodcock Conservation Plan (Plan) in 2008. The goal of the Plan was to halt the decline of American woodcock (*Scolopax minor*, hereafter woodcock) populations and to return populations to densities that provide adequate opportunity for utilization of the woodcock resource (Kelley et al., 2008). Specific objectives of the Plan were: 1) halt woodcock population declines by 2012 as measured by the American Woodcock Singing-ground Survey (SGS), 2) achieve positive population growth by 2022 as measured by the SGS, 3) halt decline of early successional forest by 2012 as measured by the Forest Inventory Analysis system (FIA), and 4) increase early successional forest by 2022 as measured by the FIA (Kelley et al. 2008).

Upon completion of the Plan, the Wildlife Management Institute (WMI) took a leadership role in implementing the Plan by forming 5 regional "Young Forest Initiatives" (Initiatives) covering 17 states within the core breeding range of woodcock (Fig. 1). The Upper Great Lakes Initiative includes all Michigan and Wisconsin, and over half of Minnesota in the northeast quadrant of the state. The Lower Great Lakes Initiative includes lands south of lakes Erie and Ontario in Ohio and Pennsylvania, and land in the St. Lawrence Valley in New York, the Champlain Valley in New York and Vermont, and the Hudson River Valley in New York. The Northern Forest Initiative includes all of Maine, most of New Hampshire, northern and western Massachusetts, and the Adirondack region of New York. The Appalachian Initiative includes all of West Virginia, southeastern Ohio, much of Pennsylvania, the southern tier of New York, the northern tip of New Jersey, and western Virginia. The Atlantic Coast Initiative includes coastal portions of Maine and New Hampshire, all of Rhode Island, Long Island, and extreme southeastern New York, southern New Jersey, the Delmarva Peninsula, and that portion of Maryland on the western shore of the Chesapeake Bay.

WMI brought together regional partners, starting in 2007, to begin implementing the habitat management objectives of the plan. Guiding principles for the initiatives were: 1) all work is science-based, 2) expert practitioners deliver conservation, 3) initiatives are partnership driven, and 4) there is accountability within the partnership.

## PLAN IMPLEMENTATION

In the early phases of each Initiative, WMI coordinated organizational meetings with potential regional partners. At these meetings, attendees learned more about the goals of the American Woodcock Conservation Plan and identified opportunities for coordinating work throughout the Initiative. Partners also identified available tools (e.g., spatially explicit woodcock abundance models developed by Thogmartin et al., 2007) for focusing work, as well as any existing information gaps.

WMI contracted with >30 habitat management specialists across the 5 Young Forest Initiatives to work on meeting plan goals. By taking advantage of a wave of retirements by state and federal natural resource agency staff, WMI assembled a team of highly trained and networked contractors to work with public and private partners to create and maintain early successional forest to benefit woodcock and >60 other species of greatest conservation need across the landscape. WMI employees and contractors coordinated with public and private partners to increase awareness of young forest/woodcock habitat issues and to implement habitat management projects. In some portions of the woodcock range, contractor work has also included management aimed at other species that

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require young forest cover types, including golden-winged warblers (*Vermivora chrysoptera*), New England cottontail (*Sylvilagus transitionalis*), ruffed grouse (*Bonasa umbellus*), and massasauga rattlesnakes (*Sistrurus catenatus*). Habitat management for these species results in young forest cover that also benefits woodcock. WMI funded the contractors through a series of grants from the National Fish and Wildlife Foundation, the U.S. Fish and Wildlife Service, state conservation agencies, the U.S. Department of Agriculture Natural Resource Conservation Service, and other partners (e.g., other non-profit organizations and private foundations).

To assist with initiative communication efforts, WMI worked with D.J. Case and Assoc. to develop a Communications Strategy (Seng and Case 2019), which has guided outreach efforts and currently supports 3 websites (www.timberdoodle.org, www.youngforest.org, and www.newenglandcottontail.org). These websites contain an abundance of information on techniques and tools, as well as success stories. WMI, with the assistance of partners, has developed a wide range of technical assistance publications, including regional Best Management Practices for woodcock, several landowner guides, communication handbooks, brochures, large format (8½ x 11 inches) science and stewardship guides, displays, guidebooks and manuals, exhibits, fact sheets, signs, and PowerPoint presentations. Many of these products are available at www.timberdoodle.org.

## INITIATIVE ACCOMPLISHMENTS

WMI maintains an online database that allows contractors to enter accomplishments from their work and that of partners. Since January, 2008, WMI has documented 1,429 assessments on 358,670 hectares (886,293 acres) of land across the initiatives (Table 1) and 2,692 treatments by public and private partners on 70,856 hectares (176,111 acres; Table 2). Initiative partners have been directly involved in 923 outreach events of all types, interacting with ≥12,272 interested landowners (Table 3). Not all accomplishments end up being entered into the database, and the number of people attending outreach events was not incorporated into the reporting until December, 2015. As such, all accomplishments should be considered as minimum numbers. Summaries for assessments, treatments, and outreach efforts for each of the initiatives are presented in Tables 1–3.

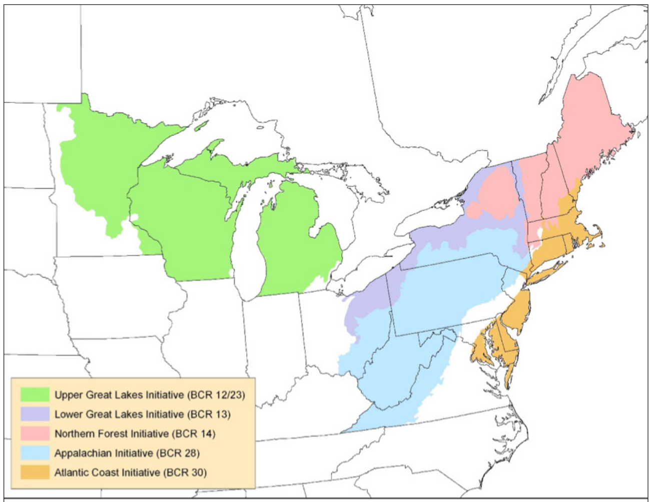

**Figure 1.** Location of the 5 Bird-Conservation-Region (BCR)-based Young Forest Initiatives in the United States.

## CONCLUSIONS

Partners have made progress in increasing the awareness of the value of young forest for woodcock and some 65 species of greatest conservation need that are closely associated with young forest. Whereas woodcock numbers have stopped their decades-long decline as measured by the SGS, there has not been an indication of population increase towards established goals, and the amount of young forest (age 0–20 years) continues to decline in most states. Efforts through these initiatives, in cooperation with partners, have likely helped stabilize woodcock populations, and in some areas initiated slight increases. Continued progress in these initiatives can help benefit wildlife species requiring young forest cover, and we recommend future work focus on engaging new partners in the existing initiatives and expanding initiative work into Canada.

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Kelley, J. R., S.J. Williamson, and T. R. Cooper, editors. 2008. American Woodcock Conservation Plan: a summary of and recommendations for woodcock conservation in North America, Migratory Shore and Upland Game Bird Working Group, Association of Fish and Wildlife Agencies. Wildlife Management Institute, Washington, D.C., USA <https://www.fws.gov/migratorybirds/pdf/surveys-and-data/Webless%20Migratory%20Game%20Birds/American%20Woodcock%20pdf%20files/WoodcockConservationPlan.pdf>. Accessed 10 June 2019.

**Table 1.** Summary of the number of assessments completed and hectares (acres) assessed for the 5 Young Forest Initiatives by primary species.

| Primary Species | No. of Assess-ments | Hectares assessed (acres) |
|---|---|---|
| **UPPER GREAT LAKES INITIATIVE** | | |
| American Woodcock | 7 | 3,609 (8,917) |
| Golden-winged Warbler | 1 | 691 (1,707) |
| Ruffed Grouse | 2 | 2,060 (5,090) |
| *Total* | 10 | 6,360 (15,714) |
| **LOWER GREAT LAKES INITIATIVE** | | |
| American Woodcock | 148 | 17,480 (43,194) |
| Golden-winged Warbler | 127 | 7,287 (18,007) |
| Massasauga Rattlesnake | 1 | 11 (27) |
| New England Cottontail | 22 | 2,498 (6,173) |
| *Total* | 298 | 27,276 (67,401) |
| **NORTHERN FOREST INITIATIVE** | | |
| American Woodcock | 323 | 169,793 (419,568) |
| Golden-winged Warbler | 3 | 212 (525) |
| New England Cottontail | 83 | 4,130 (10,205) |
| Ruffed Grouse | 15 | 2,073 (5,122) |
| *Total* | 424 | 176,208 (435,420) |
| **APPALACHIAN INITIATIVE** | | |
| American Woodcock | 224 | 108,111 (267,148) |
| Golden-winged Warbler | 60 | 11,716 (28,951) |
| Massasauga Rattlesnake | 1 | 162 (400) |
| New England Cottontail | 44 | 3,644 (9,004) |
| Ruffed Grouse | 24 | 10,943 (27,041) |
| *Total* | 353 | 134,576 (332,544) |
| **ATLANTIC COAST INITIATIVE** | | |
| American Woodcock | 67 | 4,067 (10,049) |
| New England Cottontail | 276 | 10,102 (24,962) |
| Ruffed Grouse | 1 | 81 (200) |
| *Total* | 344 | 14,250 (35,211) |
| **OVERALL SUMMARY** | | |
| American Woodcock | 769 | 303,060 (748,877) |
| Golden-winged Warbler | 191 | 19,906 (49,190) |
| Massasauga Rattlesnake | 2 | 173 (427) |
| New England Cottontail | 425 | 20,374 (50,345) |
| Ruffed Grouse | 42 | 15,157 (37,453) |
| *Total* | 1,429 | 358,670 (886,293) |

**Table 2.** Summary of the number of treatments and hectares (acres) of vegetation managed for the 5 Young Forest Initiatives by primary species.

| Primary Species | No. of Assess-ments | Hectares assessed (acres) |
|---|---|---|
| **UPPER GREAT LAKES INITIATIVE** | | |
| American Woodcock | 128 | 29,673 (73,326) |
| Golden-winged Warbler | 4 | 55 (136) |
| *Total* | 132 | 29,729 (73,462) |
| **LOWER GREAT LAKES INITIATIVE** | | |
| American Woodcock | 147 | 864 (2,137) |
| Golden-winged Warbler | 16 | 125 (310) |
| Massasauga Rattlesnake | 4 | 25 (61) |
| New England Cottontail | 13 | 32 (79) |
| Ruffed Grouse | 2 | 2 (4) |
| *Total* | 182 | 1,048 (2,590) |
| **NORTHERN FOREST INITIATIVE** | | |
| American Woodcock | 1,452 | 23,245 (57,439) |
| New England Cottontail | 39 | 404 (998) |
| Ruffed Grouse | 12 | 34 (83) |
| *Total* | 1,503 | 23,682 (58,519) |
| **APPALACHIAN INITIATIVE** | | |
| American Woodcock | 311 | 7,812 (19,303) |
| Golden-winged Warbler | 102 | 4,556 (11,258) |
| New England Cottontail | 26 | 172 (424) |
| Ruffed Grouse | 25 | 969 (2,394) |
| *Total* | 464 | 13,508 (33,379) |
| **ATLANTIC COAST INITIATIVE** | | |
| American Woodcock | 87 | 666 (1,646) |
| New England Cottontail | 323 | 2,216 (5,477) |
| Ruffed Grouse | 1 | 6 (15) |
| *Total* | 411 | 2,889 (7,138) |
| **OVERALL SUMMARY** | | |
| American Woodcock | 2,125 | 62,260 (153,848) |
| Golden-winged Warbler | 122 | 4,736 (11,703) |
| Massasauga Rattlesnake | 4 | 25 (61) |
| New England Cottontail | 401 | 2,824 (6,978) |
| Ruffed Grouse | 40 | 1,011 (2,498) |
| *Total* | 2,692 | 70,856 (175,088) |

**Table 3.** Summary of outreach activities for the 5 Young Forest Initiatives by primary activity type.

| Outreach type | No. of events | No. attending[a] |
|---|---|---|
| **UPPER GREAT LAKES INITIATIVE** | | |
| Article | 6 | NA |
| Consultation | 132 | NA |
| Field Workshop | 9 | 228 |
| Indoor presentation | 27 | NA |
| *Total* | 174 | 228 |
| **LOWER GREAT LAKES INITIATIVE** | | |
| Article | 6 | NA |
| Consultation | 17 | NA |
| Exhibit | 9 | 148 |
| Field Workshop | 8 | 311 |
| Indoor/Outdoor event | 12 | 230 |
| Indoor presentation | 51 | 627 |
| Mailing | 6 | 464 |
| *Total* | 109 | 1,780 |
| **NORTHERN FOREST INITIATIVE** | | |
| Article | 1 | NA |
| Consultation | 51 | NA |
| Exhibit | 2 | NA |
| Field Workshop | 27 | 455 |
| Indoor/Outdoor event | 5 | 163 |
| Indoor presentation | 53 | 162 |
| *Total* | 139 | 780 |
| **APPALACHIAN INITIATIVE** | | |
| Article | 15 | NA |
| Consultation | 84 | NA |
| Exhibit | 16 | 1,180 |
| Field Workshop | 30 | 678 |
| Indoor/Outdoor event | 4 | 82 |
| Indoor presentation | 95 | 976 |
| Mailing | 6 | NA |
| *Total* | 250 | 2,916 |
| **ATLANTIC COAST INITIATIVE** | | |
| Article | 12 | NA |
| Consultation | 51 | NA |
| Exhibit | 31 | 1,372 |
| Field Workshop | 33 | 589 |
| Indoor/Outdoor event | 8 | 153 |
| Indoor presentation | 78 | 830 |
| Mailing | 33 | 3,624 |
| Radio Interview | 2 | NA |
| TV Interview | 3 | NA |
| *Total* | 251 | 6,568 |
| **OVERALL SUMMARY** | | |
| Article | 40 | NA |
| Consultation | 335 | NA |
| Exhibit | 58 | 2,700 |
| Field Workshop | 107 | 2,261 |
| Indoor/Outdoor event | 29 | 628 |
| Indoor presentation | 304 | 2,596 |
| Mailing | 45 | 4,088 |
| Radio Interview | 2 | NA |
| TV Interview | 3 | NA |
| *Total* | 923 | 12,272 |

[a] The number of people attending was not recorded for all outreach activities. Recorded as NA if not known.

# American Woodcock Status

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**ABSTRACT** Annual assessment of American woodcock (*Scolopax minor*; hereafter, woodcock) populations in North America relies primarily on the American Woodcock Singing-Ground Survey (SGS). Ancillary information concerning harvest and hunting effort comes from the Harvest Information Program (HIP), and indices of recruitment come from Wing Collection Surveys (WCS). We report on long-term trends in SGS, HIP, and WCS data in the Eastern and Central Management Regions in the U.S. Analyses of SGS data indicate there have been significant long-term (1968–2017) declines of 1.05% per year in the Eastern Management Region and -0.56 % per year in the Central Management Region. Discontinuance of some routes and their replacement with new routes may have artificially lessened the long-term negative trends in the SGS. Since 2013, total harvest and number of days hunters spent pursuing woodcock have been below the long-term average (1999–2015) in both management regions. Age ratios (number of immatures per adult female) were temporally variable but exhibited no long-term trend in the Eastern Management Region. In the Central Management Region, age ratios were generally higher during the beginning of the study (1963–1987) period versus the latter part (1988–2016).

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**KEY WORDS:** American woodcock, harvest, population status, *Scolopax minor*, Singing Ground Survey

The American woodcock (*Scolopax minor*; hereafter, woodcock) is a popular game bird throughout eastern North America. The management objective of the U.S. Fish and Wildlife Service (FWS) is to increase populations of woodcock to levels consistent with the demands of consumptive and non-consumptive users (U.S. Fish and Wildlife Service 1990). Reliable annual population estimates, harvest estimates, and information on recruitment and spatial distribution are essential for comprehensive woodcock management; however, this information is difficult and often impractical to obtain. Woodcock are difficult to find and count because of their cryptic coloration, small size, and preference for areas with dense vegetation. The Singing-Ground Survey (SGS) was developed to coincide with the conspicuous courtship display of the male woodcock. Early studies demonstrated that counts of singing males provided reliable indices of woodcock populations and could be used to monitor annual changes (Mendall and Aldous 1943, Goudy 1960, Duke 1966, Whitcomb 1974).

The SGS only supplies an index to population change and does not directly address harvest or the effect of harvest on woodcock populations (Sauer and Bortner 1991). The Wing Collection Survey (WCS) provides annual indices of woodcock recruitment. Wings are collected from hunters each year, the age of each submitted wing is determined at an annual woodcock wingbee, and the resultant age ratios provide the recruitment index. Hunters who hunt woodcock (or any migratory game bird) are required to register for the Harvest Information Program (HIP) and answer a set of questions regarding what species they hunt. From this information the FWS determines which hunters are surveyed to estimate the annual number of woodcock harvested and hunting activity. The HIP was cooperatively developed by the FWS and state wildlife agencies in 1999 to provide reliable annual estimates of hunter activity and harvest for all migratory game birds (Elden et al. 2002). Prior to 1999, the annual FWS migratory bird harvest survey (Mail Questionnaire Survey)

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for all migratory game birds was based solely on hunters who purchased a federal duck stamp. The American Woodcock Harvest Strategy (Woodcock Harvest Strategy Working Group 2010) relies solely on trends derived from the SGS to inform annual harvest management decisions. Although WCS and HIP information are examined, they currently have no role in regulatory decisions.

Here we examine trends in SGS at varying temporal scales to estimate population status, and report estimates of age ratio and harvest statistics from WCS and HIP. However, the SGS data, and their use as a population assessment tool, are subject to a number of potential problems. Chief among these is the ability of the SGS index to accurately depict changes in true abundance (Dwyer et al. 1988, Sauer and Bortner 1991, Case 2010). Both Straw et al. (1994) and Case (2010) recommended addressing assumptions related to the SGS, and improvement of analytical techniques and survey methods. The spatial coverage of the survey may not extend far enough north or south in the breeding range (Moore et al. 2019), and the lack of a survey method that accounts for detection probability has the potential to cause misleading inferences. We address 1 issue regarding representativeness, that of discontinuing some SGS routes and replacing them with new routes, which may be in areas of higher quality for woodcock, thus biasing annual indices. We compare counts of woodcock at discontinued routes with counts from their replacement routes to estimate this potential bias.

## Study Area

Our study area encompassed the majority of woodcock distribution in North America (Fig. 1). The woodcock breeding range extends from southern Canada through the eastern U.S. east of 98°W (McAuley et al. 2013), whereas woodcock generally winter south from Maryland and southern New Jersey in the eastern U.S, and west into central Texas and Oklahoma. Two Management Regions were recognized by the FWS, the Eastern and the Central, and the boundary coincided with the boundary between the Atlantic and Mississippi Flyways (Fig. 1). HIP data were collected from hunters from all states within the range of the woodcock (Seamans and Rau 2017). Wings were also collected from hunters in all states within the range of the woodcock for the WCS, but most came from northern states (Seamans and Rau 2017). The SGS provided information from most of the breeding range but did not cover the very northern portion of the range in Ontario and Quebec, nor the very southern part of the range in the eastern U.S. (Seamans and Rau 2017).

## Methods

### AMERICAN WOODCOCK SINGING-GROUND SURVEY (SGS)

Before 1968, counts of woodcock were conducted on non-randomly-located routes. Beginning in 1968, routes were relocated along lightly-traveled secondary roads in the center of randomly-chosen 10-minute degree blocks within each state and province in the central and northern portions of the woodcock's breeding range (Fig. 1). Therefore, data collected prior to 1968 were not included in this analysis. Routes were surveyed by an observer who drove to each of 10 stops and recorded the number of woodcock heard peenting (the vocalization by the displaying male woodcock on the ground). Acceptable dates for conducting the survey were assigned by latitude to coincide with peaks in courtship behavior of local woodcock. In most states and provinces, the peak of courtship activity (including local woodcock and woodcock still migrating) occurred earlier in the spring than the start of the survey and local reproduction may have already been underway when the survey was conducted. However, it was necessary to conduct the survey during the designated survey dates to minimize counting migrating woodcock twice, i.e., once during migration and once on their breeding grounds. Because adverse weather conditions may have affected courtship behavior and/or the ability of observers to hear woodcock, surveys were not conducted in strong wind, heavy precipitation, or when temperature was <5°C.

The SGS consists of approximately 1,500 routes. Approximately two-thirds of these routes are surveyed each year, whereas approximately one-third are counted as "constant zero" routes for which no woodcock are heard for 2 consecutive years. To avoid expending unnecessary resources and funds, routes with constant zero status are not run for the next 5 years. If woodcock are heard on a constant zero route during its next survey, the route reverts to normal status and is surveyed again each year.

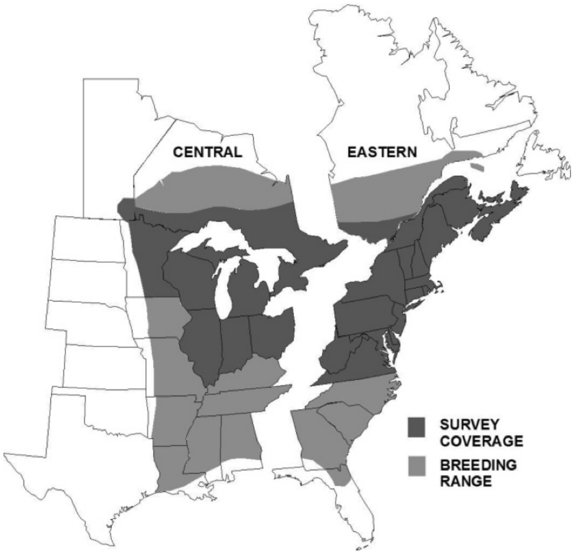

**Figure 1.** American woodcock management regions, breeding range, and Singing-Ground Survey coverage in eastern North America.

Data from constant zero routes are included in the analysis only for the years they were surveyed. Sauer and Bortner (1991) reviewed the implementation and analysis of the SGS in more detail and found estimates of population trend with and without constant zero routes were similar.

Each SGS route was targeted for survey between 22 and 58 minutes after sunset on clear evenings or between 15 and 51 minutes after sunset on overcast evenings. Due to observer error, some stops on some routes were surveyed before or after the peak times of singing activity. Earlier analysis revealed that counts from routes with ≤8 acceptable stops tended to be biased low; therefore, we included only route observations with ≥9 acceptable stops in our analysis. Our analysis was restricted to data received prior to 30 June 2017. We report sample sizes as the number of routes on which trend estimates are based, which includes any route on which woodcock were ever encountered.

We estimated temporal trends using a hierarchical model applied to SGS data collected from 1968 to 2017. Sauer et al. (2008) describe a hierarchical log-linear model for estimation of population change from SGS data. With the hierarchical model, the log of the expected value of the counts is modeled as a linear combination of strata-specific intercepts and year effects, a random effect for each unique combination of route and observer, a start-up effect on the route for first year counts by new observers, and over dispersion. The parameters of interest are treated as random and are assumed to follow distributions that are governed by additional parameters. The hierarchical model is fit using Bayesian methods. Markov-chain Monte Carlo methods are used to iteratively produce sequences of parameter estimates that can be used to describe the distribution of the parameters of interest. After an initial "burn-in" period, means, medians, and credible (or Bayesian confidence) intervals (CI) for the parameters can be estimated from the replicates. Annual indices are defined as exponentiated strata underlying trend, and year effects, which are then weighted by the proportion of routes where ≥1 woodcock was observed between 1968 and 2017. Trends are defined as ratios of the indices at the start and end of the interval of interest, taken to the appropriate power to estimate a yearly change (Sauer et al. 2008). Trend estimates are expressed as percent change per year, whereas indices are expressed as the number of singing males per route. We calculated annual indices for the 2 regions and for each state and province, and short-term (2016–2017), 10-year (2007–2017) and long-term (1968–2017) trends for each region and for each state or province.

Credible Intervals are used to describe uncertainty around estimates when fitting hierarchical models. If the CI does not overlap 0 for a trend estimate, the trend is considered significant. We present the median and 95% CIs of 10,000 estimates (i.e., we simulated 20,000 replicates and thinned by 2), which were calculated after an initial 20,000 iterations to allow the series to converge. Refer to Sauer et al. (2008) and Link and Sauer (2002) for a detailed description of the statistical model and fitting process.

SGS routes can be discontinued and replaced with new routes if: (1) running the route becomes a safety hazard, (2) an increase in noise level permanently alters the accuracy of woodcock counts at ≥2 stops along a route, or (3) a permanent change in road condition precludes further survey. Replacement routes are located within the 10-minute block of the original route and it is recommended that the replacement route be within ~4.8 km (3 miles) of the original start location. We estimated the effect of route replacement on SGS counts by comparing the average of counts during the last 3 years at a discontinued route with the average of counts during the first 3 years at its replacement route. For an individual matched pair (discontinued-replacement), we didn't conduct comparisons if no surveys were done during the last 3 years at the discontinued route or the first 3 years at the replacement route.

### WING COLLECTION SURVEY (WCS)

The primary objective of the WCS is to provide data on the annual reproductive success of woodcock. The survey is administered as a cooperative effort among woodcock hunters, the FWS, and state wildlife agencies. Participants in the survey include hunters who: (1) participated in past surveys, (2) were a subset of hunters that indicated on the HIP Survey that they hunted woodcock, or (3) contacted the FWS to volunteer for the survey. WCS participants were provided with prepaid mailing envelopes and were asked to submit 1 wing from each woodcock they harvested. Hunters were asked to record the date of the hunt and the state and county where the woodcock was shot. Hunters were not asked to submit envelopes for unsuccessful hunts. The age and sex of woodcock were determined by examining plumage characteristics (Martin 1964, Sepik 1994) during an annual woodcock wingbee conducted by state, federal, and private biologists.

We used the ratio of immature birds per adult female in the harvest as an index to recruitment of young into the population. We calculated the annual recruitment index for each state with ≥125 submitted wings as the number of immatures per adult female. We weighted regional indices by the relative contribution of each state to the cumulative number of adult female and immature wings received during 1963–2015. We calculated percent change for all comparisons using unrounded recruitment indices.

### HARVEST INFORMATION PROGRAM (HIP)

The HIP sampling frame consists of all migratory game-bird hunters. Under this program, state wildlife agencies collect the name, address, and additional information from each migratory bird hunter in their state and send that information to the FWS. The FWS then selects random samples of those hunters and asks them to voluntarily provide detailed information about their hunting activity. For example, hunters selected for the woodcock harvest survey were asked to complete a daily diary about their woodcock hunting and harvest activities during the current year's hunting season. Their responses were then used to develop nationwide woodcock harvest estimates. HIP survey estimates of woodcock harvest have been available since 1999. Although estimates from 1999–2002 have been finalized, the estimates from 2003–2016 should be considered preliminary as refinements are still being made in the sampling frame and estimation techniques (Raftovich et al. 2017). We obtained Canadian hunter and harvest estimates through the Canadian National Harvest Survey Program (Gendron and Smith 2016). HIP data are not used to inform annual regulatory decisions. We examined annual HIP estimates of harvest and hunter days afield for general changes over time or between Management Regions. The annual number of hunters or hunter success cannot be obtained due to the occurrence of individual hunters being registered in the HIP in ≥1 state.

## Results

### SINGING GROUND SURVEY

A total of 1,513 SGS routes had ≥1 woodcock detected ≥1 year during 1968–2017 (Table 1). We estimated 10-year (2007–2017) and long-term (1968–2017) trends using data from 787 routes in the Eastern Management Region and 744 routes in the Central Management Region. Short-term analysis indicated that the number of woodcock heard singing during the 2017 SGS declined from 2016 for the Eastern Management Region and remained stationary for the Central Management Region (Table 1). Trends for individual states and provinces are reported in Table 1.

The 10-year trend (2007–2017) showed a significant decline for the Eastern Management Region, whereas there was no significant trend for the Central Management Region (Table 1). Many states and/or provinces in both management regions have experienced significant long-term (1968–2017) declines (Table 1). The long-term trend estimates (1968–2017; Fig. 2) indicated significant population declines in both the Eastern (-1.05%/year, 95% CI= -0.76 to 1.32) and Central (-0.56%/year, 95% CI=-0.33 to -0.79) Management Regions. In the Eastern Management Region, the 2017 index was 2.41 singing males per route, whereas it was 2.92 in the Central Management Region.

Since 1968, 170 and 155 routes have been discontinued in the Eastern and Central Management Regions, respectively. The rate at which routes were discontinued and replaced was distributed relatively even among years from 1968–2017 (range 0–9 per year in the Eastern Management Region, 0–8 in the Central Management Region). Using a 3-year average of males per route in the Eastern Region, 55% of replacement routes had an index greater than the routes they replaced, 15% had a lower index than routes they replaced, and 30% matched the routes they replaced with a mean index value of zero (Fig. 3). In the Central Management Region, 47% of replacement routes had an index greater than the routes they replaced, 19% had an index lower than routes they replaced, and 34% matched the routes they replaced with a mean index value of zero (Fig. 3).

### WING COLLECTION SURVEY

More than 700,000 wings have been received from hunters since 1963 (Table 2). On average, recruitment indices in each Management Region appeared to be higher from 1963–1988 than after 1988 (Fig. 4). The 2016 recruitment index in the U.S. portion of the Eastern Management Region (1.42 immatures per adult female) was 12.3% less than the long-term (1963–2015) regional average, whereas in the Central Management Region, the 2016 recruitment index (1.32 immatures per adult female) was 14.3% less than the long-term regional average.

### HARVEST INFORMATION PROGRAM

In the Eastern Management Region, woodcock hunters spent an estimated 96,100 days afield and harvested 44,400 birds during the 2016–2017 hunting season. Har-

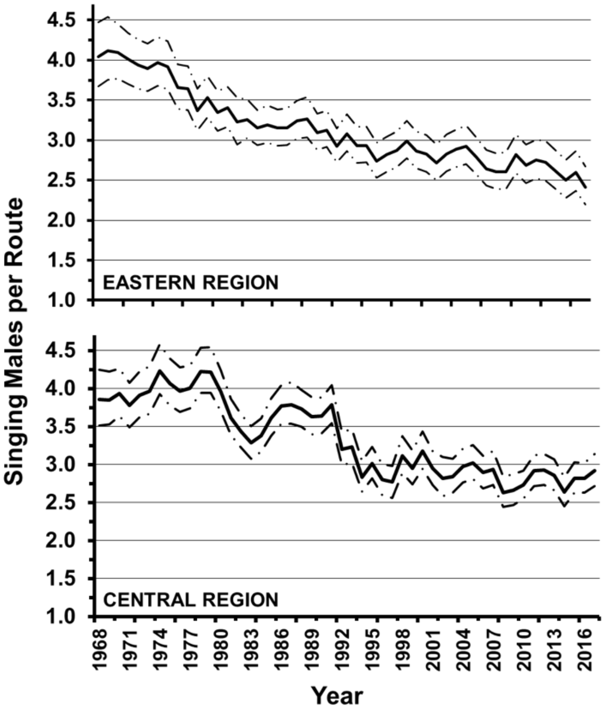

**Figure 2.** Annual indices (singing males per route) of the number of woodcock heard during the Singing-Ground Survey, 1968–2017, as estimated using hierarchical modeling. Dashed lines represent the 95% credible interval of the estimate.

**Table 1.** Short-term (2016–17), 10-year (2007–2017), and long-term (1968–2017) trends (% change per yeara) in the number of American woodcock heard per route during the Singing-Ground Survey as determined by using a hierarchical log-linear modeling technique (Sauer et al. 2008).

| State, province, or region | No. routes[a] | n[b] | 2016–2017 | | | 2007–2017 | | | 1968–2017 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | % change[c] | 95% CI[d] lower | 95% CI[d] upper | % change[c] | 95% CI[d] lower | 95% CI[d] upper | % change[c] | 95% CI[d] lower | 95% CI[d] upper |
| CT | 3 | 11 | -2.47 | -38.61 | 55.51 | -1.68 | -5.57 | 4.51 | -2.49 | -4.29 | -0.61 |
| DE | 1 | 3 | -5.97 | -89.40 | 567.29 | -3.20 | -20.47 | 19.73 | -3.65 | -9.09 | 1.42 |
| ME | 50 | 73 | -16.03 | -31.09 | 1.05 | -1.58 | -3.54 | 0.35 | -1.36 | -1.86 | -0.86 |
| MD | 7 | 26 | -2.78 | -24.68 | 33.85 | -3.73 | -6.37 | -0.45 | -3.78 | -5.15 | -2.31 |
| MA | 9 | 22 | -5.01 | -29.84 | 18.54 | -2.45 | -5.06 | 0.35 | -2.52 | -3.50 | -1.53 |
| NB | 55 | 72 | -21.97 | -36.54 | -3.80 | -2.83 | -4.95 | -0.71 | -1.35 | -2.13 | -0.58 |
| NH | 12 | 18 | -10.34 | -36.71 | 17.90 | -0.35 | -3.37 | 2.86 | -0.77 | -1.79 | 0.21 |
| NJ | 9 | 19 | -7.24 | -48.84 | 64.38 | -6.48 | -12.05 | -0.91 | -6.02 | -7.52 | -4.52 |
| NY | 81 | 115 | 3.34 | -11.30 | 20.76 | 0.89 | -0.78 | 2.80 | -0.55 | -0.98 | -0.10 |
| NS | 43 | 63 | -5.09 | -23.03 | 14.95 | -0.39 | -2.51 | 1.86 | -0.90 | -1.62 | -0.25 |
| PA | 27 | 82 | -2.08 | -23.42 | 24.78 | -0.58 | -2.91 | 2.29 | -1.03 | -1.74 | -0.32 |
| PEI | 9 | 13 | 12.33 | -14.27 | 76.51 | -1.05 | -4.44 | 2.57 | -1.08 | -2.24 | 0.20 |
| QUE | 10 | 111 | -0.92 | -16.07 | 16.41 | -0.48 | -2.10 | 1.34 | -0.59 | -1.34 | 0.15 |
| RI[e] | 0 | 3 | ----- | ----- | ----- | -12.02 | -21.77 | -1.11 | -11.78 | -17.70 | -6.01 |
| VT | 16 | 24 | -10.93 | -37.34 | 21.03 | -1.04 | -4.41 | 2.54 | -0.83 | -1.76 | 0.15 |
| VA | 20 | 75 | 0.65 | -34.37 | 66.74 | -5.53 | -9.90 | -1.16 | -5.51 | -6.58 | -4.45 |
| WV | 25 | 57 | -0.15 | -18.71 | 29.87 | -2.01 | -4.13 | 0.71 | -2.18 | -2.98 | -1.36 |
| **Eastern** | **377** | **787** | **-7.09** | **-13.80** | **-0.11** | **-0.89** | **-1.67** | **-0.08** | **-1.05** | **-1.32** | **-0.76** |
| | | | | | | | | | | | |
| IL | 14 | 47 | 21.11 | -58.21 | 247.13 | -1.63 | -12.38 | 10.33 | -0.89 | -3.51 | 2.07 |
| IN | 11 | 62 | -3.57 | -43.05 | 62.19 | -3.05 | -7.82 | 2.76 | -4.06 | -5.30 | -2.88 |
| MB[f] | 17 | 30 | 22.85 | -7.70 | 71.45 | 2.56 | -0.95 | 6.87 | 0.48 | -1.13 | 2.21 |
| MI | 119 | 155 | 1.30 | -10.50 | 14.37 | 0.30 | -1.02 | 1.72 | -0.70 | -1.06 | -0.34 |
| MN | 74 | 122 | 1.76 | -12.40 | 19.30 | 2.56 | 0.82 | 4.35 | 0.94 | 0.37 | 1.56 |
| OH | 33 | 73 | -9.84 | -32.61 | 13.74 | -0.54 | -2.96 | 2.75 | -1.65 | -2.42 | -0.93 |
| ON | 92 | 163 | 1.60 | -11.85 | 17.90 | -2.12 | -3.88 | -0.42 | -0.85 | -1.29 | -0.39 |
| WI | 77 | 122 | 15.70 | -1.60 | 36.56 | 0.37 | -1.47 | 2.26 | -0.01 | -0.49 | 0.50 |
| **Central** | **437** | **744** | **3.64** | **-3.50** | **11.37** | **-0.05** | **-0.88** | **0.79** | **-0.56** | **-0.79** | **-0.33** |
| **Continent** | **814** | **1,531** | **-1.53** | **-6.46** | **3.64** | **-0.44** | **-1.01** | **0.14** | **-0.80** | **-0.98** | **-0.61** |

[a] Total number of routes surveyed in 2017, for which data were received by 30 June 2017.

[b] Number of routes with ≥1 year of non-zero data between 1968 and 2017.

[c] Median of route trends estimated used hierarchical modeling. To estimate the total percent change over several years, use: (100((% change/100)+1)y)-100, where y is the number of years. Note: extrapolating the estimated trend statistic (% change per year) over time (e.g., 30 years) may exaggerate the total change over the period.

[d] 95% credible interval; if the interval overlaps zero, the trend is considered non-significant.

[e] Insufficient data to calculate trend.

[f] Manitoba began participating in the Singing-Ground Survey in 1992.

vest in 2016–2017 was 45.9% less than the long-term (1999–2015) average (82,047 birds/year) and 18.5% less than the 2015–2016 season (54,500 birds; Fig. 5). Woodcock hunters in the Central Management Region spent an estimated 300,200 days afield and harvested 158,000 birds during the 2016–2017 hunting season. Harvest in 2016–2017 was 26.0% less than the long-term (1999–2015; Fig. 5) average (213,400 birds/year) and 8.4% more than the 2015–2016 season (145,700 birds).

Data from Canada show a long-term decline in both the number of successful woodcock hunters and harvest (Fig. 7; Roy et al., this volume). The most recent data available indicate that an estimated 3,862 successful hunters harvested 25,173 woodcock during the 2016 season in Canada (Gendron and Smith 2017). From 2006–2016, the average annual harvest in the U.S. and Canada combined was approximately 287,000.

## Discussion

One of the main objectives of the American Woodcock Conservation Plan (Kelley et al. 2008) was to halt population declines by 2012 as measured by the SGS. To meet this objective, the Conservation Plan recommended managing for early succession forest cover in clustered large patches (100s of ha). Halting the population decline has yet to occur in either management region, but it appears closest to being achieved in the Central Management Region. The

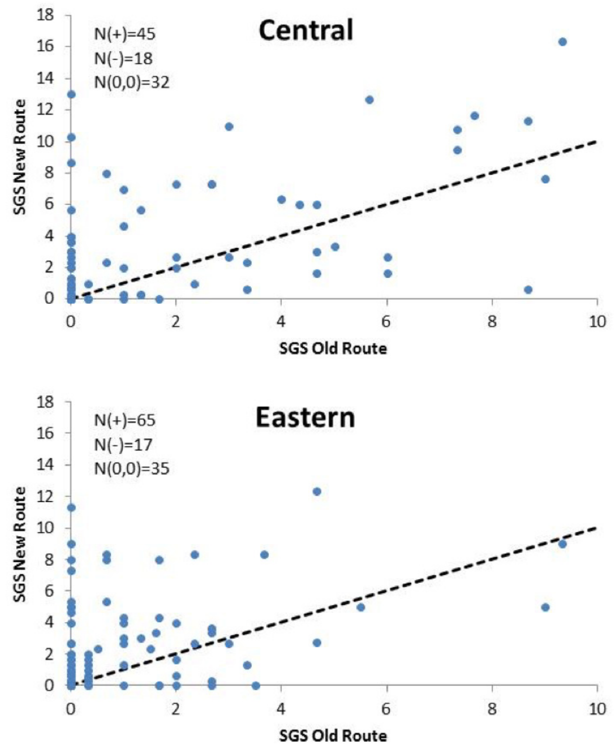

**Figure 3.** Comparison of discontinued Singing-Ground Survey (SGS) routes with their replacement routes in the Eastern (A) and Central Management Regions (B). Values based on 3-year average of total woodcock heard during the SGS prior to discontinuance (old route) or after replacement (new route). The dashed line indicates where SGS values for paired old and new routes are the same. In 90 cases of route replacement in the Eastern Management Region, SGS values were: greater at 51 new routes, greater at 23 old routes, and zero at 16 old and new routes. In 84 cases of route replacement in the Central Management Region SGS values were: greater at 36 new routes, greater at 18 old routes, and zero at 30 old and new routes.

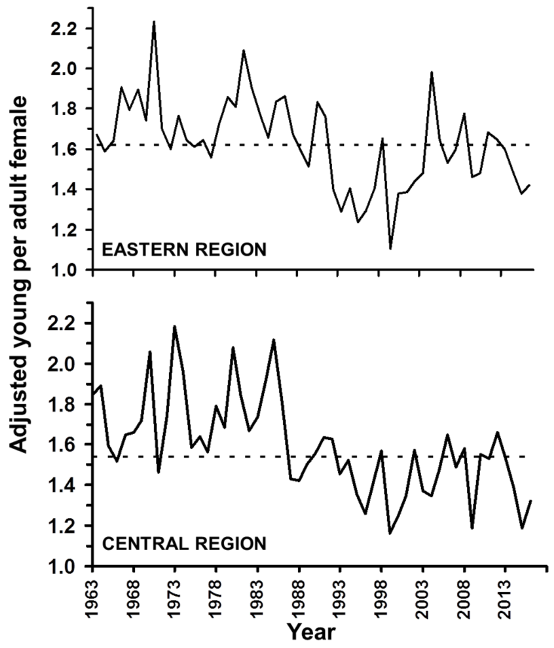

**Figure 4.** Annual indices of American woodcock recruitment (U.S. only) based on age ratios from wing collection surveys conducted in the United States, 1963–2016. The dashed line is the 1963–2015 average.

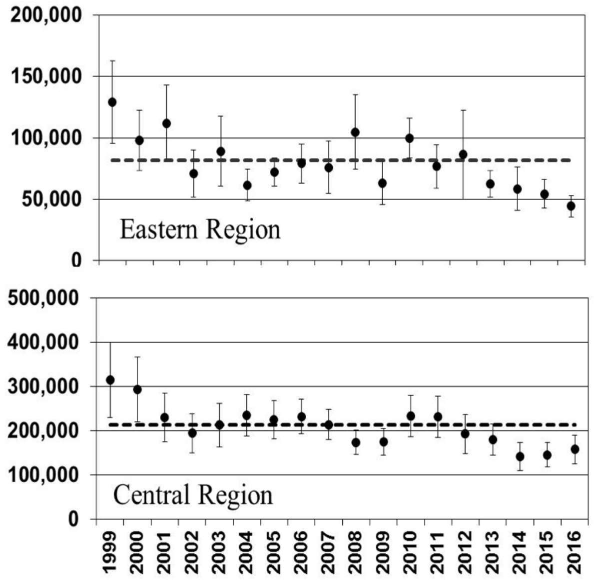

**Figure 5.** Harvest Information Program Survey estimates of American woodcock harvest in the United States from 1999–2016. The dashed line represents the 1999–2015 average and the error bars represent the 95% confidence interval of the point estimate.

SGS index long-term trend clearly indicates a significant decline in singing males during the survey period for both management regions, with the magnitude of the decline being much greater in the Eastern Management Region. We also estimated significant negative trends over the most recent 10-year period in the Eastern but not the Central Management Region, suggesting that the Central Management Region is making progress in meeting the objectives of the Conservation Plan.

Days afield hunting woodcock and total harvest were variable annually but with no clear temporal pattern in each management region from 2002–2013; subsequent to 2013, both measures exhibited a decline in both management regions. The cause of these declines is unknown but could be related to availability of woodcock (as suggested by negative trend in SGS), decrease in access to hunting areas by hunters, fewer people interested in hunting woodcock, or something else.

The magnitude of harvest relative to the woodcock population size cannot be estimated using SGS results; rather, an estimate of absolute population size is needed. Very few estimates of population size exist for American woodcock. Andres et al. (2012) placed the population size at 3–4 million birds in 2006, which would suggest an annual harvest rate of ~7–10% during that year. Harvest estimates from the early and mid-1980s peaked at about 800,000 to 900,000 birds per year (Straw et al. 1994). Using SGS results to account for the decline in the 2 populations, and assuming there were 3–4 million birds in 2006, suggests annual harvest rates in the 1980s were 15–20%. Using a population reconstruction approach (Broms et al. 2010), West (2016) placed the population size between 5.2 and 6.1 million from 1999–2007, and estimated 2013 harvest rates of 0.148 (SE = 0.017) for adult female woodcock and 0.082 (SE = 0.008) for other age-sex groups. Using West's (2016) estimate of abundance for 2006 and the estimated trends in SGS to back-calculate abundance produces estimates of annual harvest rates in the range of 11–15% during the 1980s.

Since 2012, annual harvest has been low relative to long-term averages in both the Eastern and Central Management Regions, and estimated harvest in 2017 in the Eastern Management Region was the lowest since HIP was initiated in 1999 (Seamans and Rau 2017). This may indicate that harvest rate has declined, or that harvest

**Table 2.** Number of American woodcock wings received from hunters, and indices of recruitment in the United States, 1963–2016. Recruitment indices for individual states with ≥125 submitted wings were calculated as the ratio of immatures per adult female.

| State or region of harvest | Wings received |  |  | Recruitment index |
|---|---|---|---|---|
|  | Total | Adult females | Immatures |  |
| **EASTERN MANAGEMENT REGION** |  |  |  |  |
| CT | 15,462 | 3,464 | 9,411 | 2.7 |
| DE | 527 | 83 | 360 | 4.3 |
| FL | 678 | 153 | 422 | 2.8 |
| GA | 3,357 | 1,055 | 1,425 | 1.4 |
| ME | 90,514 | 26,774 | 45,168 | 1.7 |
| MD | 5,004 | 1,221 | 2,840 | 2.3 |
| MA | 25,613 | 8,011 | 12,370 | 1.5 |
| NH | 38,079 | 12,394 | 17,626 | 1.4 |
| NJ | 27,571 | 6,374 | 16,293 | 2.6 |
| NY | 65,391 | 22,149 | 29,509 | 1.3 |
| NC | 4,457 | 1,421 | 2,121 | 1.5 |
| PA | 34,120 | 10,832 | 15,714 | 1.5 |
| RI | 2,477 | 479 | 1,639 | 3.4 |
| SC | 3,995 | 1,276 | 1,801 | 1.4 |
| VT | 29,435 | 9,679 | 13,389 | 1.4 |
| VA | 6,277 | 1,654 | 3,379 | 2.0 |
| WV | 6,572 | 1,988 | 3,286 | 1.7 |
| **Region Total** | **359,529** | **109,007** | **176,753** | **1.62** |
| **CENTRAL MANAGEMENT REGION** |  |  |  |  |
| AL | 1,014 | 282 | 462 | 1.6 |
| AR | 563 | 184 | 232 | 1.3 |
| IL | 1,516 | 355 | 854 | 2.4 |
| IN | 8,814 | 2,271 | 4,906 | 2.2 |
| IA | 1,405 | 455 | 622 | 1.4 |
| KS | 50 | 9 | 26 | ---- |
| KY | 1,224 | 336 | 632 | 2.0 |
| LA | 34,064 | 7,654 | 21,994 | 2.9 |
| MI | 147,952 | 48,609 | 71,833 | 1.5 |
| MN | 46,411 | 16,536 | 19,923 | 1.2 |
| MS | 2,016 | 573 | 1,012 | 1.8 |
| MO | 4,672 | 1,307 | 2,286 | 1.8 |
| NE | 13 | 5 | 6 | ---- |
| ND | 4 | 3 | 1 | ---- |
| OH | 15,535 | 4,800 | 7,266 | 1.5 |
| OK | 174 | 38 | 92 | 2.4 |
| TN | 1,367 | 370 | 700 | 1.9 |
| TX | 1,071 | 304 | 533 | 1.8 |
| WI | 98,174 | 33,416 | 45,945 | 1.4 |
| **Region Total** | **366,039** | **117,507** | **179,325** | **1.53** |

rate has remained steady while the population has declined. How large an effect harvest might have on the woodcock population is unclear. In general, it is thought that habitat conditions and not harvest caused the long-term decline in the woodcock population (Kelley et al. 2008, McAuley et al. 2005). McAuley et al. (2005) estimated that woodcock fall survival rates were similar between hunted and non-hunted areas. However, Bruggink et al. (2013) estimated that fall survival rates in the western Great Lakes region were significantly lower in hunted areas versus lightly hunted or non-hunted areas. Undoubtedly hunting pressure varies across the range of woodcock, and the effect of hunting on woodcock populations varies at different spatiotemporal scales (e.g., woodcock survival opening week in a small woodlot on publically accessible land versus annually within the western Great Lakes region). The data we present is valid for inference only at large spatial and temporal scales. The continuous decline of woodcock for the past 50 years, especially in the Eastern Management Region, warrants concern about the effect of hunting. However, since HIP was created, annual harvest has varied little and appears uncorrelated with this decline.

SGS routes that were discontinued during the survey period appear to have been replaced by routes that had more woodcock. It may be that woodcock density was similar between old and new routes, but detection probability was greater on the new routes versus the old due to roadside noise, as noise was a principle cause of route discontinuation. If the increase in SGS indices was not the result of increased detection probability but rather of better woodcock habitat and thus more woodcock, this would also have introduced bias into the SGS trend estimates, and estimated trends in SGS should indicate steeper declines than they do. On average, SGS indices at new routes increased by 1.1 and 1.2 singing male woodcock over old routes in the Eastern and Central Management Regions, respectively. Assuming routes were replaced uniformly among years, this suggested a small (~4%) positive bias in annual SGS estimates.

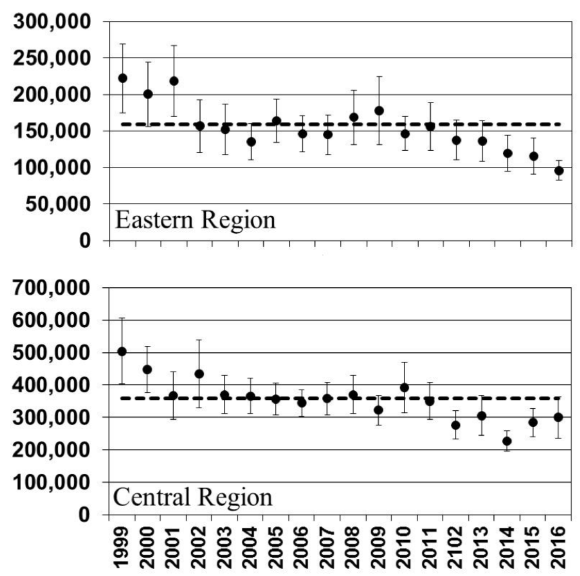

**Figure 6.** Harvest Information Program Survey estimates of days spent afield by American woodcock hunters in the United States form 1999–2016. The dashed line represents the 1999–2015 average and error bars represent the 95% confidence interval of the point estimate

## Management Implications

Loss of suitable habitat is generally credited as the cause of woodcock population decline (Straw et al. 1994, Kelley et al. 2008). Although the American Woodcock Conservation Plan (Kelley et al. 2008) suggested this loss is most problematic during the breeding season, this has not been tested in comparison to importance of non-breeding (e.g., migration, wintering) habitat. Our results indicate that the woodcock population in the Eastern Management Region appeared to be in a more severe decline than in the Central Management Region. In addition, even with decreasing annual harvest in the Eastern Management Region, the continued population decline indicates that improved habitat management is critically needed. Thus, we recommend that the priority for research is examining how habitat on the breeding, migratory, and wintering grounds affects woodcock in the Eastern Management Region. It is also clear that a better estimate of woodcock population size and the demographic response to harvest are needed to improve harvest management because of uncertainty in the SGS results and what they represent relative to population size and magnitude of harvest.

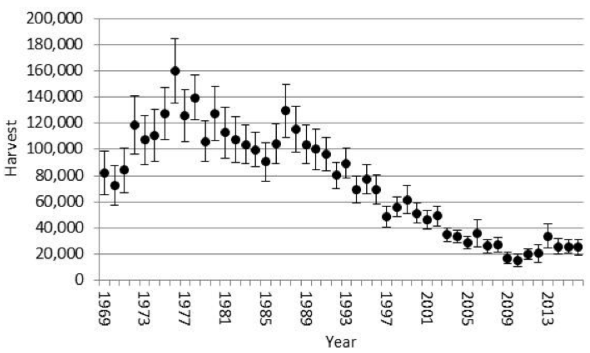

**Figure 7.** Estimated American woodcock harvest in Canada and associated 95% confidence intervals, 1969–2016.

## Acknowledgments

Personnel from the FWS, Canadian Wildlife Service, U. S. Geological Survey (USGS), U.S. Forest Service, Bird Studies Canada, and many state and provincial agencies and other individuals assisted with collecting SGS data and processing wings at the woodcock wingbee. We especially thank all who helped coordinate the SGS, the observers who conducted SGS routes, and the woodcock hunters who sent in wings for the survey. The Branch of Monitoring and Data Management within the Division of Migratory Bird Management (FWS) mailed WCS materials, organized wing submissions, assisted with data management, and provided HIP estimates (special thanks to T. Bethea, T. Ceaser II, S. Chandler, S. Finucane, K. Fleming, P. Garrettson, L. Heckstall, N. Hengst, P. Mathias, P. Padding, R. Raftovich and K. Wilkins). T. Nguyen (FWS) assisted in general maintenance for the SGS data entry website and wingbee application. R. J. Sauer (USGS) developed computer programs for calculating trends and indices from SGS data and conducted this year's analyses for the survey. We thank E. J. Blomberg and two anonymous reviewers for helpful comments.

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# Wooden Spoons for Woodcock

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**ABSTRACT:** The American woodcock (*Scolopax minor*; hereafter, woodcock) is an important game species in central and eastern North America. In this paper, we argue that the wildlife community should consider several novel ideas. At the landscape level, one of the most effective ways to perpetuate aspen (*Populus* spp.) forests is through commercial forest management. Aspen underpins the major forest products industries: its fiber is highly sought after for pulp, paper, oriented strand board and other engineered lumber products, and lumber. The most cost-effective and reliable way to maintain woodcock habitat is through commercial forest management and through periodic timber harvests. Non-commercial habitat management is possible but expensive and time-consuming. Support for forest products industry business attraction and development is good for woodcock habitat, good for local communities, and good for local economies. We recommend that the wildlife community consider greater involvement in the broader social discussion over the use of wood products, and be actively engaged in discussions involving economic development and energy use by the forest products industry at the state and local level.

***Proceedings of the American Woodcock Symposium 11: 18–20***

**KEY WORDS:** American woodcock, aspen wood products, economic contribution, forest industry

The American woodcock (*Scolopax minor*; hereafter, woodcock) is an important species in the Great Lakes states—important economically, as a recreational species, and as an ecological indicator of the status of our forest resources. Moreover, we all know the trend: over the last 50 years, the woodcock population has been decreasing in Michigan (Fig.1). This decline in the breeding population has been associated with reduction or loss of early successional aspen (*Populus* spp.) forests, which provide critical habitat for woodcock. Aspen is a short-lived forest type, chiefly regenerated through intensive commercial forest management—timber harvests. In this paper we argue that, at the landscape level, the most effective and reliable way to maintain woodcock habitat is through commercial forest management and through periodic timber harvests. Demand drives markets, and in turn, markets drive habitat! So how do we improve habitat for woodcock on a large scale? Support the forest-products industry!

## Quality habitat depends on active forest management!

Fifty-four percent (over 8 million hectares, or 20.3 million acres) of Michigan is forested (Pugh et al. 2014). The State of Michigan administers 21% of the forestland in Michigan, while private landowners own about 60%. Forests in Michigan have been managed not only for timber production but also for various ecosystem services such as wildlife habitat, watershed protection, biodiversity conservation, and forest-based recreation activities (Pugh et al. 2014). These forests continue to play an important role in supporting local and state economies, generating employment and income.

Aspen forests provide excellent habitat and recreational opportunities across the Great Lakes region. Young aspen forests support woodcock populations, with over 4 million hectares (10 million acres) of aspen forest in the Lake States region and almost 1 million hectares (2.4 million acres) in Michigan. Over 94,000 woodcock were estimated to have been harvested by hunters in Michigan in 2011, who spent

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more than 200,000 hunter-days afield (Frawley 2014). This by itself is a significant economic contribution. Forest-based outdoor recreation activities, including hunting and birdwatching, provide significant support to local economies (Poudel et al. 2017). In 2011, about 529,000 people in Michigan participated in hunting activities, spending $2.3 billion on equipment and trip-related expenses (USFWS 2012).

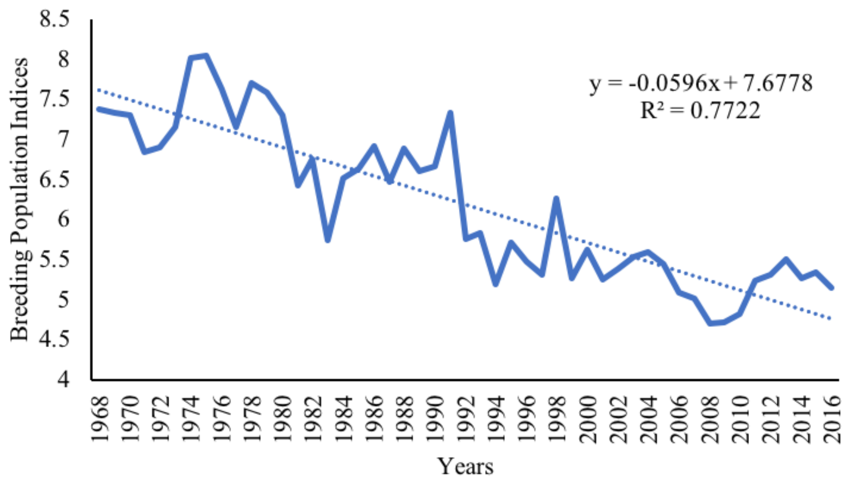

**Figure 1.** Annual trend of woodcock breeding population indices in Michigan (Data source: Seamans and Rau 2016).

Aspen forests also underpin the forest products industries and associated industry employment in the Great Lakes region. Aspen is the preferred species for manufacturing several key wood products—pulp and paper, oriented strand board (OSB), particleboard, lumber, and pallets—along with associated manufacturing byproducts that are sold as animal bedding and shavings or as additional raw material for manufacturing paper. Forest-products industries contributed over $21 billion to Michigan's economy in 2015 and supported over 99,000 jobs (Leefers 2017). Michigan has 3 pulp and paper mills that depend on aspen, 3 OSB plants, a hardboard or High Density Fiberboard (HDF) plant, and >100 sawmills that use aspen for making lumber, pallets, shavings, animal bedding, and other biomass products.

What is the market outlook for industries that use aspen? For aspen forest products? In general, good. Some end products have a better long-term market forecast than others:

- Paper: mixed market outlook
    - Writing paper and newsprint have a declining market forecast; global demand is expected to decline at a rate of 4–6% per year.
    - Packaging paper and paperboard, in contrast, are expected to have very good market demand, growing at a rate of about 4–6% per year.
- Composite board products (OSB, particleboard, and grade and industrial lumber products): demand for these products is expected to grow at a rate of 6–8% per year.

Aspen forest that serve as high-quality wildlife habitat is the result of active management. Aspen is a short-lived species that matures in 40–60 years and is chiefly reproduced by coppice root sprouts after clearcut harvesting. How can we increase active management of aspen forest resources? Support the expansion of industries that use it! Take, for example, a theoretical, cutting-edge composite-board plant (OSB or particleboard). A new, average-sized OSB plant constructed today would likely use about 300,000 standard cords of wood per year, and of that about 200,000 cords would likely be aspen, resulting in renewal of about 2,900 to 4,000 hectares (7,000 to 10,000 acres) of aspen forest per year.

### Commercial timber harvests would allow for more affordable, sustainable, and regular habitat maintenance

Commercial aspen harvests feed the mill and promote development of a balanced age-class distribution over time and space that, in turn, provides attractive habitat for woodcock across the landscape. By comparison, non-commercial habitat management is expensive and labor intensive. To create 2,900 to 4,000 hectares (7,000 to 10,000 acres) of renewed aspen forest per year using non-commercial treatments could cost about $150 per 0.4 hectare (1 acre), or about $1.5 million per year. Mechanical treatment options are slow and expensive:

- Hydroaxing: 8 hectares (20 acres) per day
- Anchor chain and roller chopping: 4 hectares (10 acres) per day
- Shearing with bulldozers: 4 hectares (10 acres) per day

Due to the cost, stand rotation could likely be lengthened to 70–80 years, resulting in older, less vigorous stands and poorer, lower density regeneration after harvest. In reality, you would not do it. You would wait until you had a market for the timber.

Another novel idea for increasing area of woodcock habitat: consider dialing back rotation age. Michigan's aspen resource is typically harvested on a 40–70-year rotation cycle (60 years on average; Fig. 2). Yet aspen generally provides high quality habitat for woodcock in the 10–40-year age classes. What if you dialed back average rotation age?

- Move 60-year rotation to a 50-year rotation = 12% more high quality habitat
- Move 60-year rotation to a 40-year rotation = 30% more high quality habitat

Supporting expansion and maintenance of Michigan's forest products industry is good for woodcock habitat, good for human habitat, and good for local jobs! Good for local rural development! Take, for example, the theoretical new OSB plant. An average plant could provide 200–300 direct jobs, support an additional 600 jobs through indirect and induced employment effects, and provide $22 million in labor income. Often these plants are located in rural communities, and provide steady, good-paying wages. Another example: Michigan was recently successful in attracting an international leader in forest-products manufacturing, Arauco, to build a state-of-the-art particleboard plant in Grayling. The company will make a >$4 billion investment in the plant and employ 200 workers in full-time, permanent jobs. Think about the support that the new plant and 200 new full-time jobs will provide to the local economy, and local schools, in a community where 50% of the students are eligible for free or reduced-price lunches.

Another way to look at this issue: How are you as a community of wildlife professionals aligned with your Governor's priorities? With your state's vision? What were Governor Snyder's priorities in year one, year four, and year eight? Jobs, Jobs and Jobs! So how can you as employees and leaders of your respective agencies become more engaged with the forest products industry? Start by building a relationship with your state economic development corporation so they are keyed in on the wildlife habitat/jobs/rural economy linkage. Give them the breakdown on assets, locations, and opportunities so they can lobby wood-products corporations to locate in your state, particularly those industries that use significant quantities of aspen. Become engaged in forest-products business attraction and developmentas a community of wildlife professionals, lend support in the media and during the attraction process. Let prospective companies know that the wildlife community is interested and supportive.

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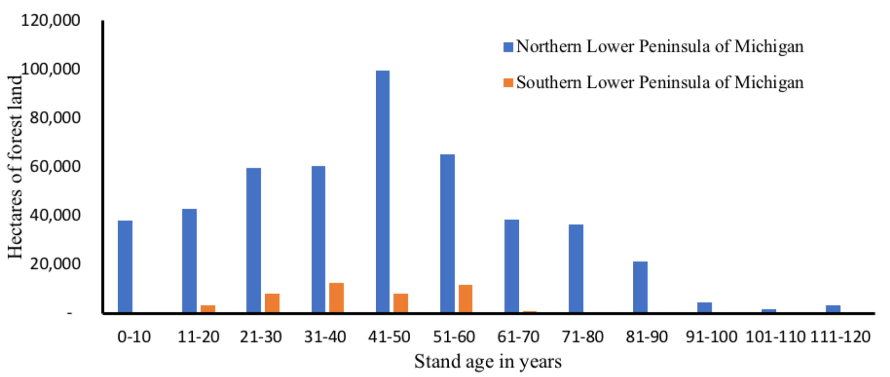

**Figure 2.** Aspen forest cover in Northern Lower Peninsula of Michigan and Southern Lower Peninsula of Michigan by stand age (based on recent Forest Inventory and Analysis (FIA) inventory cycle 2011–2016; Data source: USDA Forest Service FIA EVALIDator Version 1.6.0.03a).

# *The Future of Woodcock*

**RUSS MASON,** Michigan Department of Natural Resources Wildlife Division Chief

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American Woodcock Society

**ABSTRACT:** We welcome you to Roscommon, Michigan for this 2017 symposium. What a prime location to host a meeting of this caliber and to expand partnerships for this unique bird. It is crucial that we work together to conduct research and exchange information at meetings like this. Many people helped to make this symposium a reality and we thank all the committee members for their contributions. We especially thank symposium chairs for their diligence and leadership. Since the last symposium, in 2006, there has been considerable work in woodcock research, management, and conservation. Collectively, these efforts have helped to arrest the decade-long downward trend in woodcock populations. We continue to be optimistic about the outlook for woodcock. We believe that substantive long-range strategic planning and expanded partnerships will be key to improving the status of American woodcock in the future.

## Russ Mason

In Michigan, there is strong interest in woodcock management. In this state, approximately 24,000–35,000 hunters harvest 64,000–100,000 birds each fall and spend over 107,000 days afield. This is down from the 1976 record harvest of 390,000 woodcock harvested by 126,000 hunters spending 908,000 days afield. Federal surveys continue to show that Michigan is still the number one state in the country for American woodcock harvest and one of the top production states. Nationally, nearly 400,000 days afield are spent pursuing woodcock, and the harvest exceeds 202,000 birds.

Despite the strong interest in woodcock conservation and woodcock hunting in Michigan, there are troubling trends in hunting participation and conservation funding both here and across the country that present significant challenges. Canadian wildlife biologist and noted conservationist Shane Mahoney makes three points about the decline of hunting and the problem this poses for the North American Model of Wildlife Conservation: 1) there are too few of us who care, 2) those who do care are too sectarian, and 3) we are running out of money to fund the work.

In Michigan, we have lost 50% of our small game hunters in the past 12 years. Over that time the number of deer (*Odocoileus* spp.) hunters has declined 2–3% per year, and they are very sectarian—Michigan deer hunters hunt about 4 days per year, harvest 2.2 deer per year, and have *little to no interest* in any other hunting. This is a problem as they become the primary hunting demographic in the state. In a survey of Michigan residents, 80% say they enjoy the outdoors, but when asked to identify their primary outdoor activity, 90% say they walk their dog. How do you leverage that response into wildlife work? The challenge for funding wildlife conservation is to find new and creative ways to broaden the financial base of active support.

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The reach of American woodcock management exceeds helping this unique upland bird that uses thick young forests. Creating young forest for woodcock directly benefits more than 60 kinds of wildlife considered to be Species of Greatest Conservation Need by states within the woodcock range.

The North American Woodcock Conservation Plan, written to help guide woodcock management in each region of the continent, has provided focus for future management. As we move forward with the plan, it will be important to integrate the relationship between harvest and habitat management. It will be also be critical to develop the metrics needed to understand and manage woodcock populations by working through the Association of Fish and Wildlife Agencies' (AFWA) Migratory Shore and Upland Game Bird Support Task Force and the separate AFWA Woodcock Task Force in association with joint-venture partnerships. The *Priority Information Needs for American Woodcock, A Funding Strategy* document has also been useful in directing our future focus for woodcock conservation.

It is crucial that we work together to conduct research and exchange information at meetings like this. Since the last symposium, in 2006, there has been considerable work in woodcock research, management, and conservation. Collectively, these efforts have helped to arrest the decade-long downward trend in woodcock populations. We continue to be optimistic about the outlook for woodcock. We believe that substantive long-range strategic planning and expanded partnerships will be key to improving the status of American woodcock in the future.

### John Eichinger

In 2015, the Ruffed Grouse Society (RGS) announced the formation of a sister organization called the American Woodcock Society. The purpose of this new forest conservation organization is to enhance and increase young forest conservation efforts and upland hunting opportunities nationwide, with a special emphasis on American woodcock (*Scolopax minor*; hereafter, woodcock). However, our commitment to the conservation of woodcock began with the formation of the Ruffed Grouse Society back in 1961. The RGS Bylaws and the RGS Mission Statement have long recognized the connection between ruffed grouse (*Bonasa umbellus*), American woodcock, and other wildlife that require young forests for survival.

Today, at the American Woodcock Society and Ruffed Grouse Society, we are optimistic about the future of woodcock conservation. Our optimism is based on 3 major factors: *the bird's inherent adaptability*, a *strong foundation of research*—exemplified by these Woodcock Symposia—from which to go forward, and an upward trend in *recognition of the importance of young forests* and in the resolve to manage for young forests as part of a balanced forest landscape.

*First, the bird.* Woodcock respond positively and quickly to habitat management—you build it, and they will come. As a migratory species that requires disturbance to create its habitat, woodcock are able to find and inhabit new suitable habitat patches as they become suitable. Despite stochastic events such as late spring snowstorms or summer drought that may cause short-term population declines, they always seem to bounce back within a few years, given availability of good habitat. And fortunately, when they occupy an area, we have a pretty good ability to detect them and monitor their populations.

The *solid foundation of research dates* back to the 1930s with the establishment of Moosehorn National Wildlife Refuge in Maine and with Howard Mendall's work there and elsewhere in the state, early capture and banding work in Pennsylvania and Louisiana, and continued research efforts to the present day elsewhere across the major breeding and wintering ranges. These essential works, many of which have been presented at the Woodcock Workshops and Symposia since 1966, have informed us on the natural history of woodcock, the management necessary to provide high quality habitat, the survival and movements of woodcock in relation to hunting, and, more recently—and currently—migration ecology and the identification of potentially important stopover areas along migratory flight paths.

It is evident there is an expanding *awareness of the importance of young forest* in wildlife conservation and *appreciation of the woodcock among upland bird hunters* and the non-hunting public. The positive trend in appreciation of the importance of young forests for woodcock and many other species of wildlife is evidenced by the numerous state and regional young forest initiatives that have formed for the purpose of conserving the many young-forest-dependent species considered SGCN—species of greatest conservation need—in state conservation plans.

The genesis for these young forest initiatives is the American Woodcock Conservation Plan, a collaborative effort of many of you here today, headed up by the Wildlife Management Institute. Next, the Northern Forest Woodcock Initiative was developed to begin implementing the Woodcock Plan objectives. The Woodcock Initiative morphed into the Young Forest Project, and "young forest initiatives" were developed by conservation partners in several bird conservation regions, including the Northern Young Forest Initiative and the Upper Great Lakes Young Forest Initiative, to name but 2, and by state-specific initiatives, for example in Wisconsin and New York. This is truly collaborative conservation that benefits a multitude of species. Clearly, the early stages of forest growth are very important to the overall health of the forest landscape, and this connection to forest health needs to be a key part of our messaging to gain support from the general public for forest management.

*Just as rust never sleeps,* young forests continue to grow and mature and become less suitable as habitat for early successional forest species such as American woodcock. Woodcock habitat is short-lived, losing suitability within perhaps 15 years of the treatment or disturbance that created the forest opening. Additionally, the forest environment is not a steady state; we experience loss or major reductions in tree species such as American elm (Ulmus americana), and more recently ash (Fraxinus spp.), or the confounding effects of introduced invasive species. Variation in precipitation certainly affects availability of prey of woodcock. And land-use, such as forestry, agriculture, and residential or industrial development, changes based on societal demands. As woodcock habitat requires periodic treatment, so our mission will always continue, working with many municipal, state, university, federal, industrial forest, NGO, and private individual conservation partners.


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## CHAPTER TWO

# Population Assessment

# A Bayesian Hierarchical Model for Estimating American Woodcock Harvest

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**ABSTRACT** Estimates of total harvest help inform harvest management decisions, but such data are also useful for estimating population size and composition in demographic models. Historical estimates for U.S. harvest of American woodcock (*Scolopax minor*; hereafter woodcock) are available from 2 separate surveys: the 1964–2001 duck stamp survey (DSS) that sampled woodcock hunters who also hunted waterfowl, and the 1999–2016 Harvest Information Program (HIP) that sampled all licensed woodcock hunters. During overlap years (1999–2001), HIP estimates of total woodcock harvest were approximately twice as large as DSS estimates, but with only 3 years of overlap there was little potential to develop robust correction factors for historical DSS data. I developed a model of historical woodcock harvest that posited 3 groups of woodcock hunters, including those who always, sometimes, or never hunted waterfowl. During the HIP survey all 3 groups were included in harvest surveys; during the DSS years, however, only woodcock hunters who always hunted waterfowl were reliably sampled during all years, but I used annual duck stamp sales as a covariate to help predict harvest by woodcock hunters who hunted waterfowl irregularly. Using a reverse-time (2016 to 1964) model that assumed these 3 proportions of harvest remained constant through time, I was able to estimate total harvest in all years by estimating the latent component of harvest by non-waterfowl hunters. Averaged over all harvest jurisdictions, this model estimated that hunters who always, sometimes, or never hunted waterfowl contributed 43%, 32%, and 25% of the total woodcock harvest. Using these relationships, I estimated total harvest during all years (1964–2016) using data from both harvest surveys, although estimates based only on DSS data had greater uncertainty. In combination with band recovery data and harvest composition from the Parts Collection Survey, analysts could use estimates of historical harvest to estimate population size, composition, fecundity, and survival dating back to the initiation of harvest surveys in 1964.

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**KEY WORDS:** American woodcock, band recovery, harvest surveys, integrated population models

Reliable estimates of total harvest are necessary for harvest management, but are also important for demographers because they can be combined with band recovery data to estimate fecundity, population size, and age-sex composition at time of banding (Zimmerman et al. 2010, Alisauskas et al. 2014, Hagen et al. 2018). For species such as American woodcock (*Scolopax minor*; hereafter woodcock), which are largely monitored through surveys of displaying males and for which polygynous mating systems may give a distorted view of effective population size of breeding females (Ziel et al. 2010), determining population composition is an important additional component of monitoring programs (Hagen et al. 2018).

From 1964–2001, the U.S. Fish and Wildlife Service (USFWS) estimated woodcock harvest in the United States using a survey of waterfowl hunters who had purchased a federal Migratory Bird Hunting and Conservation Stamp (Padding et al. 2010; hereafter "duck stamp survey" or DSS). But because woodcock hunters are not necessarily waterfowl hunters, the sampling frame for the federal DSS was incomplete with respect to woodcock harvest. More importantly, proportional coverage of active woodcock hunters by the DSS likely varied through time because more duck stamps were sold during years when waterfowl populations were high (Vrtiska et al. 2013), and the proportions of woodcock hunters who were inciden-

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tally captured by the sampling frame for waterfowl hunters likely varied on an annual basis. Moreover, these temporal relationships likely varied among states due to different opportunities and traditions for hunting waterfowl and woodcock over time.

In 1999, harvest surveys for waterfowl, woodcock, and other webless migratory game birds were modified to include samples of all licensed migratory bird hunters within each state (Padding et al. 2010). The joint federal-state Harvest Information Program (HIP) was specifically designed to identify an appropriate sampling frame for woodcock hunters and other groups of migratory gamebirds (Raftovich et al. 2015). Both surveys were conducted concurrently during 1999–2001, and estimates of woodcock harvest under the HIP survey averaged 1.6-fold higher in the Eastern Management Region and 2.1-fold higher in the Central Management Region (Padding et al. 2010); these increases were undoubtedly attributable to inclusion in HIP of woodcock hunters who rarely or never hunted waterfowl.

My objective in this paper was to develop a Bayesian hierarchical model to estimate total harvest of American woodcock from 1964–2016 by achieving a mechanistically appropriate synthesis of incomplete harvest estimates based on the duck stamp survey and with more recent harvest estimates based on the HIP. By modeling harvest of woodcock hunters who never hunt waterfowl as a latent (i.e., unobserved) parameter, and by controlling for annual

**Table 1.** Estimated proportional components of American woodcock harvest during 1999–2001, based on whether hunters always, sometimes, or never hunted waterfowl (regional means are weighted by total harvest). "Fraction hunting" is estimated based on residuals from a smoothing spline fit to 42 years of duck stamp sales. Corr. is the Pearson correlation coefficient between annual woodcock harvest estimated under the duck stamp survey (DSS) framework and total or residual duck stamp sales, 1964–2001.

| | Proportion harvested by woodcock hunters who hunted waterfowl | | | Mean harvest 1999–2001 (1,000s) | Fraction hunting 1999–2001 | Corr. of DSS & stamps | |
|---|---|---|---|---|---|---|---|
| **States** | **Always** | **Sometimes** | **Never** | | | **Total** | **Resid.** |
| LA | 0.38 | 0.42 | 0.20 | 26.7 | 0.95 | 0.56 | 0.32 |
| MI | 0.28 | 0.30 | 0.42 | 115.2 | 0.47 | 0.54 | 0.41 |
| WI | 0.32 | 0.24 | 0.43 | 41.4 | 0.58 | 0.73 | 0.48 |
| MN | 0.28 | 0.32 | 0.40 | 42.7 | 0.65 | -0.06 | 0.09 |
| OH | 0.79 | 0.12 | 0.09 | 6.6 | 0.70 | 0.36 | 0.12 |
| IL+IN | 0.51 | 0.37 | 0.12 | 8.5 | 0.64 | 0.34 | 0.22 |
| IA+MO+AR | 0.66 | 0.31 | 0.04 | 5.2 | 0.86 | 0.49 | 0.32 |
| KY+TN | 0.59 | 0.30 | 0.11 | 4.4 | 0.82 | 0.36 | 0.39 |
| MS+AL | 0.88 | 0.07 | 0.05 | 1.5 | 0.24 | 0.55 | 0.61 |
| NE+KS+OK+TX | 0.48 | 0.40 | 0.12 | 6.7 | 0.90 | 0.42 | 0.36 |
| **Central MR** | **0.52** | **0.29** | **0.20** | **259.0** | **0.68** | **0.50** | **0.33** |
| NY | 0.48 | 0.28 | 0.24 | 10.6 | 0.59 | 0.93 | 0.42 |
| ME | 0.35 | 0.19 | 0.46 | 31.5 | 0.89 | 0.83 | 0.42 |
| NJ | 0.82 | 0.13 | 0.06 | 3.9 | 0.39 | 0.91 | 0.53 |
| PA | 0.32 | 0.57 | 0.11 | 16.3 | 0.53 | 0.78 | 0.50 |
| MA | 0.86 | 0.09 | 0.05 | 4.5 | 0.18 | 0.78 | 0.22 |
| VT+NH | 0.39 | 0.44 | 0.18 | 10.8 | 0.64 | 0.81 | 0.55 |
| CT+RI | 0.79 | 0.18 | 0.03 | 3.9 | 0.36 | 0.65 | 0.37 |
| DE+MD+VA+WV | 0.84 | 0.12 | 0.05 | 9.1 | 0.54 | 0.65 | 0.48 |
| NC+SC | 0.67 | 0.17 | 0.16 | 9.9 | 0.66 | 0.14 | 0.35 |
| FL+GA | 0.73 | 0.15 | 0.12 | 5.0 | 0.43 | 0.22 | 0.13 |
| **Eastern MR** | **0.62** | **0.23** | **0.15** | **105.7** | **0.52** | **0.87** | **0.40** |
| **Overall** | **0.57** | **0.26** | **0.17** | **364.7** | **0.60** | **0.77** | **0.36** |

variation in the sampled proportion of woodcock hunters who occasionally hunted waterfowl, I estimated total harvest in all years for individual states with large harvests, combined states with smaller harvests, Central and Eastern Management Regions, and the entire United States.

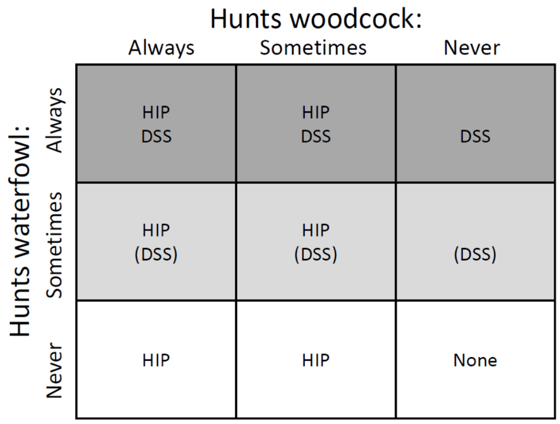
## Study Areas

American woodcock are harvested in the eastern United States, including all states within the Atlantic and Mississippi Flyways, and in the adjacent Central Flyway states of Nebraska, Kansas, Oklahoma, and Texas (Raftovich et al. 2015). I did not consider Canadian harvest, which accounts for <5% of the total North American woodcock harvest and has been monitored using consistent techniques since 1969 (Gendron and Smith 2013). I utilized harvest data from each state within the Central and Eastern Management Regions, but due to small samples and/or small areas, I aggregated data from some adjacent states to achieve 20 larger and more robust sample units: in addition to Minnesota, Wisconsin, Michigan, Ohio, New York, Maine, Massachusetts, Pennsylvania, New Jersey, and Louisiana, analyzed separately, these combinations included Vermont and New Hampshire (VT+NH), Connecticut and Rhode Island (CT+RI), the mid-Atlantic Flyway (DE+MD+VA+WV), the Carolinas (NC+SC), Georgia and Florida (GA+FL), Illinois and Indiana (IL+IN), Kentucky and Tennessee (KY+TN), Mississippi and Alabama (MS+AL), Iowa, Missouri, and Arkansas (IA+MO+AR), and the remaining Central Flyway states (NE+KS+OK+TX). For simplicity, I continue to refer to these multi-state combinations as "states" in the remainder of the paper.

## Methods

*Data sources and conceptual model* For each state, I obtained annual estimates of total woodcock harvest under the HIP (1999–2016) and federal duck stamp survey (1964–2001), and annual duck stamp sales (1964–2011). There were strong positive correlations between duck stamp sales and DSS harvest estimates in many states (Table 1), even though a federal duck stamp is not required for woodcock hunting. This could occur because numbers of waterfowl and woodcock hunters have both declined, and declines in annual duck stamp sales (Vrtiska et al. 2013) are also indicative of declining numbers of woodcock hunters (Luukkonen and Frawley 2010). Alternatively, many woodcock hunters might hunt waterfowl irregularly, with much of the annual variation in estimated harvest from the DSS arising from incomplete and variable coverage of the sampling frame of woodcock hunters due to their variable participation in waterfowl hunting. From 1999–2016, the sampling frame for the HIP survey of woodcock harvest included all individuals purchasing a state hunting license who answered "Yes" to the question: "Will you hunt migratory birds this season?" The HIP survey thus potentially included nearly all licensed woodcock hunters, excluding only small numbers of juniors, seniors, and landowners who are exempt from license purchase (Padding et al. 2010). However, concerns about non-compliance with HIP registration by hunters, and the failure of some license vendors to ask all screening questions needed for stratification, raise concerns that HIP might produce a slightly biased or less efficient sampling frame (Ver Steeg and Elden 2002).

Reconciling DSS and HIP surveys requires an understanding of how the sampling frames differed between the 2 surveys: the DSS potentially included all woodcock hunters who also hunted waterfowl each year, and partially sampled woodcock hunters who occasionally hunted waterfowl (Fig. 1). By contrast, the HIP survey had a high sampling intensity for woodcock hunters who successfully harvested woodcock during the previous season, and a smaller sampling intensity for hunters who did not hunt woodcock or were unsuccessful during the previous



| | | Hunts woodcock: | | |
|---|---|---|---|---|
| | | Always | Sometimes | Never |
| Hunts waterfowl: | Always | HIP<br>DSS | HIP<br>DSS | DSS |
| | Sometimes | HIP<br>(DSS) | HIP<br>(DSS) | (DSS) |
| | Never | HIP | HIP | None |

**Figure 1.** A conceptual model of historical survey coverage of hunters who participated in American woodcock hunting (columns) and/or waterfowl hunting (rows) by the Harvest Information Program (HIP; 1999–2016) and the federal duck stamp survey (DSS; 1964–2001). During the HIP survey, essentially all woodcock hunters were available for sampling during all years, but during the DSS, only woodcock hunters who always hunted waterfowl (top row, dark gray) were consistently surveyed. Woodcock hunters who sometimes hunted waterfowl were surveyed at irregular frequencies depending on whether or not they bought a duck stamp (middle row, light gray); woodcock hunters who never hunted waterfowl (bottom row) went unsampled during the DSS, unless they bought a duck stamp for conservation or collecting purposes.

season. Reconciling differences between these 2 surveys might be achieved by recognizing 3 components to the annual woodcock harvest, including harvest by woodcock hunters who: 1) always hunted waterfowl, and were therefore present in both the DSS and HIP sampling fames during all years; 2) irregularly hunted waterfowl, and were consistently sampled by HIP but more likely to be absent from the DSS sampling frame during years with lower duck stamp sales; or 3) never hunted waterfowl, and were therefore only sampled during the HIP survey (Fig. 1). I used this conceptual model to estimate total woodcock harvest across all 20 states, but illustrate the approach by emphasizing harvest estimates from Michigan, Minnesota, Louisiana, Maine, New York, and New Jersey—6 states with large woodcock harvests that exhibited different traditions of waterfowl and woodcock hunting. Michigan and Minnesota were also important to include because both states have conducted independent surveys of woodcock harvest using consistent methodology that spanned both the DSS and HIP surveys (Luukkonen and Frawley 2010; M. Dexter, 2015, Minnesota Department of Natural Resources, unpubl. report).

An annual woodcock harvest should be closely related to the previous year's harvest, due to year-to-year similarities in the numbers of active woodcock hunters and the regional abundance of woodcock. I therefore modeled annual woodcock harvest using an autoregressive model (Link and Barker 2010) that presumed total harvest would be related to harvest in the previous year. For 1999–2016, I assumed that the HIP survey measured all 3 components of total woodcock harvest, including harvest by hunters who always, sometimes, or never hunted waterfowl. For 1964–2001, I assumed that total woodcock harvest was partially measured by the DSS, including the full complement of woodcock harvest by hunters who always hunted waterfowl, but a variable fraction of woodcock harvest by hunters who sometimes hunted waterfowl. I indexed this fraction of occasional waterfowl hunters by using annual deviations from the long-term trends (1964–2005) in duck stamp sales within each state. I presumed that these long-term trends represented relative changes in total hunter numbers (i.e., declines in numbers of both woodcock and waterfowl hunters), whereas annual residuals represented relative participation by active woodcock hunters in harvesting waterfowl (and hence, probability of inclusion in the DSS).

*Formal hierarchical model* Because the most complete sampling frames of woodcock hunters occurred under the HIP survey, I developed models in reverse time, treating the 2016 harvest as year $t = 1$ and 1964 as year $t = 53$. For each state ($s$) and year ($t$), I treated true harvest ($H$) as an unobserved latent variable:

$$logH_{s,t+1} = logH_{s,t} + \varepsilon_{s,t+1}$$

where $logH_{s,t}$ is natural logarithm of true woodcock harvest in state $s$ during year $t$ and $\varepsilon_{s,t+1}$ is the annual rate of change in true harvest from the previously modeled year. I used state-specific HIP estimates during 2012–2016 to develop priors for year 1 (2016) log harvest ($logH_{s,1}$) and I modeled $\varepsilon_{s,t+1}$) as random normal variables with potential positive or negative state-specific trends in annual harvest ($\Delta r_s$) and state-specific annual variation($\sigma_s^2$) from this trend:

$$\varepsilon_{s,t+1} \sim Normal(\Delta r_s, \sigma_s^2)$$

where $\Delta r_s \sim Normal(\mu_r, \sigma_r)$ using vague uniform priors for $\mu_r$ (-1,1) and $\sigma_r$ (0.01,1) and $\sigma_s^2 \sim logNormal(\mu_\sigma, \sigma_\sigma)$ using vague uniform priors for both $\mu_\sigma$ and $\sigma_\sigma$ (0.01,10).

For each state, I partitioned total woodcock harvest into 3 separate components, including proportion of harvest by woodcock hunters who: 1) always hunt waterfowl ($\pi_{s,1}$), 2) sometimes hunt waterfowl ($\pi_{s,2}$), 3), and never hunt waterfowl ($\pi_{s,3}$). I used a uniform prior distribution to allow $\pi_{s,3}$ to vary from 0 to 0.7 within each state and implemented a multinomial constraint so that $\pi_{s,1} + \pi_{s,2} + \pi_{s,3} = 1$.

For observation error, I used state-specific estimates of annual variance in harvest from HIP surveys (Padding et al. 2010, Seamans and Rau 2016). If annual harvest and variance of annual harvest were estimated at 0 for a particular state due to a small sample of hunters, none of whom reported harvesting woodcock (e.g., FL 1999; P. Padding, US Fish and Wildlife Service, pers. commun.), I replaced these estimates with the minimum observed estimates of means and variances for that state to avoid taking the logarithm of 0. For states that were combined for analysis (e.g., Vermont + New Hampshire), component variances were added together to obtain total variance. Variance estimates are not calculated for the DSS, but Geissler (1990) estimated variance for a variety of waterfowl species and sampling units (e.g., flyways, states) using bootstrap methods (Efron and Tibshirani 1986). I summarized data from Geissler (1990: Tables 1–2) and estimated the variance to mean relationship for 86 harvest estimates using Taylor's (1961) power law:

$$\log(\mathrm{Var}_{\mathrm{DSS}}) = a + b^{*}\log(\mathrm{Mean}_{\mathrm{DSS}}),$$

where $a = 1.38$ (SE 0.61), $b = 1.36$ (SE 0.05), and $R^2 = 0.88$, and applied this relationship to DSS estimates for woodcock. Harvest variances from the HIP survey were transformed to the log scale using delta method approximations ($Var(logH) \approx Var(H)/\mu(H)^2$).

I modeled duck stamp sales as a continuous time series using the smooth.spline function in program R with 4 degrees of freedom, which captured long-term trends in total duck stamp sales within each state without removing shorter-term variation potentially caused by year-to-year variation in participation in waterfowl hunting (Fig. 2*a*). I used residuals from state-specific splines as an annual index of potential short-term participation in waterfowl hunting by woodcock hunters.

For 1999–2016, I presumed that HIP surveys measured total woodcock harvest with survey-specific measurement error:

$$\widehat{HIP}_{s,t} \sim Normal(H_{s,t}, \widehat{SE}_{HIP,s,t})$$

where $\widehat{HIP}_{s,t}$ is the HIP-based estimate of total harvest for state $s$ in year $t$, $H_{s,t}$ is the process model estimate of unobserved true harvest, and $\widehat{SE}_{HIP,s,t}$ is the HIP-based estimate of survey standard error. During 1964–2001, I presumed that the DSS estimated only certain parts of the total harvest:

$$\widehat{DSS}_{s,t} \sim Normal((\pi_{s1} + \pi_{s2}\,frac_{st})H_{s,t}, \widehat{SE}_{DSS,s,t})$$

where $\pi_{s1}$ represents the proportion of harvest by woodcock hunters who always hunted waterfowl, $\pi_{s2}$ represents the proportion of harvest by woodcock hunters who sometimes hunted waterfowl, $frac_{st}$ represents the fraction of occasional waterfowl hunters who were hunting waterfowl that year (as indexed by residual duck stamp sales), and $\widehat{SE}_{DSS,s,t}$ is estimated SE of the DSS harvest estimate, derived from Taylor's power law.

I modeled harvest and duck stamp data in JAGS 3.3.0 (Plummer 2012) using the jagsUI package (Kellner 2015) as implemented in R, using an adaptation phase of 1,000 iterations, followed by 3 Markov-chain Monte Carlo (MCMC) chains of 110,000 iterations each, with the first 10,000 iterations discarded as burn-in, and retaining every tenth remaining iteration, giving 30,000 observations for each posterior distribution. I verified model fit by examining trace plots and verifying that all $\hat{R}$ values were <1.03 (Gelman and Rubin 1992). Data sets and R code for running all models are provided online (Arnold et al. 2019).

## Results

During 1964–2001, annual harvest estimates of woodcock for most states were strongly correlated with annual duck stamp sales (mean $r = 0.55$). This was most prominent in the Eastern Management Region (Table 1) and was typically driven by strong declines in both woodcock harvest and duck stamp sales (Figs. 2–3). Correlations between DSS and residual duck stamp sales were weaker (mean $r = 0.36$), but positive ($r > 0$) in all states (Table 1).

During 1999–2001, when the duck stamp survey (DSS) and Harvest Information Program (HIP) overlapped, estimated harvest components averaged 57, 26 and 16% for hunters who always, sometimes, or never hunted waterfowl, respectively, but with tremendous variation among states (Table 1). Four northern states, including Michigan, Minnesota, and Maine, had large (≥40%) components of woodcock harvest by hunters who never hunted waterfowl (Table 1), and these states therefore exhibited large discrepancies between HIP and DSS estimates during the 1999–2001 overlap years (Fig. 3). Seven states, including New Jersey, had >70% of estimated woodcock harvest by hunters who always hunted waterfowl, with <10% harvested by hunters who never hunted waterfowl (Table 1). These states demonstrated little difference between HIP and DSS estimates during overlap years. For Louisiana, more than 40% of the woodcock harvest was estimated to have come from hunters who irregularly hunted waterfowl, but given that 95% of irregular waterfowl hunters were estimated to have hunted during the 1999–2001 overlap years, the DSS and HIP surveys were similar (Fig. 3). Michigan and Minnesota also had large proportions of woodcock hunters who hunted waterfowl irregularly, and accounting for annual duck stamp sales changed the shape of harvest trajectories considerably from the raw DSS data (Fig. 3). Harvest estimates for Michigan based on an independent survey conducted by the Michigan Department of Natural

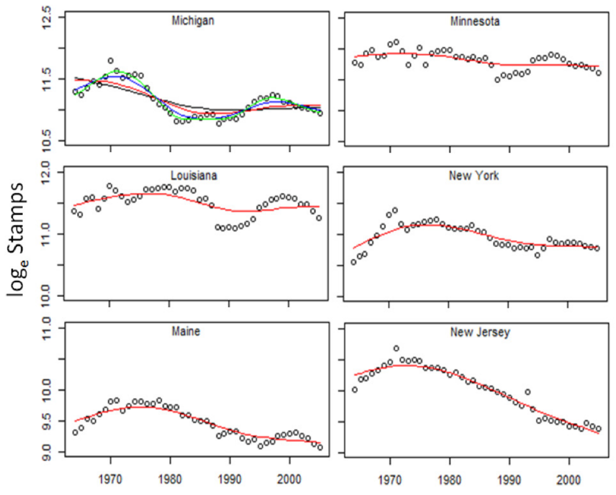


**Figure 2.** Annual duck stamp sales for Michigan, Minnesota, Louisiana, New York, Maine, and New Jersey, 1964–2005 (y-axis is on loge scale: 9, 10, and 11 represent ~8, 22, and 60 thousand stamps sold, respectively). Long-term trends were characterized using smoothing splines with 4 degrees of freedom (red lines). Fitted lines are presumed to represent long-term trends in numbers of small game hunters, whereas residuals are presumed to represent relative participation of small game hunters in waterfowl hunting (i.e., purchasers of duck stamps). For Michigan (top left panel), additional lines demonstrate fitted splines for 3, 6, and 10 degrees of freedom (black, blue, and green lines, respectively).

Resources during 1964-2015 were strongly correlated with model-based estimates from this study ($r = 0.78$, $P < 0.001$). For Minnesota, the correlation between independent harvest estimates by the Minnesota DNR and model-based estimates from this study was also strongly positive ($r = 0.73$, $P < 0.0001$).

Most state-specific harvest estimates followed a common pattern of increasing total harvest from 1964 through the mid- or late-1970s, followed by strongly declining harvest until 2016 (Fig. 3; Supplemental Materials). Aggregated harvest, summed across all states within each management unit, exhibited similar patterns (Fig. 4). The Central Management Unit exhibited tremendous variation in annual harvest estimates during the late 1970s and late 1980s, and this variation was largely driven by variation in harvest estimates from Louisiana (Fig. 3).

## Discussion

By hypothesizing that woodcock harvest consisted of birds shot by hunters who: 1) always, 2) sometimes, or 3) never hunted waterfowl, I was able to model latent components of total harvest corresponding to these 3 groups. During years when total woodcock harvest was measured using the federal duck stamp survey (DSS), only the first component and a variable but unknown fraction of the second component were measured each year. However, by model-

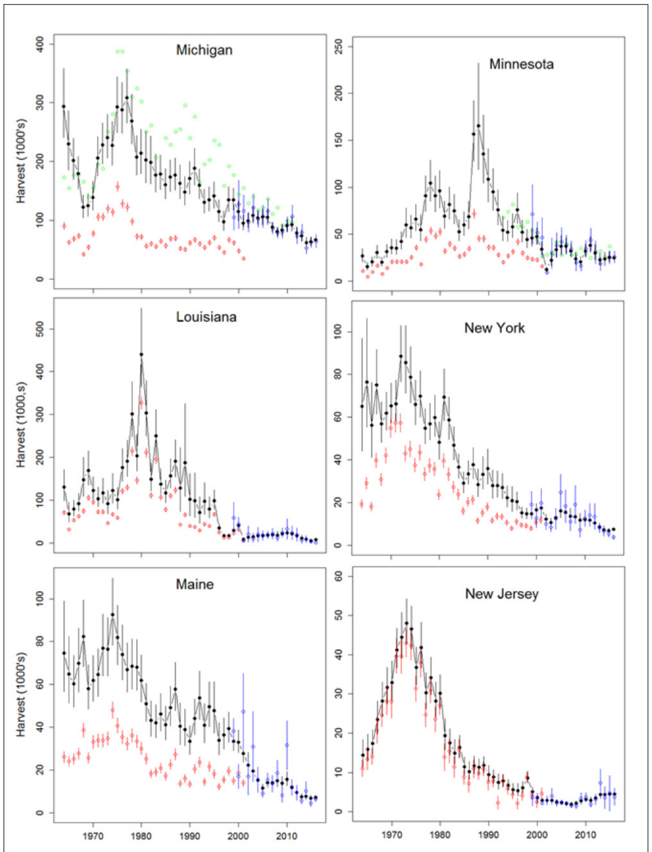


**Figure 3.** Estimates of total harvest of American woodcock during 1964–2016 for Michigan, Minnesota, Louisiana, New York, Maine, and New Jersey. Black symbols represent state-space estimates (± 80% credible intervals) from this study based on combined analysis of data from the duck stamp survey (red symbols, 80% CI) and Harvest Information Program (blue symbols, 80% CI). For Michigan and Minnesota, independent harvest estimates from the Michigan Department of Natural Resources (DNR) and Minnesota DNR are included in green.

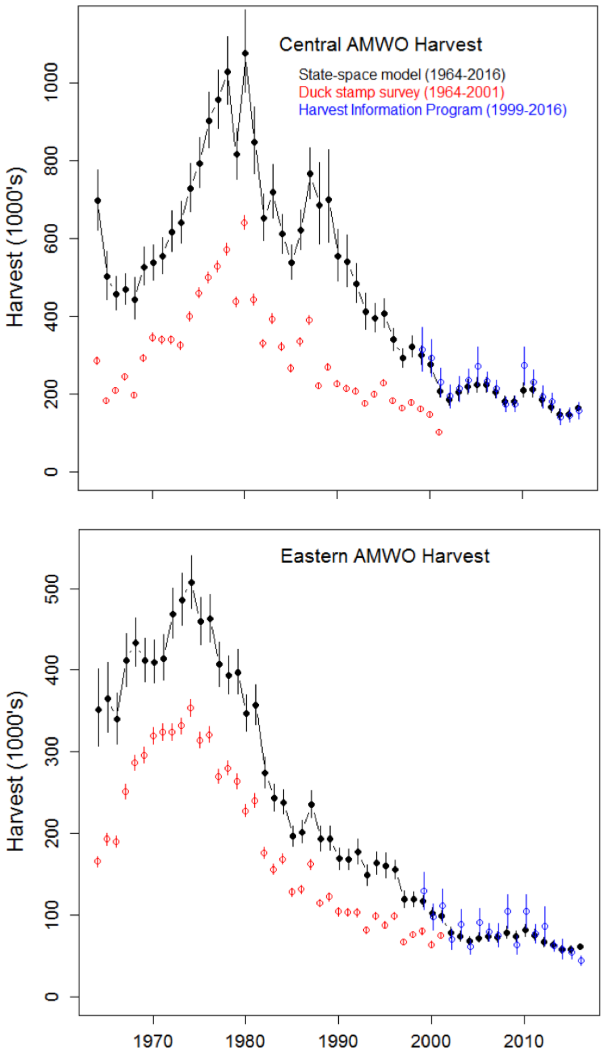


**Figure 4.** Total estimated American woodcock harvest (with 80% credible intervals) for the Central (top) and Eastern (bottom) Management Regions based on combined analysis of duck stamp survey and Harvest Information Program data, 1964–2016.

ing harvest by occasional waterfowl hunters as a function of annual variation in duck stamp sales within each state, I was able to obtain estimates of total woodcock harvest by regular and occasional waterfowl hunters. By estimating these 2 harvest components during 1999–2001, when the duck stamp survey and Harvest Information Program (HIP) were conducted concurrently, harvest of woodcock by hunters who never hunted waterfowl also became estimable. Furthermore, by using models where annual harvest was presumed to be correlated to harvest in adjacent years, I was able to discriminate between annual process variation (i.e., real annual variation in woodcock harvest) and measurement error (i.e., estimation uncertainty due to incomplete sampling of woodcock hunters). This approach allowed me to obtain seamless estimates of total woodcock harvest across both survey frameworks, 1964–2016, including measures of uncertainty during early years (Figs. 3–4) that had formerly included only point estimates (Padding et al. 2010).

In addition to the myriad assumptions necessary to avoid bias in harvest estimates (Sheriff et al. 2002), this model required several additional assumptions. Because separate components of harvest were only measured during the 1999–2001 overlap years, I had to assume that the proportion of woodcock harvest from hunters who never purchased federal duck stamps remained relatively constant during 1964–2001. I also assumed that short-term annual variation in duck stamp sales was positively correlated with the surveyed fraction of woodcock hunters who sometimes hunted waterfowl, and positive correlations between DSS-based harvest estimates and residual duck stamp sales suggested this assumption was true (Table 1). I further assumed that observation error from the DSS could be approximated using variance-mean relationships derived from waterfowl harvest estimates (Geissler 1990). An alternative model that considered state-specific variance inflation factors that allowed DSS harvest estimates to have greater than predicted sampling variances resulted in similar harvest estimates, proportions, trends, and measures of annual process variation (T. Arnold, unpublished data), suggesting that my assumption about observation error had little impact on harvest estimates.

The primary goal of this model was to obtain seamless estimates of total woodcock harvest that could be used for Lincoln population estimates of total and cohort-specific population sizes (Alisauskas et al. 2014; S. P. Saunders, et al., 2019). I believe these estimates are more reliable than simple survey-specific estimates from either the DSS or the HIP, but they could be refined based on better knowledge of hunter behavior (e.g., contemporary or historical estimates of proportions of woodcock hunters who always, sometimes, or never hunt waterfowl; and the relative harvest rates of each group). Although my primary motivation was to obtain long-term total harvest estimates for use in developing integrated population models (Schaub and Abadi 2011), further developments of this approach might be useful for understanding changing dynamics of woodcock hunters. Moreover, some state-specific harvest estimates from the HIP survey appear to be highly variable (e.g., Maine, Fig. 3c), and state-space approaches helped achieve more consistent annual harvest estimates even without the added goal of trying to synthesize estimates from the DSS and HIP surveys. Bayesian hierarchical models are highly flexible, and the preliminary models developed here could be readily modified to include other measured variables known or suspected to affect annual woodcock harvest (Luukkonen and Frawley 2010).

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# Evaluating Techniques for Estimating Post-Breeding-Season Age Ratios for American Woodcock

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**ABSTRACT** Estimating American woodcock (*Scolopax minor*; hereafter, woodcock) vital rates at a landscape scale requires considerable effort and expense, but provides a means of assessing population response to management. Age ratios derived from capturing woodcock (e.g., age ratios derived from mist-netting or night-lighting) during late summer may be useful proxies of local production, and require much less effort and expense to obtain than estimating local production directly. To assess whether such age ratios were similar to estimates of production derived from estimating vital rates, we estimated post-breeding-season age ratios (juveniles/adult female) at a habitat-management demonstration area in west-central Minnesota using radio telemetry and nest monitoring, and by capturing woodcock using mist nets and night-lighting. In 2011 and 2012 we radio-marked and tracked 41 adult female and 73 juvenile woodcock and monitored 51 broods and 48 nests; we used the collected data to inform population models and derive post-breeding-season age ratios. In July of 2011 and 2012, we captured 204 woodcock using mist nets by exploiting crepuscular movements from diurnal feeding cover to roosting fields and 69 woodcock via night-lighting on nocturnal roosting fields. Estimates of age ratios derived from our population model were 1.07 (95% CI: 0.27 – 2.45) in 2011 and 2.59 (95% CI: 1.04 – 4.95) in 2012. We attribute the higher point estimate of age ratio in 2012 to higher nest and juvenile survival rates during that year. Age ratios from mist-netting were 3.82 (95% CI: 1.99 – 7.13) in 2011 and 2.37 (95% CI: 1.43 – 3.73) in 2012 and from night-lighting were 1.62 (95% CI: 0.69 – 3.28) in 2011 and 0.42 (95% CI: 0.06 – 1.00) in 2012. Age ratio point estimates derived from mist-netting and night-lighting varied considerably between years, with neither method providing a ratio similar to point estimates derived from our population model. The only statistically significant difference (based on 95% CIs) between any of our age ratio estimates was for night-lighting in 2012, with that estimate being lower than the estimates from mist-netting and our population model. Based on these results, age ratios of production of young derived from mist-netting and might-lighting in late summer may not reflect local production, and may be influenced by both local and landscape-scale movements of woodcock following the breeding season. We conclude that without further evaluation of factors that affect post-breeding-season age ratios of local woodcock populations, age ratios derived from mist-netting and night-lighting in summer may not be useful proxies of local recruitment.

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**KEY WORDS:** American woodcock, post-breeding-season age ratio, Minnesota, *Scolopax minor*, survival

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American woodcock (*Scolopax minor*; hereafter, woodcock) have experienced long-term population declines across portions of their breeding range, based on the spring American Woodcock Singing-Ground Survey (Seamans and Rau 2017). Wing-collection surveys also have indicated a decline in woodcock productivity, especially in the Central Management Region (Seamans and Rau 2017). These declines have been speculated to be due to loss or alteration of young forest cover types that support woodcock reproduction (Gregg 1984, Dwyer et al. 1988, Sauer and Bortner 1991, Kelley et al. 2008). In response to these apparent declines in woodcock abundance and productivity, a system of woodcock habitat-demonstration areas is being developed throughout the woodcock breeding range where specific Best Management Practices (BMPs) are applied with the goal of stabilizing and ultimately increasing woodcock populations (Wildlife Management Institute 2010). These demonstration areas are meant to promote young forest management on public and private lands, and to increase the abundance and distribution of young forest cover types. Woodcock use managed areas (e.g., Hale and Gregg 1976, Wildlife Management Institute 2009), but it is unknown whether apparent increases in local woodcock abundance (Dwyer et al. 1988) are a result of movement of woodcock into these areas, of these landscapes increasing population growth rates, or of a combination of these and other factors. Part of the difficulty in assessing the effects of management for woodcock at a landscape scale is that there are no established methods to efficiently estimate production of young (e.g., as reflected in post-breeding-season age ratios).

An index of woodcock production (juveniles/adult female in the harvest) is reported annually for the Eastern and Central Management Regions and by state through a wing collection survey (Seamans and Rau 2017). These indices are used to assess both short- and long-term trends for woodcock productivity at broad spatial scales. Estimates of post-breeding-season age ratios at a demonstration-area scale (~200–800 ha), using the same metric as wing collection surveys, also can be used to assess whether BMPs applied at demonstration areas result in increased woodcock production. However, estimating post-breeding-season age ratios with methods that rely on estimates of local woodcock vital rates (e.g., estimating survival via telemetry and nest success via nest monitoring) can be expensive and require in-depth field studies. Age ratios derived from capturing woodcock during late summer (e.g., capture via night-lighting or mist-netting, see below) may provide an alternative to deriving post-breeding-season age ratios based on estimates of woodcock vital rates and may be more cost- and effort-efficient. However, it is not known whether post-breeding-season age ratios reflect local productivity at the scale of demonstration areas.

Our objectives were to (1) estimate woodcock post-breeding-season age ratios at a demonstration-area scale by monitoring nests and radio-monitoring adult females and juveniles as a measure of local woodcock production, (2) derive and compare age ratios from mist-netting and night-lighting during late summer, and (3) evaluate whether model-based estimates of age ratios and those derived from mist-netting and night-lighting were similar (and therefore might be useful as proxies of local production). Similar age ratio estimates between model-based and mist-netting and night-lighting would suggest that less costly and labor-intensive methods could be used to monitor production at the demonstration-area scale. Dissimilar age ratios would suggest bias in 1 or more of these methods, or biological factors (e.g., local or landscape-scale woodcock movements during summer) that changed age ratios following when young fledged.

### Study Area

As part of a larger study of woodcock population ecology, we estimated post-breeding-season age ratios in late summer in 2011 and 2012 at Tamarac National Wildlife Refuge (NWR) near Rochert, Minnesota, USA (47.0 N, -95.7 E). Tamarac NWR is a woodcock habitat demonstration area, lies in the glacial lake country of west-central Minnesota in Becker County, and encompasses 17,296 ha of mostly forested lands intermingled with lakes, rivers, marshes, shrub swamps, and tallgrass prairie. Tamarac NWR is located in the transition zone between coniferous forest, northern hardwood forest, and tallgrass prairie. Sixty percent of the refuge is forested, with dominant tree species of aspen (*Populus* spp.), jack pine (*Pinus banksiana*), red pine (*P. resinosa*), balsam fir (*Abies balsamea*), paper birch (*Betula papyrifera*), red oak (*Quercus rubra*), white oak (*Q. alba*), sugar maple (*Acer saccharum*), and basswood (*Tilia americana*). A substantial portion of the refuge is maintained in early successional forest cover, using timber harvest and prescribed fire, to provide habitat for woodcock, golden-winged warblers (*Vermivora chrysoptera*), and other migratory birds that utilize young forest cover types.

## METHODS

### ESTIMATING POST-BREEDING-SEASON AGE RATIOS FROM RADIO TELEMETRY AND NEST MONITORING

To estimate post-breeding-season age ratios derived from local woodcock vital rates, we monitored survival of woodcock and woodcock nests. In early spring of 2011 and 2012, we used mist nets (Avinet 38-mm black polyester nets, 4 pockets, 2.6 m high, 6 and 9 m wide; Avinet, Inc., Dryden, NY) to capture woodcock during dusk (approximately 1900 to 2300 CDT) when woodcock leave diurnal areas to roost or feed (Sheldon 1971). We determined sex of all woodcock captured based on plumage characteristics (Martin 1964), and radio-marked adult female woodcock using a glue-on backpack-style harness that in combination with the transmitter was ≤3% of their total mass (4.5 g, model A5410, Advanced Telemetry Systems, Isanti, MN; McAuley et al. 1993*a*, *b*). We relocated radio-marked female woodcock 5–7 days per week throughout the breeding season (April–June) and into July, following the nesting period. We lost radio contact with some females when they traveled long distances, out of the range of our receiving equipment and monitoring protocol. We continued searching for these females throughout our field season and, if we did not relocate them, censored them in our analyses at the time of their last known location. When we relocated a radio-marked adult female, we assessed its status (i.e., alive or dead) and, if it was dead, assessed the cause of death. If depredated, we attempted to ascertain the source of predation (mammalian or avian) using methods described by McAuley et al. (2005).

We found woodcock nests using trained pointing dogs (Ammann 1977, McAuley et al. 1993*a*) and radio telemetry of incubating radio-marked adult females. We visited each nest every 2–3 days and assessed the status of the nest as active, depredated, abandoned, or successful. If the female was not present at the nest or flushed during our visit, we floated all eggs in ambient-temperature water to estimate nest age and initiation date (Ammann 1974). We considered nests to be active during periods when the adult female was either laying or incubating eggs, or if a female was incubating at a subsequent visit. We categorized nests as depredated if eggs were broken or absent prior to the estimated hatch date. We categorized nests as abandoned if the female was not observed incubating for 2 consecutive visits. We categorized nests as successful if ≥1 egg exhibited signs of having hatched (i.e., was in or close to the nest bowl with a longitudinal split).

We assessed the status of juveniles in broods of radio-marked adult females and also radio-marked a sample of juveniles within broods of radio-marked adult females. We used trained pointing dogs to find broods of unmarked adult females (Mendall 1938; Ammann 1974, 1977), and captured and radio-marked juveniles in those broods. We custom fit a collar-type micro-transmitter (BD-2NC or BD-2C, Holohil Systems Ltd., Carp, ON and custom transmitters made by Blackburn Transmitters, Nacogdoches, TX) with a whip antenna to captured juvenile woodcock. All transmitters were ≤3% of the bird's mass (BD-2NC transmitters weighed about 0.6 g, BD-2C transmitters weighed about 1.6 g, and Blackburn transmitters weighed about 0.4 g) and we attached transmitters to juvenile woodcock with an elastic collar designed to expand as the juvenile woodcock grew. We positioned transmitters at the base of a juvenile woodcock's neck with the transmitter antenna lying down the juvenile's back. Daly et al. (2015) demonstrated that this attachment method had no influence on subsequent survival rate. Transmitter lifespan was about 21 days (17–30 day range) for BD-2NC transmitters, 63 days (49–77 day range) for BD-2C transmitters, and 28 days (24–32 day range) for Blackburn transmitters.

We radio-marked 1–4 juveniles per brood and monitored both marked and unmarked individuals within a brood after locating radio-marked juveniles. We considered juveniles within the same brood as independent experimental units in our study because Daly et al. (2015) found no evidence of dependence among juveniles in the same broods using Winterstein's (1992) second Chi-square goodness-of-fit test ($\chi^2$= 17.2, $P$ = 0.99; data reanalyzed using Winterstein's third Chi-square goodness-of-fit test in Breeding Season Survival of Woodcock, Appendix II, page 62). The survival of a juvenile woodcock was thus not statistically linked to the survival of broodmates, making it appropriate to treat each juvenile within a brood as an individual sample. We located broods 4–7 days per week by tracking either the adult female or juvenile(s). We assessed status (alive or dead) of juveniles, counted both marked and unmarked juveniles to document brood size, and assumed juveniles were dead if previously observed but subsequently not detected. We counted the number of individuals in the brood by tracking the radio-marked woodcock(s) to a distance of about 5 m and then encircling the brood until we were certain all brood members were counted. Beginning about 15 days after hatch, entire broods often flushed at our approach, which afforded us the opportunity to determine total brood size. Beyond 15 days post-hatch, the probability of detecting all members of the brood diminished. Because we were not able to accurately determine the status of unmarked juveniles after brood breakup, we right-censored unmarked juveniles at 24 days old, which was earliest we observed brood breakup.

We recorded the number of days post-transmitter deployment on females and juveniles to accurately censor individuals if radio transmitters failed prematurely. We assumed radios failed if they performed irregularly and there was no other indication an individual had died. We also assumed radios failed if they were nearing the end of their projected battery life and we subsequently received no additional signals from transmitters. We right-censored individuals in both of these circumstances, assuming the individual survived until transmitter failure (e.g., Korschgen et al. 1996).

We estimated survival rates of adult females, nests, and juveniles using the Kaplan-Meier with staggered entry estimator (Pollock et al. 1989, Nur et al. 2004) in the KMsurv package in Program R (version 2.15.2, R Core Team, 2012). We used these survival rate estimates to construct a model of the woodcock population in our study area and to derive post-breeding-season age ratio estimates in 2011 and 2012, which were the years we also derived age ratios via mist-netting and night-lighting. For the purposes of our model, we estimated adult female survival rate for a 122-day period (1 April – 31 July). We estimated nest survival rate for a 24-day period that included 3 days for egg laying and 21 days for incubation. Because the ages of the nests were known, we entered all nests into our analysis when they were initiated. We estimated juvenile survival rate for a 92-day period (1 May – 31 July).

We used estimates of period survival rate to estimate the number of female woodcock surviving the breeding season, and the number of juvenile woodcock produced and surviving through the end of the breeding season (31 July). We created an arbitrary population of 10,000 adult females and randomly selected values within our 95% CI for Kaplan-Meier period survival rate estimates of adult females to inform our population model for adult females surviving until the end of the breeding season,

$$\text{Adult females surviving the breeding season} = 10{,}000 * FS$$

where FS is a randomly selected value of adult female survival rate during the breeding season.

To supplement estimates of survival rates on our study area, we used published estimates of renesting rate, clutch sizes, and hatch rate to model the woodcock population on our study area. Woodcock are known to renest up to one time during a breeding season following a failed nest or if they lose a brood <11 days old (McAuley et al. 1990). Because we captured females into the nesting portion of the breeding season, and the time from nest or brood failure to renesting can be as short as 4–5 days (McAuley et al. 1990, also observed during this study), we were unable to assess whether the majority of nests in our study were first nests or renesting attempts. We therefore assumed the same survival probability for first nests and renests. Because of a high renesting probability for woodcock (~93%, McAuley et al. 1990), we prescribed a second nest to all woodcock in our population model that lost a first nest. The clutch size of first nesting attempts averages 4 eggs, whereas the clutch for renesting attempts is usually 3 eggs per nest, and both first nesting and renesting attempts have high hatch rates (~0.95; McAuley et al. 1990).

We initiated our model with all 10,000 adult female woodcock initiating a nest to calculate the number of juveniles produced. We applied the Kaplan-Meier estimate of nest survival rate to all nests and assumed that clutch size was 4 eggs in first nesting attempts and 3 eggs for renesting attempts. We assumed that if the nest was successful (i.e., ≥1 egg hatched), the hatch rate of eggs was 0.95. We estimated nest productivity (i.e., number of juveniles hatching; NP) as,

$$NP = (10{,}000 * 4 * HR * NS) + ([10{,}000 - (10{,}000 * NS)] * 3 * HR * NS)$$

where HR is hatch rate, and NS is a randomly selected value for nest survival within our 95% CI based on Kaplan-Meier estimates. We recalculated this estimate 1,000 times to derive a 95% confidence interval by excluding 2.5% of the highest and lowest point estimates.

From these estimates of nest productivity we calculated the number of juveniles that survived through the breeding season. We applied the Kaplan-Meier estimate of juvenile survival rate to the resulting number of juveniles to calculate the number of juveniles that were produced in 2011 and 2012, separately. We estimated the number of juveniles surviving to the end of the breeding season as

$$\text{Population of Juveniles} = NP * JS$$

where JS is a randomly selected value for juvenile period survival rate within our 95% CI around Kaplan-Meier survival-rate estimates.

We randomly selected period-survival-rate estimates with replacement for adult female, nest, and juvenile survival rates and conducted 1,000 iterations of calculations of population sizes of adult females and juveniles. For each iteration, we calculated post-breeding-season age ratios by dividing the number of juveniles that were produced and survived the breeding season by the number of adult females that survived the breeding season. From these 1,000 estimates of post-breeding-season age ratio, we calculated the mean, and the 95% CI as the interval that excluded 2.5% of estimates on either end of the distribution.

### ESTIMATING POST-BREEDING-SEASON AGE RATIOS FROM MIST-NETTING AND NIGHT-LIGHTING

We captured woodcock on summer roost fields starting in early July and concluding in early August in both 2011 and 2012 (Dwyer et al. 1988). We used mist nets to capture woodcock during crepuscular movements at dusk (approximately 1900 to 2300 CDT) and calculated net nights as the sum of the total number of mist nets set per night. We captured woodcock via night-lighting in known woodcock roosting areas (Dwyer et al. 1988) following the period of crepuscular movement. Each night we had a single person shining a spotlight (Cabela's 35-Watt HID spotlight, 3,000 lumens and Cyclops Sirius 500 spotlights, 500 lumens; Cabela's, Sydney, NE) and 1–2 people attempting to capture woodcock with long-handled nets. We assigned age (hatch year or after hatch year) and sex to all captured woodcock using body measurements and feather characteristics (Martin 1964, Sepik 1994).

We used bootstrapping techniques to resample with replacement for 1,000 iterations from woodcock captured mist-netting and night-lighting in 2011 and 2012 to derive woodcock post-breeding-season age ratios. We estimated the post-breeding-season age ratio for each iteration and derived the mean and the 95% CI based on the interval that excluded 2.5% of estimates on either end of the distribution of the 1,000 estimates we derived from bootstrapping.

We compared the post-breeding-season age ratios derived from our population model to those derived from woodcock captured via mist-netting and night-lighting based on 95% CIs, where non-overlap of 95% CIs indicated statistical significance. We also compared the age ratios in our study to those obtained from the wing-collection survey at both statewide and Central Management Region-wide scales (Cooper and Rau 2012, 2013).

Capture and marking protocols were approved by the University of Minnesota Institutional Animal Care and Use Committee under Protocol no.1103A97333.

## Results

### POST-BREEDING-SEASON AGE RATIOS FROM RADIO TELEMETRY AND NEST MONITORING

From 9 April to 1 June 2011 and 22 March to 24 May 2012, we captured and radio-marked 41 adult female woodcock (2011: $n$ = 23, 2012: $n$ = 18). We excluded 3 (~7%) radio-marked adult female woodcock in 2011 that we were unable to relocate following radio marking (likely due to transmitter failure or migration) from survival analysis. Of the remaining 38 female woodcock, we right-censored 1 female that became entrapped in its radio transmitter harness in 2012.

From 4 May to 11 June 2011 and from 9 April to 9 June 2012 we monitored 52 woodcock nests (2011: $n$ = 26, 2012: $n$ = 26). We right-censored 1 nest in 2011 and 3 in 2012. We excluded an additional 3 nest in 2011, 1 because we were not able to relocate it after first detection, and 2 we attributed to abandonment caused by our activities. Of the 45 nests we included in our survival-rate analyses, 21 (~47%) failed, 15 were depredated (71%), and 6 (29%) were abandoned by the female.

From 16 May to 29 June 2011 and 20 April to 16 June 2012 we radio-marked 73 (2011: $n$ = 22, 2012: $n$ = 51) juvenile woodcock from 51 broods (2011: $n$ = 16, 2012: $n$ = 35). We assigned fates to 134 juvenile woodcock (2011: $n$ = 63, 2012: $n$ = 71), including fates of 49 marked and 85 unmarked juveniles from 47 broods (2011: $n$ = 23, 2012: $n$ = 24). We excluded data from 24 marked juvenile woodcock due to problems with transmitter operation and failure (i.e., weak signals where we could not relocate the individual and did not know if the transmitter failed or if the juvenile was depredated).

Survival-rate estimates during the breeding season for adult female woodcock from 1 April to 31 July were 0.616 (95% CI: 0.427 – 1.000) in 2011 and 0.695 (95% CI: 0.427 – 1.000) in 2012 (Table 1). Kaplan-Meier estimates of survival rates for the 24-day laying and incubation period for nests were 0.458 (95% CI: 0.299 – 0.696) in 2011 and 0.786 (95% CI: 0.616 – 1.000) in 2012 (Table 1). Kaplan-Meier estimates of survival rates for juvenile woodcock for a 91-day period (1 May – 31 July) were 0.191 (95% CI: 0.083 – 0.481) in 2011 and 0.401 (95% CI: 0.253 – 0.761) in 2012 (Table 1). Our estimates of post-breeding-season age ratios based on survival and reproduction of females and survival of nests and juveniles were 1.07 (95% CI: 0.27 – 2.45) in 2011 and 2.62 (95% CI: 1.04 – 4.95) in 2012 (Table 2).

### POST-BREEDING-SEASON AGE RATIOS FROM MIST-NETTING AND NIGHT-LIGHTING

In 2011, post-breeding-season age ratios varied considerably as a function of capture technique. We captured more woodcock using mist-netting than night-lighting, in part because night-lighting is effective only under very specific conditions (e.g., nights with little ambient light). We spent 16.3 hours mist-netting and 23.5 hours night-lighting between 7 July and 24 July 2011. We set an average of 9.5 mist nets per night and mist-netting effort totaled 114 trap nights. The capture rate for mist-netting on summer roosting fields was 5.3 woodcock per hour (across the average 9.5 mist nets per night), whereas the capture rate for night-lighting on roosting fields was 1.8 woodcock per hour. We captured 3.50 juveniles per adult female *(n* = 87) via mist-netting and 1.46 juveniles per adult female *(n* = 42) via night-lighting (Table 2). Age ratios for woodcock captured via mist-netting were 3.82 (95% CI: 1.99 – 7.13) and 1.62 (95% CI: 0.69 – 3.28) for night-lighting (Table 2).

**Table 1.** American woodcock survival rate estimates for adult females, nests, and juveniles from Tamarac National Wildlife Refuge, Rochert, Minnesota, USA, in 2011 and 2012. We calculated survival rate estimates using the Kaplan-Meier method with staggered entry (Pollock et al. 1989) in the KMsurv package in Program R; period survival rates for female woodcock for a 122-day period, for juvenile woodcock for a 92-day period, and for woodcock nests for a 24-day egg-laying and incubation period.

| Year | Period survival rate (95% CI) | Daily survival rate (95% CI) |
|---|---|---|
| Females (122 days) | | |
| 2011 | 0.616 (0.427 – 1.000) | 0.996 (0.993 – 1.000) |
| 2012 | 0.695 (0.427 – 1.000) | 0.997 (0.993 – 1.000) |
| Nests (24 days) | | |
| 2011 | 0.458 (0.299 – 0.696) | 0.968 (0.951 – 0.985) |
| 2012 | 0.786 (0.616 – 1.000) | 0.990 (0.980 –1.000) |
| Juveniles (92 days) | | |
| 2011 | 0.191 (0.083 – 0.481) | 0.982 (0.973 – 0.992) |
| 2012 | 0.401 (0.253 – 0.761) | 0.991 (0.985 – 0.997) |

In 2012, the age ratio of woodcock captured via mist-netting was higher than that for woodcock captured via night-lighting. We spent 40 hours mist-netting and 29 hours night-lighting between 1 July and 30 July 2012, resulting in a capture rate of 2.92 woodcock per hour mist-netting and 0.93 woodcock per hour night-lighting. Trapping effort for mist-netting totaled 220 trap nights with an average of 10.5 mist nets set per night. We captured 2.28 juveniles per adult female *(n* = 117) via mist-netting and 0.38 juveniles per adult female *(n* = 27) via night-lighting (Table 2). Our post-breeding-season age ratios were 2.37 (95% CI: 1.43 – 3.73) for mist-netting and 0.42 (95% CI: 0.06 – 1.00) for night-lighting (Table 2).

### COMPARISON OF POST-BREEDING-SEASON AGE RATIOS

In both 2011 and 2012, point estimates of age ratios of woodcock captured via mist-netting were higher than those of woodcock captured via night-lighting (Table 2, Fig. 1), but point estimates of age ratios of woodcock captured via both mist-netting and night-lighting were lower in 2012 than in 2011. In contrast, point estimates of age ratio estimates derived from our population model were higher in 2012 than 2011. In 2011, the point estimate of the age ratio of woodcock captured via mist-netting was not similar to the point estimate of the age ratio derived from our population model, but these estimates were similar in 2012. The point estimates of the age ratio of woodcock captured via night-lighting were dissimilar to those derived from our population model in both 2011 and 2012. Similarly, the magnitude and direction of the difference between point estimates of age ratios derived in 2011 and 2012 were not similar for either mist-netting or night-lighting compared to the difference in age ratios derived from our population model between 2011 and 2012 (Table 2, Fig. 1). The only statistically significant difference between any of our age ratio estimates (based on non-overlapping 95% CIs) was for night-lighting in 2012, with the estimate being lower than the estimates from mist-netting and our population model (Table 2).

## Discussion

A primary objective of our assessment was to evaluate whether post-breeding-season age ratios of woodcock captured via mist-netting and night-lighting could serve as useful proxies for age ratios derived from a population model informed by estimates of local vital rates. Point estimates of age ratios derived from woodcock captured via mist-netting or night-lighting were not consistently related to point estimates of the post-breeding-season age ratio derived from our population model. However, all of the methods we used produced imprecise estimates of post-breeding-season age ratios, resulting in only 1 instance of a statistically significant difference between estimates derived using different methods (Table 2), and suggesting a need for additional assessments of these methods to estimate local production at the demonstration-area scale. Based on estimates derived from our

**Table 2.** Post-breeding-season age ratios (juveniles/adult female) derived from capturing American woodcock in summer roosting field via mist-netting and night-lighting, and an estimate from a population model based on estimates of vital rates at Tamarac National Wildlife Refuge, Rochert, Minnesota, USA, in 2011 and 2012. Post-breeding-season age ratios from mist-netting and night-lighting were created using bootstrapping with 1,000 iterations for 2011 and 2012. We calculated post-breeding-season age ratio for each iteration and derived the mean and 95% CI based on the distribution of post-breeding-season age ratios (excluding the lowest and highest 2.5% of estimates). Post-breeding-season age ratio estimates from our population model were informed by Kaplan-Meier survival rate estimates of adult female, nests, and juvenile woodcock. Post-breeding-season age ratios estimates are sample means derived from bootstrapping using 1,000 iterations and 95% confidence intervals were estimated based on the distribution of estimates of post-breeding-season age ratios.

| Method | Adult male | Adult female | Juvenile male | Juvenile female | Juveniles/ Adult female | Post-breeding-season age ratio (95% CI) |
|---|---|---|---|---|---|---|
| **2011** | | | | | | |
| Mist-netting | 24 | 14 | 39 | 10 | 3.50 | 3.82 (1.99 – 7.13) |
| Night-lighting | 10 | 13 | 14 | 5 | 1.46 | 1.62 (0.69 – 3.28) |
| Population Model | | | | | | 1.07 (0.27 – 2.45) |
| **2012** | | | | | | |
| Mist-netting | 35 | 25 | 41 | 16 | 2.28 | 2.37 (1.43 – 3.73) |
| Night-lighting | 9 | 13 | 2 | 3 | 0.38 | 0.42 (0.06 – 1.00) |
| Population Model | | | | | | 2.62 (1.04 – 4.95) |

population model, we expected post-breeding-season age ratios derived from mist-netting and night-lighting to increase from 2011 to 2012; however, they decreased in 2012 compared to 2011. We therefore conclude that additional assessment is needed of each of these methods. Based on point estimates, neither age ratios of woodcock captured via mist-netting nor those of woodcock captured via night-lighting appeared to be a useful proxy of local woodcock production.

If woodcock post-breeding-season age ratios at the demonstration-area scale are driven primarily by local production of young, in years of high local production both mist-netting and night-lighting would produce higher age ratios compared with age ratios from years with lower local production. Furthermore, settings with higher amounts and appropriate juxtaposition of nesting, brood-rearing, and roosting cover (e.g., woodcock demonstration areas) would have higher age ratios than settings with other cover-type configurations (Dunford and Owen 1973). Although point estimates of age ratios of woodcock we captured via both mist-netting and night-lighting were similar between years, neither was concordant with point estimates derived from our population model, informed by estimates of local production (generally higher in 2012 than 2011).

There are several possible explanations for this inconsistency. First, post-breeding-season age ratios of woodcock captured via mist-netting and night-lighting could be inflated by an influx of juvenile woodcock to areas with high-quality habitat in late summer. Second, post-breeding-season age ratios of woodcock captured via mist-netting during crepuscular periods also may be inflated (i.e., relatively higher proportion of juveniles; Table 2) if adult females are less likely to be captured in mist nets than juveniles. Capturing a relatively higher proportion of juvenile woodcock via mist-netting could be influenced by behavioral differences between juveniles and adults during crepuscular flights (Sheldon 1961, Dunford and Owen 1973, Owen and Morgan 1975). In previous studies of woodcock behavior in summer, adults flew later than juveniles; were 6 times more likely than juveniles to walk from diurnal covers to nocturnal sites, perhaps due to molt; flew shorter distances; and were less likely to take multiple flights to reach nocturnal sites (Dunford and Owen 1973, Owen and Morgan 1975). We opened mist nets prior to when woodcock began crepuscular flights and kept them open beyond when flights ceased to account for differences in flight times between juveniles and adults. Therefore, differences in flight times likely do not account for the bias toward juveniles of woodcock we captured via mist-netting. Instead, it seems that juvenile woodcock were more likely to be captured using mist nets than adults or that juveniles disproportionately immigrated into our study area in late summer. Juveniles have been observed moving greater distances than adults, especially juvenile males (Owen and Morgan 1975, Berdeen and Krementz 1998), which could lead to an influx of juveniles in summer. However, we were unable to assess this possibility in our study.

Third, how adult and juvenile woodcock use roosting fields may

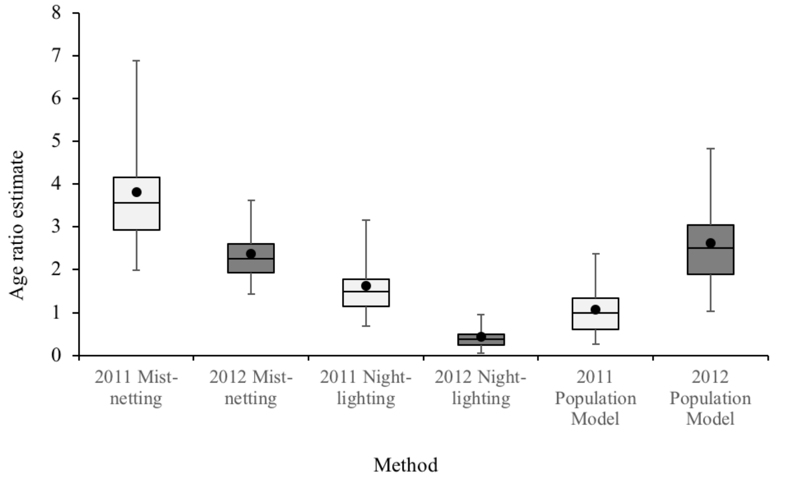

**Figure 1.** Post-breeding-season age ratios (juveniles/adult female) derived from capturing American woodcock in summer roosting field via mist-netting and night-lighting, and an estimate from a population model based on estimates of vital rates at Tamarac National Wildlife Refuge, Rochert, Minnesota, USA, in 2011 and 2012. Post-breeding-season age ratios from mist-netting and night-lighting were derived using bootstrapping with 1,000 iterations for 2011 and 2012. We calculated post-breeding-season age ratio for each iteration and derived the mean and 95% CI based on the distribution of post-breeding-season age ratios (excluding the lowest and highest 2.5% of estimates). Post-breeding-season age ratio estimates from our population model were informed by Kaplan-Meier survival rate estimates of adult female, nests, and juvenile woodcock. Post-breeding-season age-ratio estimates are sample means derived from bootstrapping using 1,000 iterations. Point estimates for post-breeding-season age ratios are indicated be the dot and 95% CIs are based on the distribution of the estimates. Box plot represents the quartiles of the estimates for each method by year.

influence age ratios of woodcock captured via mist-netting and night-lighting. Although the characteristics of roosting fields used by adults and juveniles are similar (Owen and Morgan 1975, Berdeen and Krementz 1998), adult and juvenile woodcock may use these areas in different spatial and temporal patterns. For instance, Owen and Morgan (1975) reported adult woodcock remaining closer to the edge of roost fields, whereas juveniles were generally farther from edges. Moreover, Krohn (1971) and Whitcomb (1972) reported greater relative use of roosting fields by juvenile woodcock during the summer, which could be related to the higher relative abundance of juveniles following the breeding season for woodcock. The higher relative abundance of juveniles and potential higher relative use of roosting fields by juveniles would result in higher age ratios immediately post-breeding. Conversely, use of winter roosting fields by radio-marked woodcock did not vary by age or sex (Berdeen and Krementz 1998), suggesting that age and sex cohorts of woodcock change their roosting behaviors between summer and winter, or that the relatively higher use of roosting fields by juveniles in summer is solely due to higher relative abundance of juveniles in summer than winter. The point estimates of age ratios of woodcock captured via night-lighting were lower than those of woodcock captured via mist-netting and lower than those derived from our population model in 2012, which suggests that in 2012, adult females were more readily captured via night-lighting than juveniles, because they were either more abundant or easier to capture. This result contradicts previous studies that suggested juvenile woodcock use of roosting fields was higher than that of adults in summer months (Krohn 1971, Whitcomb 1972). Adults and juveniles likely use roosting fields differently during different seasons (Krohn 1971, Whitcomb 1972, Berdeen and Krementz 1998) and also may use roosting fields in different spatial and temporal patterns within the same site and season (Owen and Morgan 1975). Better understanding of how adults and juveniles use roosting fields during the post-breeding-season would be useful in interpreting age ratios of woodcock captured via mist-netting and night-lighting.

We also note that because we focused our night-lighting efforts on only 2 roosting fields (4.7 ha and 14.5 ha in size), our capture-related activities may have affected our success capturing woodcock at these locations. Woodcock exhibit high nocturnal site fidelity (Berdeen and Krementz 1998), but site fidelity could be affected by human activity (Sheldon 1961, Krohn 1971, Dunford and Owen 1973). Lower post-breeding-season age ratios would result if juvenile woodcock were more likely than adult females to abandon a roosting field in response to repeated capture efforts. Our post-breeding-season age ratios of woodcock captured via night-lighting in 2012 also could be lower because adult woodcock generally roost closer to edges, and therefore have a lower likelihood of being encountered (Owen and Morgan 1975) or were less likely to be captured because they were closer to areas where they could escape.

Finally, our population model may have produced biased estimates of post-breeding-season age ratios, although for the purposes of comparison with age ratios derived from mist-netting and night-lighting, our population model likely provided a reasonable estimate of the difference between 2011 and 2012 in production of young. We used values for some vital rates estimated in a previous study of woodcock reproduction and survival (e.g., hatch rate, renesting probability, and clutch sizes in first nests and renests; McAuley et al. 1990) in Maine because we were unable to estimate all of the parameters in our population model on our study area. For instance, because of the high likelihood that a female will renest, we assumed that all adult females renested following a failed first nesting attempt. Despite woodcock having a high renesting probability (McAuley et al. 1990), all woodcock that experience nest failure may not have renested on our study area, which would result in a positive bias in our model-derived estimates of post-breeding-season age ratios. Furthermore, the similarity of vital rates estimated elsewhere (e.g., McAuley et al. 1990) to those in our study population is unknown, and using these estimates could introduce bias in our estimates of post-breeding-season age ratios of unknown size and direction.

To more fully assess the utility of post-breeding-season age ratios of woodcock captured via mist-netting and night-lighting to represent production of young at the demonstration-area scale, it is likely necessary to better understand movement behavior of juveniles and adults and the relationship between woodcock movements and environmental conditions during late summer. Few studies have evaluated spatial-use patterns of woodcock at the landscape scale in summer following brood rearing (e.g., Dunford and Owen 1973, Owen and Morgan 1975). Movements and habitat selection of woodcock have been related to foraging quality and environmental conditions, especially soil moisture (Dunford and Morgan 1973, Doherty et al. 2010). Woodcock generally return to areas with high food availability, and food availability and forage quality are related to soil moisture (Doherty et al. 2010). Because woodcock also forage at night (Stribling and Doerr 1985), and it is likely that food availability is at a seasonal low in roosting fields during mid-summer due to high temperatures, adult woodcock may use roosting fields less than juvenile woodcock during summer, and may use forest cover at higher rates during summer than during the remainder of the year (Berdeen and Krementz 1998).

We also note that the post-breeding-season age ratio estimates derived from our population model provide insight into woodcock demography and population ecology. First, post-breeding-season age ratios derived from our model are primarily influenced by nest and juvenile survival rates, as has been demonstrated for some other bird species (e.g., Streby and Andersen 2011) that use young forest cover types. Adult female survival in our study was high and therefore had little influence on age ratios. Second, our estimates of post-breeding-season age ratios suggest that the demonstration area where we conducted our study was perhaps a population source. Estimates derived from our population model were generally greater (1.07 [95% CI: 0.27 – 2.45] in 2011 and 2.62 [95% CI: 1.04 – 4.95] in 2012) than indices in Minnesota derived from the wing-collection survey (1.0 juveniles/adult female in both 2011 and 2012; Cooper and Rau 2012, 2013) and the Central Management Region (1.5 in 2011 and 1.66 in 2012; Cooper and Rau 2012, 2013).

However, even though 95% CIs overlapped for most of our estimates of age ratios (excepting age ratios derived from night-lighting in 2012), our assessment of post-breeding-season age ratios of woodcock captured via mist-netting and night-lighting at a landscape scale likely are not reliable proxies for estimating post-breeding-season age ratios from locally derived vital rates. Without additional information about relative capture probabilities of adult versus juvenile woodcock, relative use of roosting areas by adult and juvenile woodcock, and landscape-level movements of woodcock during late summer and early fall, it is difficult to assess the usefulness of mist-netting and night-lighting to monitor production of young. Evaluating these factors at specific sites may not be practical, as doing so would likely involve investment of resources comparable to those required to estimate vital rates of local woodcock populations. Additionally, our population model included vital rate estimates from other studies as substitutes for estimates we were unable to derive in our study (e.g., hatch rate). Future studies that employ a similar approach to directly estimate woodcock productivity at a landscape scale may be better served by deriving all vital rates necessary to inform a population model from the study population. Furthermore, we suggest that future studies incorporate the assumptions and drawbacks of each of the methods we deployed and that further evaluation is necessary before indirect methods can be reliably used as proxies of local woodcock recruitment.

## Management Implications

Surveying wildlife populations following habitat management is a critical part of adaptive wildlife management. A current strategy for increasing woodcock abundance is establishment of an abundance of cover types used by woodcock at a landscape scale, as exemplified in demonstration areas. However, it is not obvious how best to assess woodcock population response in these landscapes. Estimating productivity of young derived from local vital rates is time consuming and expensive, but presumably provides productivity estimates that best reflect local populations. Age ratios of woodcock captured via mist-netting and night-lighting require less time and expense to obtain, but additional assessment of these methods is needed prior to knowing if they are useful proxies of estimating local productivity. In our assessment at a woodcock demonstration area in west-central Minnesota, USA, neither point estimates of age ratios of woodcock captured via mist-netting nor of woodcock captured via night-lighting seemed to reflect the difference between years we observed in age-ratio estimates from our population model, which incorporated direct estimates of production of young. This suggests that other factors (e.g., influx of juvenile woodcock into areas with high habitat quality) may be influencing post-breeding-season age ratios derived from mist-netting and night-lighting. Future studies designed to evaluate local woodcock production may benefit from further assessment of the methods used and evaluation of the assumptions inherent in each method.

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# Breeding Season Survival of American Woodcock at a Habitat Demonstration Area in Minnesota

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**ABSTRACT** American woodcock (*Scolopax minor*; hereafter woodcock) best management practices (BMPs) applied at a landscape scale have been proposed to increase woodcock population densities, yet little information exists regarding population vital rates following application of BMPs. We estimated survival rates of woodcock adult females, nests, and juveniles at a woodcock habitat-management demonstration area in west-central Minnesota during the spring and summer (23 March – 30 June) of 2011 and 2012. We radio-marked and tracked 41 adult female and 73 juvenile woodcock, and monitored 51 broods and 48 woodcock nests to determine fates. We used Kaplan-Meier survival analysis to estimate survival rates of females, nests, and juveniles for both 2011 and 2012 and logistic-exposure models to assess relationships between survival and weather covariates, individual life history traits, and vegetation characteristics resulting from BMPs. Breeding season cumulative survival rate for adult females from 1 April – 30 June was 0.695 (95% CI: 0.357 – 1.052) in 2011, 0.740 (95% CI: 0.391 – 1.091) in 2012, and 0.751 (95% CI: 0.499 – 1.000) when pooling data from both years. Nest survival rate for the 24-day laying and incubation period was 0.458 (95% CI: 0.299 – 0.696) in 2011 and 0.786 (95% CI: 0.616 – 0.998) in 2012. Cumulative survival rate for juvenile woodcock for a 61-day period (1 May – 30 June) following hatch through mid-summer, when juveniles are independent from adults, was 0.330 (95% CI: 0.188 – 0.613) in 2011 and 0.576 (95% CI: 0.398 – 0.833) in 2012. In all logistic-exposure survival models, we included a year covariate (females: $\beta_{2011} = -0.16$, 95% CI: −1.67 to 1.45, nests: $\beta_{2011} = -0.768$, 95% CI: −1.70 to 0.166, juveniles: $\beta_{2011} = -0.85$, 95% CI: −1.77 to 0.07) to account for between-year variation in survival rates, although removing that covariate in models did not result in changes in relations between survival rates and other covariates. Our best-supported model of female survival rate was the null model, suggesting female survival rate was constant across years, and our best-supported model of nest survival rate included only a year covariate. Our best-supported model of juvenile survival rate included the covariates year, juvenile age ($\beta_{AGE} = 0.098$, 95% CI: 0.04 to 0.16), minimum temperature ($\beta_{MINT} = 0.14$, 95% CI: −0.004 to 0.28), and precipitation ($\beta_{PCPT} = -0.20$, 95% CI: −0.39 to −0.01). Juvenile survival rate increased with age and decreased with the amount of precipitation and had a weak positive relation with stem density ($\beta_{STEM} = 0.0001$, 95% CI: 0.000 to 0.0003). Woodcock in our study almost solely used areas where BMPs had been applied on the landscape within the last 20 years and that had similar vegetation structure; in those settings, only juvenile survival rate was related to local environmental conditions.

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American woodcock (*Scolopax minor*; hereafter woodcock) have experienced long-term population declines in the Eastern and Central Management Regions (0.8 % per year) since American Woodcock Singing-ground Surveys (SGS) were first implemented in the mid-1960s (Seamans and Rau 2016). These declines in population size are coupled with declines in woodcock recruitment across their range (indexed through juvenile/adult female ratios derived from wing-collection surveys; Seamans and Rau 2016). Extensive loss or alteration of breeding habitat, characterized by young regenerating forested areas with interspersed open grassy or cleared areas, has been suggested as the main cause of these declines (Dwyer et al. 1988, Gregg 1984, Sauer and Bortner 1991, Kelley et al. 2008, Wildlife Management Institute 2009). Kelley et al. (2008) proposed stabilizing and ultimately increasing the size of woodcock populations by increasing woodcock density on portions of the primary breeding range to that observed during the 1970s. As part of that effort, a system of woodcock habitat demonstration areas has been developed throughout the primary woodcock breeding range where specific best management practices (BMPs) are applied (Wildlife Management Institute 2010). These areas are meant to demonstrate management practices to increase the amount and improve the quality of existing breeding habitat to encourage increases in woodcock breeding population density and size.

Application of BMPs at a demonstration-area scale (~200–800 ha) is designed to positively influence woodcock population growth by improving habitat quality and abundance at a landscape scale. BMPs create or maintain young forest cover through clear-cutting, timber harvest, shearing of brush and small trees, and prescribed burning (Wildlife Management Institute 2009). BMPs are applied at specific sites within the larger landscape, but when applied at multiple locations at the demonstration-area scale, they create a juxtaposed mosaic of young forest cover of different age classes that provides courtship, nesting, brood-rearing, and diurnal feeding habitat for woodcock. Woodcock abundance is known to increase in response to vegetation management (Dwyer et al. 1988, McAuley et al. 1996); therefore, increasing the amount of young forest cover at the demonstration-area scale is assumed to increase woodcock population size. The influence of BMPs applied at a landscape scale on woodcock vital rates is not well understood in the Central Management Region, although there are some woodcock survival-rate estimates in the eastern portion of the woodcock breeding range where BMPs have been applied (Dwyer et al. 1988; McAuley et al. 1996, 2010; Longcore et al. 2000). These studies were completed prior to the establishment of demonstration areas, making it difficult to relate survival rates with application of BMPs at the demonstration-area scale.

We evaluated woodcock vital rates in an area where BMPs were applied at the demonstration-area scale in the western portion of the woodcock breeding range by assessing adult female, nest, and juvenile survival rates and factors associated with these rates. Our specific objectives were to (1) describe characteristics of nest sites and locations used by woodcock broods potentially related to survival rates, (2) estimate adult female, nest, and juvenile survival rates of woodcock at a demonstration-area scale, and (3) assess relationships between survival rates and vegetation structure (e.g., stem density, distance to edge, and basal area) resulting from BMPs, life history traits (e.g., date of nest initiation, number of nesting attempts, and female reproductive status), and weather (e.g., precipitation, maximum temperature, and minimum temperature). We expected that woodcock survival rates would be positively related to conditions resulting from BMPs applied at a demonstration-area scale, and that survival rates would be related to characteristics of cover types, life history, and weather, based on relationships reported previously (e.g., Dwyer et al. 1988).

## Study Area

We conducted our study at the Tamarac National Wildlife Refuge (NWR), located near Rochert, Minnesota, USA (47.0 N, -95.7 E), during spring and summer 2011 and 2012. Tamarac NWR lies in the glacial lake country of west-central Minnesota in Becker County and encompasses 17,296 ha dominated by forests, intermingled with lakes, rivers, marshes, shrub swamps, and tallgrass prairie. Tamarac NWR is located in the transition zone between coniferous forest, northern hardwood forest, and tallgrass prairie. Sixty percent of the refuge is forested; the dominant tree species are aspen (*Populus* spp.), jack pine (*Pinus banksiana*), red pine (*P. resinosa*), balsam fir (*Abies balsamea*), paper birch (*Betula papyrifera*), northern red oak (*Quercus rubra*), white oak (*Q. alba*), sugar maple (*Acer saccharum*), and basswood (*Tilia americana*). A substantial portion of the refuge is managed for early successional forest (consistent with BMPs; Wildlife Management Institute 2009), primarily through timber harvest, shearing, and prescribed fire, to provide courtship, nesting, and brood-rearing habitat for woodcock, golden-winged warblers (*Vermivora chrysoptera*), and other migratory birds that utilize young forests.

## Methods

### CAPTURE AND RADIO TELEMETRY

In 2011 and 2012 we captured and equipped adult female and juvenile woodcock with VHF radio transmitters at

Tamarac NWR, where BMPs had been applied during the past 20-year period. In March – June of 2011 and 2012, we used mist nets to capture woodcock during dusk (approximately 1900 to 2300 CDT) when woodcock leave diurnal areas to roost or feed (Sheldon 1971). We determined sex of all woodcock captured based on plumage characteristics (Martin 1964) and radio-marked adult female woodcock using a glue-on backpack-style harness that was ≤3% of their total mass (~4.8 g, model A5410, Advanced Telemetry Systems, Isanti, MN; McAuley et al. 1993*a*, 1993*b*). We relocated radio-marked female woodcock from the time that we released them through late June or early July of each year to estimate survival rate during the courtship, nesting, and brood-rearing periods, and for the beginning of the period following brood break-up and prior to migration. We relocated radio-marked female woodcock 5–7 days per week throughout the breeding season (April – June) and into the beginning of the pre-migration season (July – October). We lost radio contact with some females when they traveled long distances, out of the range of our receiving equipment and monitoring protocol. We continued searching for these females throughout our field season and if we did not relocate them, we classified these females as "lost." When we relocated an adult female radio-marked woodcock, we assessed its status (i.e., alive or dead) and assigned it to 1 of 4 categories related to reproduction: pre-nesting, incubating, brood-rearing, or pre-migration. If a radio-marked woodcock was dead when relocated, we assessed the cause of death, and if possible, assigned the cause of death as either mammalian or avian predation using methods described by McAuley et al. (2005). Pre-nesting included the time from capture until egg laying and also the period between nest or brood loss and renesting. If a female renested following a failed nesting or brood-rearing attempt, we categorized her status as pre-nesting between loss of eggs or young and initiation of another nesting attempt. Incubation was the period between the beginning of egg laying and either loss of the nest or until eggs hatched. Brood rearing was the period from when eggs hatched to the loss of all juveniles in the brood or fledging (15 days post-hatch). Pre-migration was the period from the end of breeding activity (i.e., date of fledge or loss of a brood or nest without a re-nesting attempt) until we last knew whether a female woodcock was alive or dead.

We found woodcock nests using trained pointing dogs (McAuley et al. 1993*a*) and via monitoring radio-marked adult females. We visited each nest at 2–3 day intervals and assessed the status of the nest as active, depredated, abandoned, or successful. If the female was not present at the nest or flushed during our visit, we floated any eggs present in ambient-temperature water to estimate nest age and initiation date (Ammann 1974). We considered nests to be active when the adult female was engaged in egg-laying or incubation, or if a female was incubating at a subsequent visit. We categorized nests as depredated if eggs were broken or absent prior to the estimated hatch date. We categorized nests as abandoned if the female was not observed incubating for 2 consecutive visits. We categorized nests as successful if there was evidence that ≥1eggs hatched (i.e., eggshells in or close to the nest bowl and with a longitudinal split).

To estimate survival rate of juvenile woodcock, we assessed the status of juveniles in broods of radio-marked adult females and also radio-marked a sample of juveniles within broods of radio-marked adult females. We used trained pointing dogs to find additional broods of unmarked adult female woodcock (Mendall 1938; Ammann 1974, 1977) and captured and radio-marked juveniles in those broods. We custom fit a micro-transmitter (BD-2NC or BD-2C, Holohil Systems Ltd., Carp, ON and custom transmitters made by Blackburn Transmitters, Nacogdoches, TX) with a whip antenna to captured juvenile woodcock by means of an elastic collar. All transmitter packages were ≤3% of a woodcock's mass (BD-2NC transmitters were approximately 0.6 g, BD-2C transmitters were approximately 1.6 g, and Blackburn transmitters were approximately 0.4 g). We attached transmitters to juvenile woodcock with an elastic collar that expanded as the juvenile woodcock grew. We positioned transmitters at the base of a juvenile woodcock's neck with the transmitter antenna lying down the juvenile's back (Daly et al. 2015). Transmitter lifespan was approximately 21 days (17–30 day range) for BD-2NC transmitters, 63 days (49–77 day range) for BD-2C transmitters, and 28 days (24–32 day range) for Blackburn transmitters.

We radio-marked 1–4 juveniles per brood and monitored both marked and unmarked individuals within a brood after locating radio-marked juveniles. We located broods 4–7 days per week via radio telemetry monitoring of either the adult female or juvenile(s). We assessed status (alive or dead) of juveniles and counted both marked and unmarked juveniles to document brood size. We counted the number of individuals in the brood using radio telemetry to approach a radio-marked woodcock to a distance of approximately 5 m and then encircled the brood until we were certain we detected and counted all brood members. Beginning approximately 15 days after hatching, entire broods often flushed upon our approach, affording us the opportunity to simultaneously count the number of juveniles in a brood. Beyond 15 days post-hatch, the probability of detecting all members of the brood diminished as individuals from broods became more dispersed until we no longer considered them associated with one another. Federal and State permits for capture, banding, and radio-marking were granted by the U.S. Geological Survey Bird Banding Laboratory (Permit no. 06258, Wayne Bruninger), and by the Minnesota Department of Natural

Resources (Permit nos. 17377 and 17973, Wayne Brininger). Capture and marking protocols were approved by the University of Minnesota Institutional Animal Care and Use Committee under Protocol no.1103A97333.

### NEST SITE AND BROOD LOCATION VEGETATION

We measured stem density (STEM), basal area (BAS), and distance to edge (EDGE) at a subset of woodcock brood locations and at all nest locations. We measured vegetation structure using plot-based methods modified from McAuley et al. (1996), centering plots 0.4 ha in area (11.3 m radius) at nests and brood locations. We counted the number of trees in 5 size-classes adapted from James and Shugart (1970) based on diameter at breast height (DBH; 7.6 – 15.2 cm, 15.3 – 22.9 cm, 23.0 – 38.1 cm, 38.2 – 53.3, and >53.3 cm), and estimated basal area (m2/ha, McAuley et al. 1996) by assigning each individual tree the average DBH for its assigned size class using the formula from Avery and Burkhart (2002):

$$\text{Basal Area} = 0.00007854 \times \text{DBH}^2$$

We then summed basal area for all trees in the plot to estimate basal area for the plot. To estimate woody stem density (stems/ha, McAuley et al. 1996), we established 4 belt transects beginning at the central point of the plot, 3 m in width and 20 m in length (0.006 ha), in 1 random azimuth in each quadrant (NE, SE, SW, NW). On each transect, we counted the number of woody stems <7.6 cm DBH and >1 m tall within the transect area and pooled the stem counts for the 4 transects to estimate stem density for the plot.

We defined edges as distinct changes in height of forest vegetation that were either anthropogenic (i.e., roads, trails, or forest clearcuts) or natural (i.e., forest openings or wetland edges) and measured distance to edge by visually interpreting changes in forest vegetation height using 1-m resolution aerial photographs (2010 photos) in ArcMap 10.0 (ESRI 2011). We summarized vegetation characteristics by year at both nest sites and brood locations, and compared between years using t-tests.

### FEMALE, NEST, AND JUVENILE SURVIVAL RATES

We used the Kaplan-Meier method with staggered entry (Pollock et al. 1989) using the KMsurv package in Program R (version 2.15.2, R Core Team, 2012, Vienna, Austria) to estimate survival rate of adult females, nests, and juveniles. We estimated survival rate of adult females, nests, and juveniles separately for 2011 and 2012, because all these vital rates are known to vary temporally. We also estimated adult female survival rate pooled across years to compare our results with other published estimates of female survival rates. We estimated survival rates for the biological period defined by the data for 2011 (11 April – 30 June) and 2012 (1 April – 29 June), then calculated daily survival rate (DSR) estimates from these period survival rate (PSR) estimates. We extrapolated the DSR estimates over the same-length period for 2011 and 2012 to compare survival rate between years. We also estimated female survival rate combined for both 2011 and 2012 using data pooled from both years. For female woodcock we estimated survival rate for a 91-day period (1 April – 30 June). We estimated nest survival rate using a 24-day period that included 3 days for egg laying and 21 days for incubation. We estimated juvenile survival rate for a 61-day period (1 May – 30 June), which represented the period from hatching to mid-summer when juveniles are independent from adult care. Because we were not able to accurately determine the fate of unmarked juveniles after the brood separated (~24 days old), we right-censored unmarked juveniles at 24 days old, which was the earliest we observed brood separation.

We recorded the number of days from when we deployed transmitters on females and juveniles to more accurately censor individuals if radio transmitters failed prematurely. We assumed radios failed if they performed irregularly and there was no other indication an individual had died. We also assumed radios failed if they were nearing the end of their expected battery life and we received no subsequent signals from transmitters. We right-censored individuals in both of these circumstances, assuming the individual survived until transmitter failure (Korschgen et al. 1996).

### SURVIVAL RATE MODELS

For monitored females, nests, and juveniles, we used covariates for year, weather (i.e., maximum temperature, minimum temperature, and precipitation), and attributes of individuals (e.g., juvenile age) to create a set of models of survival rate (see Appendix I for a description of model covariates and expected relationships with survival rates). We also incorporated vegetation-structure covariates (i.e., stem density, basal area, and distance to nearest edge) in models of nest survival rate and juvenile survival rate (see below and Appendix I).

*Temporal covariates* We included year (YEAR, 2011 or 2012) as a class variable in our models to account for between-year variation in survival rates because survival rates of females, nests, and juveniles can vary among years (Gregg 1984, Longcore et al. 2000, McAuley et al. 2010). We also assessed the influence of the YEAR covariate *post hoc* by repeating our model selection (see below) procedure without that covariate in our candidate model set. Removing YEAR as a covariate in models did not result in changes in relations between survival and other covariates (unpublished data), and we therefore only report results using models that included YEAR as a covariate.

*Covariates related to weather* We included weather covariates in our survival rate models because weather early in the breeding season influences woodcock recruitment (Sepik et al. 2000). We obtained daily weather data from a standard 20.3-cm diameter precipitation gauge and digital temperature logger (Nimbus Digital Thermometer, Sensor Instruments Company Inc., NH) at Tamarac NWR during 2011 and 2012. Precipitation and temperature data were recorded approximately 6 to 8 km southeast of the location where we monitored woodcock. If precipitation and temperature data from Tamarac NWR were not available, we used weather data from the nearest National Weather Service station in Detroit Lakes, Minnesota (approximately 22 km southeast of Tamarac NWR). We used the sum of precipitation (cm) for each day in the interval between individual woodcock observations to calculate total interval precipitation (PCPT). We used the recorded maximum (MAXT) and minimum (MINT) temperatures (°C) during each interval between observations in models of survival rate of woodcock females, nests, and juveniles.

*Covariates related to individual woodcock* Because reproductive status influences behavior and energetic requirements of female woodcock (Rabe et al. 1983), we modeled survival rate including 4 categories of reproductive status (REPRO: pre-nesting, incubating, brood rearing, and pre-migration). We could not clearly define period lengths for each reproductive status because these periods varied with each individual; therefore, we used Mayfield's method (Mayfield 1961, Johnson 1979) to estimate female daily survival rates for reproductive status and compared daily survival rate estimates among reproductive status categories. We also included a covariate indicating whether females were with broods (BROOD) in our models of adult female survival rate.

We included age and hatch date in our models of juvenile survival rate and calculated juvenile age by knowing the hatch date of juveniles or estimating age at capture based on bill-length measurements (Ammann 1982, Sepik 1994). Because intervals between relocations of individual broods were short, we used the age of a juvenile at the midpoint of the interval in our survival rate models. We estimated Julian hatch date (HD) by either monitoring nests of radio-marked females or by aging juveniles at the time of capture and deriving HD based on juvenile age. Because we monitored nests of radio-marked females every 2–3 days, we generally were able to estimate HD within 1 day.

Woodcock are known to readily renest; however, only 1 re-nest per female has ever been observed in a single breeding season (McAuley et al. 1990, KOD personal observation). Woodcock generally renest following a failed nest or if they lose a brood <11 days old (McAuley et al. 1990). We were unable to assess whether most nests in our study were first nests or renesting attempts; therefore, we could not include nesting attempt as a covariate in our analysis. We estimated nest initiation date by floating eggs in ambient-temperature water (Ammann 1974) at nest discovery, or by monitoring nests until hatch and back dating 24 days.

For our survival rate analyses where we were missing covariate data, we used the mean covariate value for that year if <5% of the data were missing (e.g., if initiation date was not known for a nest, we used the average nest initiation date for all nests for which we knew the nest initiation date that year). If ≥5% of the data were missing, we excluded all observations with missing covariate data from analysis.

We developed logistic-exposure female, nest, and juvenile survival-rate models (Shaffer 2004) in SAS 9.3 (SAS Institute Inc., NC) to evaluate relationship(s) that considered both weather and individual characteristics (e.g., female reproductive status, see below). We also used logistic-exposure models to assess the relationship(s) between vegetation characteristics and survival rates of nests and juveniles. We evaluated models using a sequential approach (e.g., Amundson and Arnold 2010, Daly et al. 2015) in an information-theoretic framework (Burnham and Anderson 2002). We incorporated YEAR in each model of survival rate of females, nests, and juveniles to assess whether survival rates differed between 2011 and 2012 and to account for reported differences in woodcock survival rates among years (Gregg 1984, Longcore et al. 2000, McAuley et al. 2010; and as noted above, excluding YEAR from models did not change relationships between other covariates and survival rates).

We included a null model (no covariates) in our set of candidate models as a means of evaluating whether including covariates in models of survival rate was supported by our data. During each step of our modeling process subsequent to the initial model, we added covariates to the best-supported model from the previous step individually and in all combinations and ranked models based on Akaike's Information Criterion adjusted for sample size ($AIC_c$) to identify the best-supported model among all candidate models. We defined our best-supported model as the model with the lowest $AIC_c$ ($\Delta AIC_c = 0$) and competing models as any models with $\Delta AIC_c \leq 2$. We considered covariates uninformative if they did not reduce overall $AIC_c$ when added to the best-supported model from the previous step (Arnold 2010). We did not consider models containing uninformative covariates to be competitive with our best-supported model, and excluded them from subsequent analyses.

In all of our best-supported models, we used the ESTIMATE statement in SAS 9.3 (SAS Institute Inc., NC) to assess the relationship(s) between daily survival rate and individual covariates in the best-supported model by entering multiple values representing the range of observed values for that covariate while holding the other model variables constant at their mean values. We assessed the strength of relationships between survival rates and covariates based on whether 95% confidence intervals included zero.

*Female survival rate models* We added reproductive status of female woodcock (REPR) to the model including only YEAR from Step 1 for our second step of modeling female survival rate. We only considered the covariates NEST and BROOD if REPR was an informative variable (i.e., reduced overall $AIC_c$ when compared with the initial model) in our best-supported model because both NEST and BROOD were correlated with the reproductive status of the female (REPR). For Step 3, we added weather covariates (PCPT, MINT, and MAXT) to our best-supported model from Step 2 to assess the relationship between weather and female survival rate.

*Nest survival rate model development* We added INIT and NAGE as nest-specific covariates to the model from Step 1 that included only the YEAR covariate. For Step 3, we then added weather covariates to the best-supported model from Step 2 to evaluate the relationship between weather and survival rate of woodcock nests. Finally, in Step 4, we added STEM, BAS, and EDGE to evaluate the relationship between nest survival rate and vegetation characteristics.

*Juvenile survival rate model development* Survival rate of individual juveniles may not be independent from survival rate of other individuals of the same brood (Chouinard and Arnold 2007, Amundson and Arnold 2010). Therefore, we evaluated whether survival rate was independent among individual juveniles within broods using Winterstein's (1992) third Chi-square goodness-of-fit test (average *P* = 0.3238; Appendix 11) in a re-analysis of survival data presented and analyzed in Daly et al. (2015); neither assessment indicated intra-brood dependence among survival rates of brood mates. Daly et al. (2015) also evaluated whether radio transmitters affected survival rate of juveniles and found no evidence of effects on survival rate. We therefore treated individual juveniles as independent samples in subsequent survival rate analyses.

We added JAGE, HD, and the interaction between HD and YEAR to the model from Step 1 that included only the YEAR covariate. We included the interaction between HD and YEAR in models of juvenile survival rate because annual changes in temperature and precipitation affect the timing of woodcock breeding (Murphy and Thompson 1993). Next, in Step 3, we added weather covariates (MAXT, MINT, and PCPT) to the best-supported survival rate model from Step 2 to account for relationships between weather conditions and survival rate of juvenile woodcock.

To evaluate additional relationships between vegetation characteristics and juvenile survival rate, we conducted *post hoc* analyses by considering STEM, BAS, and EDGE as covariates in models of juvenile survival rate. We assessed these covariates in *post hoc* analyses because only a subset of juvenile locations had associated vegetation characteristic data. To the best-supported model from our models of juvenile survival rate, we added STEM, BAS, and EDGE singularly and in all possible combinations. We used the best-supported model from our *post hoc* analysis to assess the relationships between daily juvenile survival rate and covariates included in the model.

## Results

### VEGETATION CHARACTERISTICS

*Nest vegetation characteristics* We measured vegetation characteristics (stem density, basal area, and distance to edge) at 45 nest locations (Table 1). Nests in 2011 and 2012 had similar stem densities; nests in 2011, however, had greater basal area and were farther from edges than nests in 2012 (Table 1).

**Table 1.** Comparisons of vegetation characteristics surrounding American woodcock nests in 2011 (*n* = 22) and 2012 (*n* = 23) and juvenile American woodcock locations in 2011 (*n* = 116) and 2012 (*n* = 119) at Tamarac National Wildlife Refuge, Rochert, Minnesota, USA.

| Vegetative characteristic | Year | $\bar{x}$ (SD) | t-statistic | Df | P |
|---|---|---|---|---|---|
| **Woody Stem Density (stems/ha)** | | | | | |
| Nests | 2011 | 12,113 (8,358) | | | |
| | 2012 | 10,216 (4,297) | 0.95 | 31 | 0.35 |
| Juveniles | 2011 | 11,588 (5917) | | | |
| | 2012 | 13,834 (5566) | −2.07 | 88 | 0.04 |
| **Basal Area ($m^2$/ha)** | | | | | |
| Nests | 2011 | 7.7 (13.7) | | | |
| | 2012 | 29.3 (36.9) | −2.62 | 28 | 0.01 |
| Juveniles | 2011 | 11.9 (13.9) | | | |
| | 2012 | 18.4 (17.3) | −2.16 | 80 | 0.03 |
| **Distance to Edge (m)** | | | | | |
| Nests | 2011 | 45.3 (72.2) | | | |
| | 2012 | 16.1 (23.6) | 1.80 | 25 | 0.08 |
| Juveniles | 2011 | 75.1 (86.6) | | | |
| | 2012 | 55.6 (55.7) | 2.04 | 195 | 0.02 |

*Brood-rearing vegetation characteristics* We measured vegetation characteristics (woody stem density, basal area, and distance to edge) at 121 woodcock brood locations (2011: *n* = 66, 2012: *n* = 43) representing 45 juvenile woodcock (2011: *n* = 22, 2012: *n* = 23) from 14 broods (2011: *n* = 8, 2012: *n* = 6). Woody stem density and basal area at juvenile woodcock locations were higher in 2012 than in 2011 (Table 1). Woodcock brood locations were closer to edges in 2012 than in 2011 (Table 1).

### SURVIVAL RATES

Female survival rates From 9 April to 1 June 2011 and 22 March to 24 May 2012, we captured and radio-marked 41 adult female woodcock (2011: *n* = 23, 2012: *n* = 18). We excluded 3 (~7%) radio-marked adult female woodcock in 2011 from survival-rate analysis that we were unable to relocate following radio marking (likely due to transmitter failure or migration). Of the remaining 38 female woodcock, we right censored 1 female that became entrapped in its radio telemetry harness in 2012.

In 2011 and 2012, we observed 692 intervals and 2,149 exposure days of radio-marked adult female woodcock. Intervals averaged 3.1 days between relocations and ranged from 1 day to 40 days (although intervals were generally short, 1 female left the search area and later returned and was relocated alive after 40 days). Seven of 38 (~18%) adult females were killed by predators during our study (2011: *n* = 4, 2012: *n* = 3). Mammalian predation was the highest source of mortality (*n* = 4), with the remainder attributed to raptors (*n* = 3). Mortalities of female woodcock occurred during pre-nesting (*n* = 2), nesting (*n* = 2), brood-rearing (*n* = 1), and pre-migration periods (*n* = 2). Daily survival rate estimated using Mayfield's method (Mayfield 1961, Johnson 1979) was nearly constant across reproductive status [pre-nesting = 0.9946 (95% CI: 0.9871 – 1.0021), nesting = 0.9958 (95% CI: 0.9900 – 1.0016),

**Table 2.** Comparison of American woodcock survival rate estimates for adult females, nests, and juveniles from Tamarac National Wildlife Refuge, Rochert, Minnesota, USA, in 2011 and 2012, and American woodcock survival rate estimates from previous studies. Period survival rates (PSR) are estimated for the breeding season for adult females and juvenile woodcock. PSR for female woodcock were calculated from daily survival rates (DSR) for a 91-day period, for juvenile woodcock for a 61-day period, and for woodcock nests for 24-day egg-laying and incubation period.

| PSR (95% CI) | DSR (95% CI) | Year(s) | Source |
|---|---|---|---|
| **Females** | | | |
| 0.695[a] (0.357 – 1.052) | 0.996 (0.989 – 1.001) | 2011 | This study |
| 0.740[a] (0.391 – 1.091) | 0.997 (0.990 – 1.001) | 2012 | This study |
| 0.751 (0.499 – 1.000) | 0.997 (0.992 – 1.000) | 2011 – 2012 | This study |
| 0.913[a] (0.833 – 1.000) | 0.999 (0.998 – 1.000) | 1982 – 1984 | Derleth and Sepik 1990 |
| 0.761[a] (0.694 – 0.913) | 0.997 (0.996 – 0.999) | 1986 – 1989 | Longcore et al. 2000 |
| **Nests** | | | |
| 0.458[a] (0.299 – 0.696) | 0.968 (0.951 – 0.985) | 2011 | This study |
| 0.786[a] (0.616 – 1.000) | 0.990 (0.980 –1.000) | 2012 | This study |
| 0.62[b] | | 1943 | Mendall and Aldous 1943 |
| 0.43[c] | | 1969 – 1980 | Gregg 1984 |
| 0.59[b] | | 1986 – 1989 | McAuley et al. 1996 |
| **Juveniles** | | | |
| 0.330[a] (0.188 – 0.613) | 0.982 (0.973 – 0.992) | 2011 | This study |
| 0.576[a] (0.398 – 0.833) | 0.991 (0.985 – 0.997) | 2012 | This study |
| 0.166[d] (0.073 – 0.374) | 0.971 (0.958 – 0.984) | 1976 – 1979 | Dwyer et al. 1988 |
| 0.613[c] (0.274 – 0.885) | 0.992 (0.979 – 0.998) | 1984 – 1985 | Wiley and Causey 1987 |
| 0.833[a] (0.693 – 1.000) | 0.997 (0.994 – 1.000) | 1982 – 1984 | Derleth and Sepik 1990 |
| 0.114[a] (0.073 – 0.177) | 0.965 (0.958 – 0.972) | 1986 – 1989 | McAuley et al. 2010 |

[a] Kaplan-Meier estimates. [b] Apparent survival, 95% CI not available. [c] Mayfield method used, no variation reported. [d] Closed population mark-recapture model estimates.

brood-rearing = 0.9964 (95% CI: 0.9895 – 1.0034), and pre-migration = 0.9980 (95% CI: 0.9952 – 1.0008)]. Breeding-season cumulative survival rate for adult females from 1 April – 30 June based on Kaplan-Meier estimates was 0.695 (95% CI: 0.357 – 1.052) in 2011, 0.740 (95% CI: 0.391 – 1.090) in 2012, and 0.751 (95% CI: 0.499 – 1.000) for both years combined (Table 2).

*Nest survival rate* We monitored 52 woodcock nests (2011: $n = 26$, 2012: $n = 26$) from 4 May to 11 June 2011 and from 9 April to 9 June 2012. We censored 4 nests from our analysis (1 in 2011 and 3 in 2012). Of the 45 nests we included in our analyses, eggs failed to hatch in 21 (~47%) and eggs that failed to hatch were either depredated (71%) or abandoned by the female (29%). Kaplan-Meier cumulative survival rate estimates for a 24-day laying and incubation period for nests were 0.455 (95% CI: 0.297 – 0.696) in 2011 and 0.786 (95% CI: 0.620 – 0.995) in 2012 (Table 2).

*Juvenile survival rate* From 16 May to 29 June 2011 and 20 April to 16 June 2012, we radio-marked 73 (2011: $n = 22$, 2012: $n = 51$) juvenile woodcock from 51 broods (2011: $n = 16$, 2012: $n = 35$). We assigned fates to 134 juvenile woodcock (2011: $n = 63$, 2012: $n = 71$), including fates of 49 marked and 85 unmarked juveniles from 47 broods (2011: $n = 23$, 2012: $n = 24$), resulting in an effective sample size of 859 observation intervals. We excluded data from 24 marked juvenile woodcock due to uncertainty regarding transmitter failure (i.e., we did not know if the transmitter failed or if the juvenile was depredated). Cumulative survival rate for juvenile woodcock based on Kaplan-Meier estimates for the 61-day period from 1 May – 30 June was 0.330 (95% CI: 0.188 – 0.613) in 2011 and 0.576 (95% CI: 0.398 – 0.833) in 2012 (Table 2).

### SURVIVAL RATE MODELS

*Female survival rate* Our best-supported model of adult female woodcock survival rate was the null model (Table 3), suggesting that female survival was relatively constant between 2011 and 2012. Although we constructed our base model to include YEAR to account for differences in survival between 2011 and 2012, survival was similar between years ($\beta_{2011}$= −0.16, 95% CI: −1.67 to 1.45) and a null model that excluded year effects had a lower AIC$_c$ ($\Delta$AIC$_c$ = 1.94, Table 3). No other covariates were related to survival of adult females. Models that included MINT, MAXT, and PCPT were within 2 AIC$_c$ units of our best-supported model (Table 3); we considered these covariates to be uninformative, however, because they did not reduce AIC$_c$ relative to the simpler, higher-ranked model (Arnold 2010). Because there was no evidence to suggest that REPR was related to female woodcock survival rate (Table 3), we did not assess the relationship(s) between female survival rate and NEST and BROOD in *post hoc* analyses.

*Nest survival rate* Our best-supported model of nest survival rate included only YEAR, with no difference in survival rate between 2011 and 2012 ($\beta_{2011}$= −0.768, 95% CI: −1.70 to 0.166, Table 4). Addition of other covariates did not result in competitive models (Table 4).

*Juvenile survival rate* Our best-supported model of juvenile woodcock survival rate included YEAR, JAGE, MINT, and PCPT (Table 5). In our best-supported model, 95% confidence intervals around coefficient estimates for YEAR ($\beta_{2011}$= −0.85, 95% CI: −1.77 to 0.07) and MINT

**Table 3.** Model-selection results and models of American woodcock adult female survival rate at Tamarac National Wildlife Refuge, Rochert, Minnesota, USA, in 2011 and 2012. Models consider reproductive status (REPR; pre-nesting, incubating, brood-rearing, or pre-migration), maximum and minimum temperature (MAXT and MINT), and precipitation (PCPT). Models were ranked according to the difference in Akaike's information criterion ($\Delta$AIC$_c$; AIC$_c$ of top-ranked model = 71.25) adjusted for sample size *(n* = 2,091 intervals) within steps. Akaike model weights ($\omega_i$) and number of estimable parameters (K) are presented for each model. Null model includes only an intercept and no covariates and is presented as reference. Sequential model development started with an initial model including only a YEAR. Step 2 included the addition of the REPR covariate and Step 3 included the addition of weather-related covariates.

| Model step | Model | AIC$_c$ | $\Delta$AIC$_c$ | $\omega_i$ | K |
|---|---|---|---|---|---|
| | Null | 71.21 | -- | -- | 1 |
| Initial model | YEAR | 73.15 | -- | -- | 2 |
| Step 2 | YEAR [a] | 73.15 | 0.00 | 0.92 | 2 |
| | YEAR+REPR | 78.06 | 4.91 | 0.08 | 6 |
| Step 3 | YEAR [b] | 73.15 | 0.00 | 0.29 | 2 |
| | YEAR+MINT | 73.74 | 0.59 | 0.21 | 3 |
| | YEAR+PCPT | 74.89 | 1.74 | 0.12 | 3 |
| | YEAR+MAXT | 75.11 | 1.96 | 0.11 | 3 |
| | YEAR+MINT+PCPT | 75.27 | 2.12 | 0.10 | 4 |
| | YEAR+MAXT+MINT | 75.61 | 2.46 | 0.08 | 4 |
| | YEAR+MAXT+PCPT | 76.64 | 3.49 | 0.05 | 4 |
| | YEAR+MAXT+MINT+PCPT | 77.27 | 4.12 | 0.04 | 5 |

[a] Indicates best-supported model for each step, model moved on to next step in analysis.

[b] Indicates best-supported overall model; AIC$_c$ of top-ranked model = 73.15.

($\beta_{MINT}$ = 0.14, 95% CI: −0.004 to 0.28) included zero, indicating no statistically significant relationship with survival rate of juvenile woodcock (Table 5). JAGE ($\beta_{AGE}$ = 0.098, 95% CI: 0.04 to 0.16) was positively associated with juvenile survival rate and PCPT ($\beta_{PCPT}$ = −0.20, 95% CI: −0.39 to −0.01) was negatively associated with juvenile survival rate. Daily survival rate of juvenile woodcock decreased approximately 0.007 for each additional cm of precipitation during the interval between subsequent locations. Juvenile daily survival rate increased approximately 0.002 for each additional day of age up to 15 days old.

We considered covariates related to vegetation structure in our *post hoc* analysis of juvenile survival rate. STEM was the only covariate related to vegetation characteristics to decrease $AIC_c$ when added to our best-supported model based on our sequential analysis (Table 6). STEM had a significant positive relationship with juvenile woodcock survival rate ($\beta_{STEM}$ = 0.0001, 95% CI: 0.000 to 0.0003). Juvenile daily survival rate increased with stem density, resulting in a 0.006 increase in survival for every additional 10,000 stems/ha.

## Discussion

Understanding the relationship(s) between BMPs applied at a demonstration-area scale and woodcock vital rates can help elucidate how the application of BMPs at this scale may affect local population dynamics and growth rates. Although female, juvenile, and nest survival rates have been estimated previously for woodcock, these estimates are limited to the eastern portion of their breeding range (e.g., Wiley and Causey 1987, Derleth and Sepik 1990, Krementz and Berdeen 1997, Longcore et al. 2000) and estimates of these vital rates are not available at the demonstration-area scale.

Our estimates of survival rates of females and nests were lower than those reported from other studies (Table 2; Mendall and Aldous 1943, Gregg 1984, Derleth and Sepik 1990, McAuley et al. 1996, Longcore et al. 2000) and our estimates of juvenile survival rate were similar to (Gregg 1984, Wiley and Causey 1987) or higher than survival rate estimates reported elsewhere (Table 2; Dwyer et al. 1988, McAuley et al. 2010). These previous studies also were conducted in areas where management for woodcock had been implemented. Woodcock are known to respond to vegetation management and select suitable

**Table 4.** Model-selection results and models of American woodcock nest survival rate at Tamarac National Wildlife Refuge, Rochert, Minnesota, USA, in 2011 and 2012. Models consider nest age (NAGE), nest initiation date (INIT), maximum and minimum temperature (MAXT and MINT), precipitation (PCPT), woody stem density (STEM), basal area (BAS), and distance to edge (EDGE). Models were ranked according to the difference in Akaike's information criterion ($\Delta AIC_c$; $AIC_c$ of top-ranked model = 140.51) adjusted for sample size (*n* = 548). Akaike model weights ($\omega_i$) and number of estimable parameters (K) are also presented. Null model includes only an intercept and no covariates and is presented as reference. Sequential model development started with an initial model including only a YEAR covariate. Step 2 included the addition of AGE and INIT covariates, Step 3 included the addition of weather-related covariates, and Step 4 included the addition of vegetation structure covariates.

| Model step | Model | $AIC_c$ | $\Delta AIC_c$ | $\omega_i$ | K |
|---|---|---|---|---|---|
| | Null | 141.66 | -- | -- | 1 |
| Initial model | YEAR | 140.95 | -- | -- | 2 |
| Step 2 | YEAR [a] | 140.95 | 0.00 | 0.48 | 2 |
| | YEAR+NAGE | 142.38 | 1.43 | 0.24 | 3 |
| | YEAR+INIT | 142.81 | 1.86 | 0.19 | 3 |
| | YEAR+NAGE+INIT | 144.29 | 3.34 | 0.09 | 4 |
| Step 3 | YEAR [a] | 140.95 | 0.00 | 0.27 | 2 |
| | YEAR+MAXT | 141.88 | 0.93 | 0.17 | 3 |
| | YEAR+MAXT+MINT | 142.33 | 1.38 | 0.13 | 4 |
| | YEAR+MINT | 142.41 | 1.46 | 0.13 | 3 |
| | YEAR+PCPT | 142.46 | 1.68 | 0.12 | 3 |
| | YEAR+MAXT+PCPT | 143.74 | 2.79 | 0.07 | 4 |
| | YEAR+MINT+PCPT | 143.82 | 2.87 | 0.06 | 4 |
| | YEAR+MAXT+MINT+PCPT | 144.23 | 3.27 | 0.05 | 5 |
| Step 4 | YEAR [b] | 140.95 | 0.00 | 0.29 | 2 |
| | YEAR+STEM | 141.48 | 0.53 | 0.22 | 3 |
| | YEAR+EDGE | 142.86 | 1.91 | 0.11 | 3 |
| | YEAR+BAS | 142.93 | 1.98 | 0.11 | 3 |
| | YEAR+STEM+EDGE | 143.06 | 2.11 | 0.10 | 4 |
| | YEAR+STEM+BAS | 143.34 | 2.39 | 0.09 | 4 |
| | YEAR+BAS+EDGE | 144.86 | 3.91 | 0.04 | 4 |
| | YEAR+STEM+BAS+EDGE | 144.94 | 3.99 | 0.04 | 5 |

[a] Indicates best-supported model for each step, model moved on to next step in analysis.

[b] Indicates best-supported overall model; $AIC_c$ of top-ranked model = 140.95.

managed areas for courtship, nesting, and brood-rearing (Dwyer et al. 1988, McAuley et al. 1996). Breeding woodcock are also known to select for a narrow range of vegetation structure and composition (McAuley et al. 1996). We did not observe any evidence of relationships between survival rates of nests and vegetation characteristics; we did, however, observe a slight positive relationship between juvenile survival rate and woody stem density. We likely had difficulty detecting relationships between survival rates and vegetation characteristics created by application of BMPs because female woodcock selected for a narrow range of vegetation characteristics for diurnal cover, nesting, and brood rearing.

### FEMALE SURVIVAL RATE

No covariates included in our analysis were associated with female woodcock survival rate, suggesting that female survival rate did not differ between years, with reproductive status, or in relation to the environmental conditions we observed. In contrast, Longcore et al. (2000) reported that survival rate of female woodcock breeding in Maine varied among years during the 4-year course of their study on an area that was managed for woodcock. Longcore et al. (2000) estimated mean female survival rate during the breeding season (1 April to 15 June) to be 0.810 for second-year females (females known to be in the second calendar year of life), and 0.815 for after-second-year females (females known to be in their third or later calendar year of life) in a similar radio-telemetry study in Maine. Derleth and Sepik (1990) reported post-breeding season (15 June – 20 October) survival rate of adult females ranged from 0.88 to 0.90. Our breeding-season survival rate estimates generally were lower than those reported by Longcore et al. (2000) for the same 76-day period (1 April to 15 June), and lower than their 4-year mean of 0.826, suggesting that females in the western portion of the breeding range of woodcock may survive at lower rates during the breeding season. However, some breeding-season survival rate estimates for years reported by Longcore et al. (2000) were similar to our estimates (Table 2), suggesting that adult female woodcock survival rate is variable among breeding seasons.

Inter-year variation in survival rate has been observed in woodcock in both the breeding season and during fall (Longcore et al. 2000, Bruggink et al. 2013). Longcore et al. (2000) attributed inter-year differences in survival rate to 1 year with lower female survival rate due to an extended period of nesting. We observed no relationship between reproductive status of females and survival rate (although

**Table 5.** Model-selection results and models of juvenile American woodcock survival rate at Tamarac National Wildlife Refuge, Rochert, Minnesota, USA, in 2011 and 2012. Models consider juvenile age (JAGE), hatch date (HD), maximum and minimum temperature (MAXT and MINT), precipitation (PCPT), woody stem density (STEM), basal area (BAS), and distance to edge (EDGE). Models were ranked according to the difference in Akaike's information criterion ($\Delta\text{AIC}_c$; $\text{AIC}_c$ of top-ranked model = 235.60) adjusted for sample size (*n* = 1,754). Akaike model weights ($\omega_i$) and number of estimable parameters (K) are also presented. Null model includes only an intercept and no covariates and is presented as reference. Sequential model development started with an initial model including only a YEAR covariate. Step 2 included the addition of AGE and HD covariates, and Step 3 included the addition of weather-related covariates.

| Model step | Model | $\text{AIC}_c$ | $\Delta\text{AIC}_c$ | $\omega_i$ | K |
|---|---|---|---|---|---|
| | Null | 245.59 | -- | -- | 1 |
| Initial model | YEAR | 247.10 | -- | -- | 2 |
| Step 2 | YEAR+JAGE [a] | 238.83 | 0.00 | 0.54 | 3 |
| | YEAR+JAGE+HD | 240.76 | 1.93 | 0.20 | 4 |
| | YEAR+JAGE+HD+(HD×YEAR) | 241.87 | 3.04 | 0.12 | 6 |
| | YEAR+JAGE+(HD×YEAR) | 241.86 | 3.04 | 0.12 | 5 |
| | YEAR | 247.10 | 8.27 | 0.01 | 2 |
| | YEAR+HD | 248.04 | 9.22 | 0.01 | 3 |
| | YEAR+HD+(HD×YEAR) | 248.15 | 9.32 | 0.01 | 5 |
| | YEAR+( HD×YEAR) | 248.15 | 9.32 | 0.01 | 4 |
| Step 3 | YEAR+JAGE+MINT+PCPT [b] | 235.03 | 0.00 | 0.28 | 5 |
| | YEAR+JAGE+MAXT+MINT+PCPT | 235.57 | 0.54 | 0.21 | 6 |
| | YEAR+JAGE+MAXT+PCPT | 236.22 | 1.19 | 0.15 | 5 |
| | YEAR+JAGE+PCPT | 236.81 | 1.78 | 0.11 | 4 |
| | YEAR+JAGE+MINT | 236.85 | 1.82 | 0.11 | 4 |
| | YEAR+MAXT+ +MINT | 238.22 | 3.19 | 0.06 | 5 |
| | YEAR+JAGE | 238.83 | 3.80 | 0.04 | 3 |
| | YEAR+MAXT | 239.38 | 4.35 | 0.03 | 4 |

[a] Indicates best-supported model for each step, model moved on to next step in analysis.

[b] Indicates best-supported overall model; $\text{AIC}_c$ of top-ranked model = 235.03.

we acknowledge that in our study, our power to detect differences among reproductive status categories was likely low), which suggests females may not be more vulnerable during nesting as speculated by Longcore et al. (2000) and reported for other ground-nesting species (e.g., Brasher et al. 2006). Female woodcock may be vulnerable to predation at a similar rate independent of their reproductive status due to their cryptic nature and relatively high mobility (Derleth and Sepik 1990).

Temperature and precipitation conditions varied considerably throughout our study; we did not, however, observe a relationship between female survival rate and minimum or maximum temperatures or precipitation. Longcore et al. (2000) found no relation between survival rate and minimum temperature in the spring. Females also may delay or reduce energetically costly behaviors (e.g., egg-laying and incubation) in spring if weather conditions are adverse or food availability is low, allowing for high survival rate of females during the spring (Rabe et al. 1983, Longcore et al. 2000). Females likely are able to withstand consistent temperatures below freezing because of their relatively large body size and associated increased thermoregulatory ability to conserve heat (Mendall and Aldous 1943, Longcore et al. 2000).

We did not assess the relationship between adult female survival rate and vegetation characteristics during the breeding season because our vegetation data were recorded only when females were associated with a nest or brood. Because few radio-marked female woodcock in our study died, our estimates of breeding-season survival rate were relatively high for both years, which constrained our ability to assess relationships between habitat characteristics and adult female survival rate. However, at less-fine categories [e.g., hardwoods, conifers, and alder (*Alnus* spp.)] of forest cover types in Maine, Longcore et al. (2000) detected survival rate differences of adult female woodcock among cover types.

### NEST SURVIVAL RATE

We found no relationships between year, initiation date, weather, or vegetation characteristics and survival rate of woodcock nests. Considerable differences can occur in nest-site selection when females return to breeding areas in spring, and snow depth likely influences availability of nest sites (Sepik et al. 1989, McAuley et al. 1990). Spring phenology (e.g., leaf-out timing) was much earlier in 2011 than 2012 on our study site, and snow depths in 2011 were substantially higher than in 2012 early in the nesting period.

We also suspect that difference in snow depth between 2011 and 2012 affected the timing of nesting; the mean initiation date in 2011 was 3 May (SE = 2.3 days) and in 2012 was 19 April (SE = 3.6 days). Roboski and Causey (1981) and Dwyer et al. (1988) also found nest initiation dates differed between years and suggested local weather conditions as the cause. In Missouri, Murphy and Thompson (1993) observed nest initiation peak when male displaying activity was highest, which also could be delayed if unfavorable weather conditions are present. Therefore, female woodcock likely are taking advantage of favorable weather conditions to nest, as suggested by Whiting (2006). If nest-site selection is dependent on early spring snow conditions, vegetation characteristics around nest sites are likely to vary among years. Our results indicated nest-site selection differed between years at our study site. Basal area was higher around nest locations in 2012, perhaps because lower snow depth that year made areas farther from edges and with more mature trees available for nesting. Although distance to edge may have been farther in 2011 than 2012, this may have been an artifact of our sample of females. In 2011, we captured a higher proportion of females prior to nesting than we did in 2012. In

**Table 6.** Model-selection results and models from *post hoc* analysis assessing the relationship of juvenile American woodcock survival rate and habitat covariates at Tamarac National Wildlife Refuge, Rochert, Minnesota, USA, in 2011 and 2012. Models consider juvenile age (JAGE), minimum temperature (MINT), precipitation (PCPT), woody stem density (STEM), basal area (BAS), and distance to edge (EDGE). We assessed our best-supported model from sequential analysis of juvenile survival (see text for explanation) and added all combinations of vegetation structure covariates to this best-supported model. Models were ranked according to the difference in Akaike's information criterion ($\Delta AIC_c$; $AIC_c$ of top-ranked model = 87.52) adjusted for sample size (*n* = 420); Akaike model weights ($\omega_i$) and number of estimable parameters (K) are also presented.

| Model | $\Delta AIC_c$ | $\omega_i$ | K |
|---|---|---|---|
| YEAR+JAGE+MINT+PCPT+STEM[a] | 0.00 | 0.38 | 6 |
| YEAR+JAGE+MINT+PCPT[b] | 1.90 | 0.15 | 5 |
| YEAR+JAGE+MINT+PCPT+STEM+BAS | 1.93 | 0.14 | 7 |
| YEAR+JAGE+MINT+PCPT+STEM+EDGE | 2.06 | 0.13 | 7 |
| YEAR+JAGE+MINT+PCPT+EDGE | 3.28 | 0.07 | 6 |
| YEAR+JAGE+MINT+PCPT+BAS | 3.89 | 0.05 | 6 |
| YEAR+JAGE+MINT+PCPT+STEM+BAS+EDGE | 4.01 | 0.05 | 8 |
| YEAR+JAGE+MINT+PCPT+EDGE+BAS | 3.99 | 0.02 | 7 |

[a] Indicates best-supported overall model, $AIC_c$ of top-ranked model = 91.50.

[b] Indicates the best-supported model from sequential analysis.

2012, we captured more females when they were already associated with a nest that we found by searching along edges with dogs, perhaps biasing our sample in that year to nests closer to edges (e.g., Peterson et al. 2015). We found no difference in woody stem densities between years, which suggests that woodcock selected for high woody stem densities independent of other nesting vegetation characteristics.

Woodcock select for nest sites with relatively low basal area and high woody stem density (McAuley et al. 1996). Woody stem density around nests in our study was similar to that in Maine (McAuley et al. 1996, also based on radio telemetry), where woody stem density was high ($\bar{x}$ = 13,919 stems/ha, SE = 1,688). Nest sites we found in 2011 had similar basal area as nest sites in Maine ($\bar{x}$ = 9.5 $m^2$/ha, SE = 1.0, McAuley et al. 1996); however, nest sites in 2012 had higher basal area than those in 2011 and than those reported by McAuley et al. (1996) in Maine. Our 2012 estimate of basal area surrounding nest sites is the highest reported to date (McAuley et al. 1996), which may have been due to the unseasonably early spring. Under the conditions we observed in 2012, woodcock may have selected more mature forest cover types for nesting if those areas had less snow and therefore afforded more available nest sites. Murphy and Thompson (1993) measured stem densities, basal area, and distance from field in a study of woodcock nest sites in Missouri; their average stem density and distance to field were considerably lower than our average stem density and distance to edge, but their estimates of basal area were similar to ours. The difference in these measurements could be due to a bias in their study because they only searched along edges to locate nests (Murphy and Thompson 1993).

Our apparent nest survival rate for both years combined (0.56) was similar to the apparent survival rate of 0.59 reported by McAuley et al. (1996), 0.62 reported by Mendall and Aldous (1943), and 0.26 – 0.51 reported by Gregg (1984) using Mayfield's method (Mayfield 1961). Although we found no evidence that inclement weather or nest initiation date was related to nest survival rate, a late-season snow storm occurred on 7–8 May 2011 and resulted in many nests being abandoned, suggesting extreme weather events may cause lower nest survival rate in woodcock. A later nest initiation date in 2011 also may have affected nest survival rate; we may, however, have been unable to detect these relationships because we included year as a covariate in our analysis and year may be correlated with other covariates. Similar to results reported by McAuley et al. (1996), we found no evidence that vegetation characteristics around nest sites influenced nest survival rate (Table 4). Across their breeding range, woodcock select nest sites with high stem density (McAuley et al. 1996), and we also observed high and similar stem density at both failed and successful nests.

### JUVENILE SURVIVAL RATE

Total interval precipitation (PCPT) was the only covariate that showed a statistically significant relationship with juvenile woodcock survival rate. Precipitation, especially high precipitation within an interval, was negatively related to juvenile woodcock survival rate. Sheldon (1971) and Owen (1977) suggested that periods of adverse weather (i.e., precipitation) can cause significant mortality in juvenile woodcock. Dwyer et al. (1988) reported finding a significant negative relationship between precipitation and juvenile production; this relationship also has been suggested in other precocial birds (e.g., Pietz et al. 2003, Brundey et al. 2013). Rabe et al. (1983) suggested that due to growth requirements of juvenile woodcock, weather-related stress has the greatest potential to limit survival rate of juveniles during the brood-rearing period.

Although juvenile age (JAGE) and minimum temperatures (MINT) did not exhibit a statistically significant relationship with survival rate in our best-supported model, in initial steps in our modeling of juvenile survival rate, JAGE was positively related to survival rate, suggesting that survival rate increased with juvenile age. As juveniles age, they are better able to thermoregulate (Rabe et al. 1983) and may therefore better survive periods of inclement weather, and they also are better able to escape predators as they gain the ability to fly. This is contrary to what Wiley and Causey (1987) estimated in Alabama, where juvenile woodcock had a higher survival rate prior to fledging (<15 days), and were most vulnerable between fledging and brood break-up (15 to 32 days). However, they also suggested that this may have been due to their research methods, which may have negatively influenced juvenile survival rate (in contrast, we found no evidence for an effect of transmitters on survival; Daly et al. 2015). In contrast to our results, Wiley and Causey (1987) reported no apparent effects of weather on juvenile woodcock survival rate. McAuley et al. (2010) however, found a positive relationship between juvenile survival rate and minimum temperature in Maine, similar to our observations. Juvenile woodcock in northern parts of the breeding range (e.g., Minnesota and Maine) may be more likely to be physiologically stressed from exposure to cold and wet weather than juveniles in southern portions of their breeding range (e.g., Alabama). However, it was difficult for us to determine proximate cause of death of many radio-marked juveniles (e.g., predation versus exposure and subsequent consumption by a predator); therefore, it was not apparent whether or how predation and weather may have interacted to affect juvenile woodcock survival rate in our study. We also were unable to determine the cause of death of unmarked juvenile woodcock.

Previous studies of woodcock survival rate were concentrated in the eastern portion of the woodcock breeding range on landscapes where young forest cover was an emphasis of management, and in general, published estimates of survival rate are higher than our estimates. Adult female survival rate was constant between years and under the environmental conditions experienced in our study, but nest and juvenile survival rates differed between years. Similar to recent studies of songbird productivity (Streby and Andersen 2011) that considered juvenile survival, our results suggest that juvenile survival rate from hatch to independence from adult care, and factors related to juvenile survival rate, may contribute more to woodcock population dynamics than adult survival.

## Management Implications

Our results suggest that adult female woodcock select nesting sites and raise broods in cover types with similar structural characteristics (e.g., high woody stem density). Cover types with high woody stem density are thought to be selected by woodcock to provide cover from predators and shelter from inclement weather. Inclement weather (e.g., precipitation, cold temperatures) during the nesting and brood rearing periods likely has negative impacts on woodcock seasonal productivity and subsequent recruitment. Weather conditions between our field seasons varied greatly, and likely resulted in lower seasonal productivity in 2011 than 2012. BMPs established for woodcock include management of landscapes to provide diverse stages of young forests, providing woodcock with cover that may mitigate mortality during critical biological periods. Precipitation and severe weather events are projected to increase during the spring when woodcock are nesting and rearing broods (International Panel on Climate Change 2014). Providing high-quality nesting and brood-rearing habitat for woodcock during spring that mitigate the potential negative effects of weather conditions on nest and juvenile survival rates is likely critical to managing landscapes that will support woodcock populations.

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**Appendix I.** Covariates used in logistic-exposure analysis of survival rates of American woodcock females, juveniles, and nests at Tamarac National Wildlife Refuge, Minnesota, USA, in 2011 and 2012, symbol, model(s) in which each covariate was included, and explanation of expected relationship between covariate and survival rate.

| **Covariate / Symbol / Model(s)** | |
|---|---|
| Basal area<br>BAS<br>Nest & Juvenile | Woodcock choose areas with relatively low basal area (Sepik and Dwyer 1982, McAuley et al. 1996, Dessecker and McAuley 2001). Areas with greater basal area provide a greater number of perches for raptors and therefore we hypothesize basal area to have a negative relationship with juvenile and nest survival rates. |
| Distance to edge<br>EDGE<br>Nest & Juvenile | It is a common assertion that edges provide travel corridors for mammalian, avian, and reptilian predators, although empirical evidence is lacking or contradicting (Chalfoun et al. 2002, Lariviére 2003). However, nest survival rates of ground nesting birds have been shown to decrease around edges (Manolis et al. 2002). We hypothesized that survival rate of nests would be positively related to distance to an edge (Gregg 1984, Manolis et al. 2002) and made the same hypothesis for juvenile woodcock survival rate (Gregg 1984). |
| Hatch date<br>HD<br>Juvenile | Juveniles that hatch earlier are more likely to be from the females in the best condition (Blums et al. 2005); therefore we hypothesized that hatch date is negatively associated with juvenile survival rate. |
| Initiation date<br>INIT<br>Nest | Nests initiated earlier in the season experience higher survival rates than nests initiated later for many species (Newlon and Saab 2011); therefore, we hypothesized nest initiation date to have a negative relationship with nest survival rate. |
| Juvenile age<br>JAGE<br>Juvenile | Survival rate likely asymptotically increases with age of the juvenile because they are better able to thermoregulate as they age (Rabe et al. 1983) and likely most vulnerable to predation soon after leaving the nest (Streby and Andersen 2013); therefore, we hypothesized a positive relationship with age and juvenile survival rate. |
| Maximum temperature<br>MAXT<br>Female, Nest, and Juvenile | We predicted that maximum temperature would be positively related to survival rate of females in the spring and was likely positively related to survival rates of nests and juveniles, especially early after egg laying or hatching. During the breeding season, energetic demands are high for female woodcock (Rabe et al. 1983), especially during egg laying, incubation, and brood rearing. Higher maximum temperatures likely increase survival rate of females during incubation and brood rearing (Rabe et al. 1983, Longcore et al. 2000). Females are also more active at higher ambient air temperatures (Vander Haegen 1992) and females will brood juveniles when temperatures are low (McAuley et al. 2010); therefore, at higher temperatures females likely spend more of their time foraging and are more capable of meeting their own energetic requirements and those of juveniles in their brood because females will feed juveniles for the first 7 days after hatch (Gregg 1984, Vander Haegen 1992). |

**Appendix I** (continued)

| **Covariate / Symbol / Model(s)** | |
|---|---|
| Minimum temperature<br>MINT<br>Female, Nest, and Juvenile | We predicted female, nest, and juvenile survival rates would have a positive relationship with minimum temperature. Lower minimum temperatures likely decrease survival rate of adult females by decreasing earthworm availability in the spring (Vander Haegen et al. 1993) when energetic requirements are the highest during the breeding season (Rabe et al. 1983). Nests are likely to experience low temperatures and other adverse weather conditions in the spring (Dwyer et al. 1988) and may fail either because associated females have lower survival rates or females abandon nests due to high energetic demands. Juveniles may be less likely to survive at lower minimum temperatures because they lack the ability to thermoregulate (Sheldon 1971, Owen 1977, Rabe et al. 1983, McAuley et al. 2010). |
| Nest age<br>NAGE<br>Nest | Survival rate asymptotically increases with nest age, therefore we hypothesized that nest age has a positive relationship with nest survival rate. |
| Precipitation<br>PCPT<br>Female, Nest, & Juvenile | Precipitation hinders the ability of woodcock to thermoregulate (Rabe et al. 1983) and has been negatively related to juvenile woodcock survival rate (Dwyer et al. 1988); therefore, we hypothesized that precipitation is negatively associated with female and juvenile survival rates. High amounts of precipitation also can cause nests to flood in low lying areas or females to abandon nests and can thus decrease nest survival rate. We hypothesized precipitation to have a negative relationship with nest survival rate. |
| Reproductive status [a]<br>REPR<br>Female | Energetic requirements and behavior of adult females differ depending on reproductive status (Rabe et al. 1983). High energetic costs during nesting and incubation and the females' association with the nest can make the female more vulnerable to predation (Longcore et al. 2000). Brood-rearing also can decrease the female survival rate due to sharing of food resources and tending to juveniles (Rabe et al. 1983). For these reasons, we hypothesized survival rate would be higher when females were not associated with a nest or brood. |
| Woody stem density<br>STEM<br>Nest & Juvenile | Woodcock select areas with high woody stem density (Sepik and Dwyer 1982, McAuley et al. 1996, Dessecker and McAuley 2001) that provide thermoregulatory cover for juveniles and predatory cover for juveniles and nests. We hypothesized areas with higher woody stem density have a positive association with juvenile and nest survival rate. |
| Year<br>YEAR<br>Female, Nest, & Juvenile | Woodcock survival rate has been shown to differ among years (Gregg 1984, Longcore et al. 2000, McAuley et al. 2010). We included year in our analysis to account for annual variation in survival rates of females, juveniles and nests. |

[a] Indicates a categorical variable.

**Appendix II.** Assessment of independence of survival among brood mates of juvenile American woodcock monitored via radio telemetry at Tamarac National Wildlife Refuge, Minnesota, USA, during 2011 and 2012. We used survival data from broods with >1 juvenile at the time of capture and radio attachment (*n* = 38), and conducted 50 iterations of estimates of survival rate, randomly partitioning broods in each iteration to estimate daily survival rate using data from half the broods (*n* = 19) and using data from the remaining half of the broods (*n* = 19) to derive a chi-square statistic based on observed and expected number of juveniles alive and dead at the end of the 15-day survival period. Average P-value for these 50 iterations was 0.3239, indicating no support for the null hypothesis of inter-dependence among survival of brood mates.

**Table AII.1.** Brood identification (Id), number of juveniles in a brood when first observed and on day 15, the sum of exposure days for radio-marked juveniles, the number of days a brood was monitored up to 15 days post hatch, and the number of losses during the observation period for American woodcock monitored at Tamarac National Wildlife Refuge in northwestern Minnesota, USA, during 2011 and 2012.

| Brood Id | Juveniles at start of observation | Juveniles observed alive on day 15 | Exposure days | Number of days brood monitoried | Losses |
|---|---|---|---|---|---|
| 11AA | 3 | 3 | 15 | 5 | 0 |
| 11B | 4 | 4 | 32 | 8 | 0 |
| 11BB | 4 | 1 | 52.5 | 15 | 3 |
| 11C | 2 | 2 | 6 | 3 | 0 |
| 11E | 2 | 0 | 14 | 7 | 2 |
| 11F | 4 | 4 | 24 | 6 | 0 |
| 11G | 2 | 2 | 30 | 15 | 0 |
| 11I | 3 | 3 | 45 | 15 | 0 |
| 11J | 3 | 2 | 10 | 4 | 1 |
| 11K | 2 | 2 | 8 | 4 | 0 |
| 11L | 3 | 3 | 9 | 3 | 0 |
| 11M | 4 | 3 | 39.5 | 11 | 1 |
| 11O | 4 | 2 | 42.5 | 15 | 2 |
| 11R | 2 | 1 | 15 | 14 | 1 |
| 11S | 3 | 2 | 39.5 | 15 | 1 |
| 11T | 2 | 2 | 28 | 14 | 0 |
| 11U | 2 | 2 | 12 | 6 | 0 |
| 11V | 4 | 2 | 28 | 10 | 2 |
| 11X | 3 | 1 | 30 | 15 | 2 |
| 11Y | 2 | 1 | 14.5 | 10 | 1 |
| 12B | 4 | 4 | 48 | 12 | 0 |
| 12BB | 4 | 4 | 36 | 9 | 0 |
| 12C | 3 | 2 | 24.5 | 12 | 1 |
| 12CC | 2 | 1 | 14.5 | 11 | 1 |
| 12E | 4 | 4 | 36 | 9 | 0 |
| 12FF | 3 | 2 | 18.5 | 8 | 1 |
| 12G | 4 | 3 | 23 | 7 | 1 |
| 12H | 4 | 4 | 44 | 11 | 0 |
| 12HH | 4 | 4 | 60 | 15 | 0 |
| 12I | 4 | 4 | 16 | 4 | 0 |
| 12LL | 2 | 2 | 16 | 8 | 0 |
| 12M | 3 | 3 | 42 | 14 | 0 |
| 12O | 4 | 2 | 44 | 13 | 2 |
| 12Q | 3 | 3 | 9 | 3 | 0 |
| 12R | 4 | 4 | 12 | 3 | 0 |
| 12T | 3 | 3 | 9 | 3 | 0 |
| 12U | 4 | 4 | 36 | 9 | 0 |
| 12Y | 4 | 4 | 44 | 11 | 0 |
| **Total** | **121** | **99** | **1027** | — | **22** |

Mayfield Daily Survival Rate (DSR) estimate = 0.9786

Period Survival Rate (PSR; 15 days) estimate = 0.7227

**Table AII.2.** Mayfield survival rate estimate and Chi-square test for independence from 1 iteration used in Winterstein's third Chi-square test (Winterstein 1992) for independence within broods of juvenile American woodcock at Tamarac National Wildlife Refuge in northwestern Minnesota, USA, during 2011 and 2012 using a randomly partitioned data set *(n* = 38 broods).

| **Mayfield estimate to 15 days** | | | **Chi-square test** | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Brood ID** | **Losses** | **Exposure days** | **Brood ID** | **Obs.** | **Exp.** | **$\chi^2$** | **Obs** | **Exp.** | **$\chi^2$** |
| 12HH | 0 | 60 | 12B | 4 | 3.106 | 0.257 | 0 | 0.894 | 0.894 |
| 12LL | 0 | 16 | 12Q | 3 | 2.816 | 0.012 | 0 | 0.184 | 0.184 |
| 11R | 1 | 15 | 11M | 3 | 3.172 | 0.009 | 1 | 0.828 | 0.036 |
| 12M | 0 | 42 | 11C | 2 | 1.877 | 0.008 | 0 | 0.123 | 0.123 |
| 12E | 0 | 36 | 11K | 2 | 1.838 | 0.014 | 0 | 0.162 | 0.162 |
| 12R | 0 | 12 | 11T | 2 | 1.489 | 0.175 | 0 | 0.511 | 0.511 |
| 12C | 1 | 24.5 | 11G | 2 | 1.458 | 0.202 | 0 | 0.542 | 0.542 |
| 11E | 2 | 14 | 11Y | 1 | 1.620 | 0.237 | 1 | 0.380 | 1.011 |
| 11V | 2 | 28 | 12FF | 2 | 2.535 | 0.113 | 1 | 0.465 | 0.614 |
| 12CC | 1 | 14.5 | 11I | 3 | 2.187 | 0.302 | 0 | 0.813 | 0.813 |
| 12U | 0 | 36 | 11F | 4 | 3.525 | 0.064 | 0 | 0.475 | 0.475 |
| 12I | 0 | 16 | 11BB | 1 | 2.916 | 1.259 | 3 | 1.084 | 3.386 |
| 12T | 0 | 9 | 11U | 2 | 1.762 | 0.032 | 0 | 0.238 | 0.238 |
| 11O | 2 | 42.5 | 11B | 4 | 3.379 | 0.114 | 0 | 0.621 | 0.621 |
| 11AA | 0 | 15 | 11X | 1 | 2.187 | 0.644 | 2 | 0.813 | 1.732 |
| 11J | 1 | 10 | 11S | 2 | 2.187 | 0.016 | 1 | 0.813 | 0.043 |
| 12BB | 0 | 36 | 12H | 4 | 3.172 | 0.216 | 0 | 0.828 | 0.828 |
| 12Y | 0 | 44 | 12G | 3 | 3.451 | 0.059 | 1 | 0.549 | 0.371 |
| 11L | 0 | 9 | 12O | 2 | 3.041 | 0.357 | 2 | 0.959 | 1.131 |
| **Total** | **10** | **479.5** | **Total** | **47** | **47.720** | **4.091** | **12** | **11.280** | **13.713** |

$\hat{S} = 0.9791$

Total $\chi^2 = 4.091 + 13.713 = 17.804$

Degrees of freedom = 18

$P = 0.469$

## CHAPTER THREE

# Communication Strategies

# Communicating Effectively about Young Forest Management to Benefit Associated Wildlife Species

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**ABSTRACT** To conserve declining populations of American woodcock (*Scolopax minor*; hereafter woodcock) and other young forest-associated species, the Wildlife Management Institute contracted with DJ Case & Associates to assess existing communication efforts and investigate strategies that would help achieve the difficult objective of encouraging private landowners to implement young forest management practices on their lands. Our efforts included a literature review, interviews of 30 natural resources professionals, 7 focus groups with private landowners, and a metadata analysis of National Woodland Owner Survey (NWOS) data. Based on this research, we identified 5 target audiences (private, non-industrial woodland owners, conservation professionals with direct landowner contact, other conservation professionals, residents of forested communities, and hunters, especially woodcock and ruffed grouse [*Bonasa umbellus*] hunters), with objectives for each. We also identified broad strategies for achieving these objectives with each target audience and developed messages based on what these audiences indicated was important to them. Finally, we recommended 3 big-picture actions for the woodcock conservation community to implement the specific communications strategies: 1) design and develop a comprehensive website that provides the information and resources needed by each of the target audiences, 2) create detailed pilot communications campaigns in selected five-county pilot areas, and 3) develop large-scale partnerships among other organizations and entities interested in young forest management. The Wildlife Management Institute and others in the conservation community have embraced and implemented these communication strategies and messages as part of a larger woodcock conservation effort in the Northeast and Upper Midwest USA. Partners have employed many of these messages and strategies in an even broader effort to promote and encourage young forest management throughout the country.

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**KEY WORDS:** American woodcock, communications, early successional forest, outreach planning, *Scolopax minor*, woodcock, young forest

The *American Woodcock Conservation Plan* (Kelley et al. 2008) established a goal of seeking full recovery of American woodcock (*Scolopax minor*; hereafter woodcock) populations to 1970 levels. To achieve this, the Plan identified the need to add 1.3 million hectares (3.2 million acres) of young forest to existing levels in Bird Conservation Region (BCR) 14 (Atlantic Northern Forest) and another 1.2 million hectares (3.0 million acres) in BCR 28 (Appalachian Mountains).

Given the large proportion of privately held lands in these regions, achieving these lofty goals depends heavily on successful establishment of young forest by private landowners. Unfortunately, establishment of young forest often requires extensive cutting of established forests, which landowners often misunderstand and view negatively.

The Wildlife Management Institute's (WMI) goal for this project was to develop effective communication strategies for encouraging landowners to establish and maintain young forest habitat on private lands. Specifically, WMI wanted to investigate communication strategies to integrate private landowner habitat management interests and

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capacities into programs designed to implement the *American Woodcock Conservation Plan* through identification of critical audiences, testing of key messages, and documentation of optimal delivery mechanisms.

## Study Area

We focused specifically on owners of small (~4–40 hectare or 10–100-acre) woodlands in the 11 states that are part of BCRs 14 and 28 (ME, MA, CT, VT, NH, NY, PA, OH, MD, VA, and WV). We did not address communication needs of large landowners, industrial landowners, or public lands managers. However, we did design our efforts to provide foundational insights, approaches, and communications strategies that may be applicable in other areas.

## Methods

WMI contracted with DJ Case & Associates (DJ Case) to conduct an investigation and develop a communications strategy centered on increasing creation and management of woodcock habitat on private land. We used the following techniques to develop the communications strategy:

1. *Literature Review:* We compiled and reviewed pertinent literature regarding private, non-industrial woodland owners and management of their forested lands.
2. *Professional Interviews:* We identified and interviewed 30 natural resource professionals who engage in young forest management and outreach on private lands to learn about their efforts, messages, audiences, and assessment of such efforts.
3. *Focus Groups*
    a. Phase I: We conducted 4 focus groups (1 in NH, 1 in NY, and 2 in PA) with private, non-industrial woodland owners to determine the fundamental reasons why they might choose to either actively manage their land for young forest or not. We tested the appeal of potential messages that stakeholders may use in a communications and outreach campaign aimed at increasing the area of private lands being managed as young forest.
    b. Phase II: We conducted an additional set of 3 focus groups (2 in NY and 1 in PA) to test communication vehicles (images, messages, tag lines, and print ads) that might be used to encourage private landowner participation in young forest management. We compared and contrasted the characteristics of Phase I focus group participants with those of the Phase II focus groups.
4. *National Woodland Owner Survey (NWOS) Analysis:* We reviewed results of the NWOS (2002–2006) for small woodland owners in BCRs 14 and 28, to determine their understanding of and attitudes toward forest ownership and management and other natural resource conservation issues (U. 2008). We also compared demographics of and results from survey participants with participants in Phase II focus groups, to determine to what degree focus group participants were representative of the broader woodland owner population, and whether results and insights obtained in focus groups could be applied to the broader population.

## Results

### LITERATURE REVIEW

We reported our full results in *Annotated Bibliography for Investigating Communication Strategies to Support Implementation of the North American Woodcock Conservation Plan Project* (Christoffel and Case 2009a). What we present here is a condensed version of the primary conclusions presented in our full report.

Although the total forest area has remained relatively constant in the Northeast USA, the amount of young forest has declined in recent years. In addition, fragmentation of forests into ever-smaller ownerships has caused reduction in forest management options. Not surprisingly, most disturbance-dependent species, especially birds, are declining throughout the region.

Private forestlands have the following ownership patterns: 61% of family forest owners in the USA own <4 hectares (10 acres) of forestland, but 53% of the family forestland is owned by people with >40 hectares (100 acres). Most family forest owners own their forestland for multiple reasons, most commonly beauty/scenery, to pass land on to heirs, privacy, nature protection, and part of home/cabin. Few indicate financial motivations. Compared to the general population, a greater proportion of family forest owners are older white males who are more educated and wealthier. Many private forest landowners are interested in the numerous social benefits that private forests produce, including clean water and air, biodiversity, lumber/wood fiber, wildlife for consumptive and non-consumptive uses, recreation, and a scenic backdrop for a rural tourism industry.

The literature we reviewed for our report (Christoffel and Case 2009a) indicated that appearance plays a major role in the use and appreciation of forestland. Of all management actions, clear cutting generally has the greatest negative visual impact, especially if large amounts of slash are visible. This appearance plays a role in how people feel about the technique; significant segments of landowners and the public believe in banning clear cutting. Helping people understand the purposes of forest management practices, however, can help increase their tolerance of practices such as clear cutting.

Most family forest owners do not have written management plans, and few have sought professional advice from a forester or utilized a public assistance program for forest management. Owners of larger tracts are more likely to seek assistance, and there may be substantial regional differences with respect to the propensity to use forestry services, attitudes toward regulation, and reasons for owning forestland.

Because there are a large number of forest landowners with variable interests and motivations, it is difficult to design programs to encourage them to adopt management to promote young forests, and the landowners' high turnover, diverse objectives, and varied participation present additional barriers. The probability of program adoption is higher when management focuses on amenities, such as wildlife habitat, compared to timber harvests. Most non-industrial private forestland owners want to see a demonstration area before deciding whether to participate.

There are some bright spots. Most family forestland owners appear interested in protecting their land from development, even though few have conservation easements or other protections on their land. To assist identifying landowners who might be interested in establishing young forest on their lands, we segmented NWOS respondents into 4 groups in terms of their interest and engagement in land management:

- Model owners: already exhibit behavior consistent with good land stewardship and sustainable use (but not necessarily management to promote young forests).
- Prime prospects: are not currently engaged in land stewardship activities but are likely to consider it.
- Potential defectors: currently engaging in land stewardship activities but are likely to quit because of lack of interest or other barriers.
- Write-offs: exhibit low levels of engagement in land management and low levels of interest in doing so.

Communication efforts targeted to the first 3 groups (with separate messages and media for each) could help encourage more management to promote young forests among private woodland owners.

### PROFESSIONAL INTERVIEWS

We reported our full results in *Summary of Semi-Structured Interviews with Natural Resource Professionals* (Christoffel and Case 2009b). What we present here is a condensed version of the primary conclusions presented in our full report.

We interviewed 30 natural resource professionals representing state agencies, federal agencies, and non-governmental organizations. The average length of employment for the interviewed professionals was 7 years. Most (77%) interviewees contributed directly to outreach associated with young forest and its management, and restricted their activities to a single state, though 23% had regional responsibilities. The outreach activities most commonly used were individual consultations, presentations, provision of technical assistance, and workshop participation. Private landowners and natural resources professionals were the primary audiences for these outreach activities. Their objectives for outreach activities related primarily to wildlife habitat management, education of landowners, and young forest management. The four key messages most often delivered by interviewees to their audiences included: 1) management and wildlife populations are linked, 2) wildlife and habitats are linked, 3) specific how-to advice, and 4) landowners have responsibilities and opportunities. Most interviewees (73%) indicated they had produced outreach materials related to young forests and/or wildlife for use with private landowners.

Nearly two-thirds of the interviewees indicated that they worked with ≥5 partner organizations in their young forest conservation efforts. Only one-third of interviewees had any kind of formal evaluation metrics built into their program/efforts. The evaluation efforts identified by interviewees were generally limited to simple outputs, such as numbers of landowners enrolled or areas treated.

The barriers to young forest management on private lands that were most often perceived by interviewees included negative perceptions associated with cutting trees and with the costs associated with creating and maintaining young forests. Conversely, the most commonly perceived opportunities were education and outreach (these were listed by interviewees twice as often as any other), along with funding assistance.

### FOCUS GROUPS – PHASE I

We reported our full results in *Summary of Focus Group Meetings with Private Landowners* (Christoffel and Case 2009c). What we present here is a condensed version of the primary conclusions presented in our full report.

Most participants in the Phase I focus groups indicated they owned their parcels of land individually or jointly. Nearly half had owned their parcel >20 years, and more than half lived on or within 2 km (response was categorized as <1 mile) of their parcels. Four out of 5 indicated they were the primary decision maker for their forest parcels. More than half the participants indicated that their woodland parcel was <40 hectares (100 acres) in size and almost a quarter indicated that their parcels were ~40–80 hectares (100–199 acres) in size. Most said their parcels were ≥50% wooded.

Focus group participants said beauty was the most important reason for owning their wooded parcel, while 3 reasons ranked second—to protect the land, to be close to nature, and to provide wildlife habitat. The reason ranked least important was to cultivate/collect non-timber forest products. Nearly three-fourths of participants had participated in some kind of cost-share program on their land, the most common being the Wildlife Habitat Incentive Program (WHIP) through the USDA Natural Resource Conservation Service. About a fifth of participants indicated they currently had an easement on their parcel.

Most participants had harvested trees on their parcels, most commonly for firewood and saw logs. The sources of forest management information most commonly consulted with were state foresters (79%) and extension foresters (64%).

We asked focus group participants to rank the appeal of eight potential messages for use in a communications and outreach campaign to encourage private landowners to manage or create young forest on their land. The two messages ranked highest by focus group participants were: 1) A diversity of wildlife requires a diversity of habitats; and 2) Early successional forest habitat has greatly decreased in [location], and so have the dozens of wildlife species dependent on this habitat.

### FOCUS GROUPS – PHASE II

We report our full results in *Message Testing Focus Group Meetings with Private Landowners (Phase II)* (Christoffel and Case 2009d). What we present here is a condensed version of the primary conclusions presented in our full report.

In the Phase II focus groups, half the participants had owned their parcel >20 years, whereas about a third had owned it <10 years. Two-thirds lived either on or within 2 km (1 mile) of their parcels. Almost two-thirds of participants said they were the primary decision makers for their forest parcels. A majority of participants stated their woodland parcels were >20 hectares (50 acres) in size, whereas about a quarter had parcels of ~40–80 hectares (100–199 acres).

Focus group participants ranked to enjoy beauty or scenery as the most important reason for owning their woodland parcels. Second in importance was to protect nature and biodiversity, and third was privacy. The reason ranked least important was to cultivate/collect non-timber forest products.

Formalized protection of their lands was not common. Only 15% of participants had participated in any kind of cost-share program on their land or had a written management or stewardship plan for their parcels. Only 6% of participants had any kind of conservation easement.

Active management was more common. In fact, all participants had engaged in ≥1 management activities on their parcels. Almost three-quarters of focus group participants harvested trees on their parcels, mostly for saw logs. About a third of participants had received advice or information about their woodland parcels. The two sources most often consulted by participants included state Departments of Natural Resources (DNR) employees and private consultants. We asked participants to rank the usefulness of 12 sources for information about woodland management. The sources rated highest included talking with a forester or other natural resources professional; newsletters, magazines or newspapers; publications, books or pamphlets; and talking with other woodland owners. A blog for woodland owners ranked as the least useful of the sources.

During the focus groups, we asked participants to rate the appeal of six images, six messages, seven tag lines, and five print ads. The image with the highest average appeal was that of a stand of mature, deciduous trees; the least appealing image, which scored in the low appeal range, was an image of a clear cut. The message that participants gave the greatest average appeal score was "A diversity of wildlife requires a diversity of habitats"; the least appealing message was "Shrubby habitat helps to preserve privacy".

Participants rated the tag line "Do right by the land" as the most appealing. The tag line that rated least appealing was "Forever young". The five print ads that focus group participants rated all received medium appeal scores.

Phase II focus group participants were less familiar than Phase I participants with natural resource professionals and programs, and with the language of natural resource management and conservation. For example, they did not know what a Species of Greatest Conservation Need was and wondered what it meant for landowners. Participants also shared disbelief regarding the message about a decrease in the amount of young forest and the animals dependent on young forest.

### NATIONAL WOODLAND OWNER SURVEY ANALYSIS (RESPONDENTS FROM BCRS 14 AND 28)

We report our full results in *Analysis of National Woodland Owner Survey Data for Bird Conservation Regions 14 and 28* (Christoffel and Case 2009e). What we present here is a condensed version of the primary conclusions presented in our full report.

NWOS respondents in BCRs 14 and 28 were similar to Phase II focus group participants in composition, motivations, and preferences for advisors and communication channels. Some specific findings from NWOS participants:

- The average age in both BCRs was >55.
- About 83–85% of respondents were male.
- Most acquired woodland parcels through purchase.
- 73% of owners lived within ~2 km (1 mile) of their woodland parcel.
- Less than 10% of owners in both BCRs had written management plans.
- Beauty or scenery was the top reason for owning woodland, followed by privacy, part of home, and to protect nature and biodiversity.
- The top 3 reasons for conducting management on their property in past 5 years were: private recreation, post land, and road/trail maintenance.

- The top 3 channels through which survey respondents said they could be reached regarding forest management issues were: publications, talk with natural resources professionals, and newsletters, etc.

There were a few notable differences between NWOS respondents and Phase II focus group participants. Focus group participants demonstrated a greater propensity to engage in timber harvest and other land management activities. In addition, focus group participants were more likely to have a written management or stewardship plan, hold a conservation easement on their properties, and to have participated in a cost-share program to manage their woodlands. Overall, results from our comparison suggested that insights gained from the Phase II focus groups were likely to be broadly applicable in communicating about and promoting young forest management to many private woodland owners in BCRs 14 and 28.

### COMMUNICATION STRATEGY

We used the results from the four approaches described above to develop a communication strategy for helping to achieve the goals of the *American Woodcock Conservation Plan*. The communication strategy contains four parts: 1) target audiences, 2) objectives and strategies, 3) messaging, and 4) actions.

***Target audiences*** We recommend targeting five specific audiences through the communication strategy for helping to achieve the goals of the *American Woodcock Conservation Plan*:

1. Private, non-industrial woodland owners of ~4–40 hectares (10–100 acres) in BCRs 14 and 28. These end users are prime candidates to implement young forest management on their lands. This communication strategy focused on owners of small parcels, whereas other efforts are targeting large parcel owners.
2. Conservation professionals with direct landowner contact. These people have direct contact with small parcel owners as part of their normal operations/activities. They could be agency or extension staff, members of conservation organizations that encourage young forest management, etc.
3. Other conservation professionals. These are people who have potential contact with end users, and/or whose agencies/organizations have programs or efforts that encourage young forest management.
4. Residents of forested communities. These people live in or near communities that have significant forested area (or lands potentially managed as young forest).
5. Hunters, especially woodcock and ruffed grouse (*Bonasa umbellus*; hereafter grouse) hunters. Hunters have a stake in young forests because of the positive impacts such forests have on the species they pursue. In particular, a portion of this audience that has a passion for taking action to further support their hunting and conservation interests.

***Objectives and Strategies*** Following is the objective for each target audience, along with our recommended broad strategy for achieving it.

1. Private, non-industrial woodland owners of ~4–40 hectares (10–100 acres) in BCRs 14 and 28
   **OBJECTIVE:** Create and maintain young forests on their lands.
   **STRATEGY:** Because there are so many landowners in this target audience, and because their holdings are relatively small, it is not likely that natural resources agencies and their partners will be able to have direct, face-to-face contact (intensive methods) with enough of them to achieve the overall habitat objectives of the *American Woodcock Conservation Plan*. Therefore, stakeholders must develop, deliver, and evaluate communication methods that are indirect or require less personal contact. A comprehensive website would be a major part of this strategy. This website might be most effective if it had sections targeted to the specific audiences. Direct mail and/or direct e-mail are potential alternatives to encourage landowners to visit a website (perhaps with incentives for participation) along with the use of brochures and information sheets. All communications should include a reference to the website. Landowners said that good ways to deliver information to them included written materials (newsletters, magazines, pamphlets) and other landowners. If the conservation community can identify key landowners (early adopters and influential individuals) in target areas, it might be worth making direct contact with them. If they can be convinced to adopt young forest management, they are likely to have positive influence among their neighbors.

2. Conservation professionals with direct landowner contact
   **OBJECTIVE:** Help woodland owners create and maintain young forests.
   **STRATEGY:** There are conservation professionals who are already making contacts with small woodland owners in the target areas as part of their existing jobs (agency landowner program managers, extension professionals, conservation organization landowner liaisons, etc.). The top priority will be to assess whether these professionals are supportive of young forest management. That is, what do they

know about it? Are they willing to recommend it to the landowners they contact? For some, there may be cultural, economic, or other reasons that they do not recommend (or might even oppose) young forest management to their constituents. Getting these professionals to advocate clear cutting will be an entirely different challenge than getting them to advocate selective cutting. For such conservation professionals, the primary effort becomes learning about their objections to young forest management and showing them the need for and benefits of this management regime. For those who are willing to support and recommend young forest management, the primary effort should be to provide training and materials to help them communicate effectively with landowners about the benefits of young forest management and how it can help them achieve their objectives. They need to know the messages and delivery mechanisms to use and the resources available to help them. If possible, they also should be provided lists of key landowners in key areas (early adopters, influential individuals) who could influence other landowners regarding forest management.

3. Other conservation professionals
   **OBJECTIVE:** Allow and help woodland owners (both public and private) create and maintain young forests.
   **STRATEGY:** There are numerous conservation professionals who have indirect contact and interaction with small woodland owners and/or who administer public forestlands. These professionals may have the opportunity to support (or oppose) young forest management through their work and interactions. Educating them about the importance and benefits of young forest management will help support efforts to promote and manage young forests and associated wildlife. For agencies that administer public forestlands, the primary effort should be to encourage young forest management wherever appropriate. Rotating demonstration areas (with easy access) that provide local examples of what young forest management looks like over time could be particularly important in encouraging other landowners to promote and manage young forests. In addition, young forest supporters need to emphasize coordination among all conservation professionals, so all know about the decline in young forests and associated species.

4. Residents of forested communities
   **OBJECTIVE:** Allow creation and maintenance of young forests on public and private lands.
   **STRATEGY:** Even if they do not have direct control over the land, residents living in and around forestlands may have significant influence over land management. For instance, if the common feeling among residents is to ban clear cuts because they look terrible, these residents may be able to bring tremendous pressure to bear on landowners to avoid this type of management. On the other hand, if these residents understand the benefits of young forest management, they are less likely to oppose this management regime, and may instead support it. The primary objective for this audience is informed consent. The conservation community should identify key areas where tracts of forestlands are interspersed with homes, and attempt to communicate extensively with the residents over time about the benefits of young forest management. Communication should address the clear cutting issue head on. That is, we should not try to convince people that clear cutting is not ugly to the eye. Rather, messaging should focus on how ugly is good in other ways, and how ugly grows quickly into beautiful. Messaging should focus on creating social acceptance. If residents in and around a forested area are not actively opposed, it will be much easier for the landowner(s) to adopt young forest management. This will continue be a communications challenge that will take time to achieve.

5. Hunters, especially woodcock and grouse hunters
   **OBJECTIVE:** Advocate for and support creation and maintenance of young forests on public and private lands.
   **STRATEGY:** Young forests benefit many species of hunted forest wildlife, so hunters should be strong proponents for this management regime. However, some hunters do not recognize or understand this connection. The conservation community needs to communicate with hunters the fact that in many cases, the more young forest that is available, the more animals they will have to pursue. With the advent of electronic licensing systems, it is possible in many states to identify hunters who buy specific license types. For instance, in many states, resource professionals need to identify and communicate directly with woodcock, grouse, wild turkey (*Meleagris gallopavo*), and deer (*Odocoileus* spp.) hunters, all of whom benefit from young forest management. This will require cooperation from the state wildlife agency, which should be a natural partner in promotion of young forest management. Sportsmen's groups and conservation organizations (e.g., National Wild Turkey Federation, Ruffed Grouse Society, and others) should encourage their

members to advocate for young forest management in key areas. Members of these organizations are often passionate, action-oriented people who could be well suited for this type of work. Hunter-related organizations could develop demonstration areas that show what young forest management looks like, and they could sponsor and administer information-sharing campaigns among their members and/or landowners in key areas.

***Messaging*** When developing messages, the conservation community should always take into consideration target audience, regional considerations, and context of usage, but in general, messages should include and/or depict natural beauty and scenery—the most popular reasons that focus group participants gave for buying their lands. Another strong motivator was conservation of wildlife and nature for future generations, especially within their own families. Because landowners want to contribute to healthy ecosystems, communicators should feature the fact that young forests contain high plant and animal diversity. Similarly, landowners are interested in conserving wildlife and nature close to home. To engage audiences, communicators should feature iconic species of local or special interest. Not all landowners will care about woodcock conservation, but other species may motivate them to take action.

Messages should use this wording:

- *Young forests* — Focus group participants liked this wording; it evokes a sense of a healthy, vigorous ecosystem
- *A diversity of wildlife requires a diversity of habitats* — This was the top-rated message as identified by focus group participants

Messages should NOT use this wording:

- *Early successional* — most people do not understand what this term means
- *Shrub or Scrub* — both of these terms had negative connotations for most focus group participants
- *Woodcock as the lead concept* (except with the hunter audience) — many people do not know what a woodcock is, and may not care about woodcock conservation
- *Jargon such as Species of Greatest Conservation Need (SGCN) or State Wildlife Action Plan (SWAP)* — Nothing makes people lose interest in a message faster than seeing an acronym they do not recognize. It tells them that they are not the intended target audience, so they do not need to pay attention.

Recognize that getting small woodland owners to adopt young forest management will be a big challenge. Most landowners bought their land for beauty/scenery, and there is no way to convince them that a clear cut is as beautiful as mature woodland. We recommend messaging that focuses on the other benefits provided by young forest management.

***Actions*** Following are 3 key actions the conservation community should take to persuade small parcel landowners to implement young forest management on their lands in BCRs 14 and 28 for the purpose of achieving goals of the *American Woodcock Conservation Plan*. That is, these actions are designed to benefit woodcock habitat specifically, not just young forests. The third action broadens the effort beyond woodcock conservation—to seek synergies and economies of scale—but woodcock conservation is the ultimate goal of all efforts.

The first key action is for the conservation community to design and develop a comprehensive website that provides the information and resources needed by each of the target audiences. We recommend segmenting the site to customize various sections specifically for each of the target audiences. Young forest management is a complex topic, and a well-built website affords the opportunity to tell the full story in nested fashion, so people can access as much or as little information as they need. Communicators should research existing websites that already deliver various pieces of this information, and build the site to complement and leverage these efforts. It will also be important to create section(s) of the site that encourage and sustain two-way communications with the target audiences. An on-line community for the effort could be helpful for encouraging two-way communications and for building relationships between and among the target audiences.

The second key action is to develop Five-County Pilot Areas that include detailed communications campaigns to increase young forest management on private lands in ≥1 limited areas (5 counties within 1 state, perhaps). There is too much variability (habitat types, programs, social norms, etc.) across the range of woodcock for partners to effectively implement a single communications campaign. Each of these pilot areas should be large enough to show impacts, but small enough so stakeholders can deliver a reasonable amount of communications and assess impacts in a meaningful manner. These pilot area campaigns should be customized to the local landowners, ecology, assistance programs, and wood markets. If these pilot campaigns show positive results, we recommend expanding them to encompass broader areas. Managers should consider developing a specific campaign plan for the pilot area. The plan should identify and take advantage of the habitat types, landowner programs, audiences, iconic species, and other issues specific to the local (5-county) area. Managers should design/develop/conduct a series of workshops/presentations with natural resource professionals in the pilot areas to convince them of the need for young forest management (as necessary) and to share the key messages and communication tools and techniques they should use with private woodland owners (electronic presentation, printed materials, etc.). Materials should identify and include information on all currently available funding/cost-share programs, and we recommend designing all materials to share a family look with the design of the website. Ideally, the conservation community would create a network or registry of small woodland owners who are engaged in young forest management, and would ensure they understand the key messages so they can advocate for young forest management with other landowners who may contact them. Finally, it is important to include evaluation metrics in all actions so partners can assess increases in area of young forest on private lands, improved knowledge/attitudes among target audiences, and utility of specific techniques and methods used in the campaign.

The third key action is development of large-scale partnerships. The use of broad-scale communication efforts to reach landowners across large geographical regions to support young forest management for woodcock conservation is not strategically justifiable. That is, there are not enough landowners interested in woodcock conservation to make such a strategy succeed, and this approach probably is not economically feasible, either. Other organizations and partners, however, have interest in young forest management, though not necessarily in woodcock conservation. Deer, grouse, wild turkeys, golden-winged warblers (*Vermivora chrysoptera*), and a wide array of other wildlife and plants are dependent on young forests, just like woodcock. A wider array of species of interest will bring a much larger support base to advocate on the issue. Messages that all such groups hold in common include: 1) young forests are important for healthy ecosystems; and 2) timber harvest and other forest management, when done responsibly, benefit many types of plants and wildlife.

Practitioners should recognize that not all young forest management efforts benefit woodcock. For instance, young forest on arid, upland sites may be of limited value to woodcock due to limited food availability, but partnerships can create synergy of effort for all partners and help create informed consent for young forest management with the broader public.

## Discussion

We developed the following guiding principles based on the results described above. We recommend their consideration during the planning and implementation of communication efforts regarding development of young forest management for woodcock habitat in BCRs 14 and 28. We do not list the guiding principles in any particular order.

We recommend directing communication efforts to a broader audience than just woodcock fans. Efforts can focus on a single ecosystem or habitat type (young forest), but should cover all species, both animals and plants, that benefit from or require young forest for survival. Specific target audiences (see below) should receive specific messages, but the overall campaign should not be limited to any single target audience. Support for woodcock conservation alone probably is not broad or deep enough to achieve habitat goals (such as those of the *American Woodcock Management Plan*), but support for other plants and animals of young forests can assist tremendously.

Communication efforts should focus on the fact that young forest management is necessary for the survival of a host of declining species of wildlife and plants. Next to beauty/scenery, the highest rated reason for owning woodland property for most landowners was protecting nature or biodiversity. A simple description of the ecology of young forests will be compelling for many landowners.

Many private woodland owners have negative perceptions about how young forest management (especially clear cutting) will make the land look. Most bought their land for beauty or scenery, and they are concerned that clear cutting will create an eyesore, or that young forest will not be as picturesque as mature forest. We believe it is important to communicate to them the management options (techniques, spacing, and timing) that will address their concerns.

Partners must continually communicate with private landowners to encourage the establishment and maintenance of young forests on their lands. Young forests are always growing into older forests, and even if partners achieve the lofty habitat goals of the *American Woodcock Conservation Plan*, area of young forest will not be maintained automatically. Partners will need to provide continual and considerable effort to communicate the benefits of young forest management to landowners and their heirs.

Most woodland landowners have harvested trees on their property, most often for firewood or saw logs. This suggests that they do not oppose harvest per se; however, asking them to implement a clear cut is very different from cutting firewood or implementing a selective cut. They will need to understand how young forest management can fit with their other objectives when considering the management of their land.

For a large majority of woodland owners in our target audience, financial return is not a primary motivating factor for owning their lands. However, the financial implications of implementing young forest management (lack of sufficient return, poor timing of return, etc.) might be a significant obstacle to them changing the way they view managing their property with considerations for young forest.

Many woodland landowners do not speak the language of natural resources conservation. Many have limited or erroneous understanding of even the most basic ecological concepts, not to mention forest management techniques and programs. It is critical that the conservation community begin with very basic, non-technical, non-jargon approaches to communicate the benefits of young forest management with this audience.

Many landowners are willing to meet with experts. Nearly 1 in 5 NWOS survey respondents sought forest management advice in the past 5 years, and most indicated that the best way to communicate with them was through a natural resources expert. State agency natural resources staff, extension experts, and private consultants were sources most often sought for advice and deemed most credible.

Face-to-face meetings are preferred for delivering key messages to target audiences, but there are far too many small woodland landowners (those owning between ~4–10 hectares [between 10 and 100 acres]) to be reached this way. Reaching this diverse and far-flung audience will require use of extensive communication techniques such as websites, publications, and other media. There is a need for more and better evaluation of outreach efforts. Currently, we know very little about what methods are effective at getting landowners to adopt young forest management on their lands.

## Management Implications

Achieving the goals of the *American Woodcock Conservation Plan* in BCRs 14 and 28 will depend upon cooperation and participation from private landowners throughout the region. Building this cooperation and participation will require strategic and effective use of communication efforts. Given the diverse and far-flung nature of the private landowners in these BCRs, communications will need to rely on extensive (rather than intensive) efforts. That is, the woodcock conservation community will need to develop and implement communications that deliver its messages broadly across its target audiences, and only focus intensive efforts on a few key landowners who control large or critically important lands. Our results and recommendations provide guidance for communicating effectively with small woodland owners in BCRs 14 and 28, but are also likely to be effective in other BCRs. However, given limited resources, we recommend implementing and evaluating the actions we proposed through pilot-area campaigns, and refining as appropriate before expanding efforts into other regions.

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# How to Evaluate Woodcock Habitat Management: are Landowners the Answer?

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**ABSTRACT** Loss of young forest, also termed early successional forest, in North America is negatively impacting wildlife populations that rely on this regenerating forest type, especially birds. The Wisconsin Young Forest Partnership (WYFP) targets young forest management efforts to benefit American woodcock (*Scolopax minor*; hereafter, woodcock) on private lands in Wisconsin. The WYFP uses an adaptive strategy to iteratively evaluate and adjust their habitat management activities. Citizen science can be a valuable evaluation tool in this process. The WYFP aims to develop a citizen science program whereby landowners monitor woodcock in management areas on their properties. We explored the woodcock monitoring preferences and abilities of landowners through questionnaires, interviews, and pilot woodcock surveying to inform the development of a citizen science woodcock monitoring program. Landowners were enthusiastic about participating in woodcock monitoring. When creating a citizen science program for monitoring woodcock it is important to use English units for estimating distance, evaluate landowners' physical ability to hear peenting woodcock, provide in-person monitoring training, and have flexible data submittal options. Development of a successful citizen science program for monitoring woodcock requires balancing researcher goals with participant preferences and abilities.

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Young or early successional forests, defined here as regenerating even-aged forest stands that are generally under 20 years old (Kelley et al. 2008), play an important role for many wildlife species. These cover types were historically created and maintained across the landscape by natural disturbances such as windthrow and fire; human activities such as cropland abandonment and forest harvesting are now the main sources of young forest creation (Trani et al. 2001). Young forests provide a unique vegetation structure, with many dense shrubs, saplings, and herbaceous plants. This dense cover is important to a variety of species (Gilbart 2012) including bobcat (*Lynx rufus*), smooth green snake (*Opheodrys vernalis*), New England cottontail (*Sylvilagus transitionalis*), and American woodcock (*Scolopax minor*; hereafter, woodcock). Early successional forest quickly matures and becomes unsuitable for young forest wildlife species unless some form of disturbance occurs to maintain young growth (Trani et al. 2001, Gilbart 2012). Avifauna have been highly impacted by the loss of young forest cover, with population declines of young forest birds paralleling changes in land use and forest succession (Trani et al. 2001).

The Young Forest Project (youngforest.org) was established to address the loss of young forest cover in the eastern United States. Through a collaborative effort by professionals, managers, and private landowners, the Young Forest

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Project creates young forest cover to benefit wildlife. Using best management practices, the Young Forest Project creates demonstration areas on public lands and provides resources and recommendations for management on private property. Funding opportunities for wildlife management are made available to private landowners through collaboration with the U.S. Department of Agriculture's Natural Resources Conservation Service, the U.S. Fish and Wildlife Service, the National Fish and Wildlife Foundation, the Ruffed Grouse Society, state agencies, and other partners.

The Wisconsin Young Forest Partnership (WYFP, youngforest.org/WI), a subgroup of the Young Forest Project, focuses its management efforts in north-central Wisconsin, and uses the woodcock and the golden-winged-warbler (*Vermivora chrysoptera*) as focal species for its young forest management efforts. The Partnership works within an adaptive management framework (Walters 1986) that necessitates an iterative process of evaluation and appropriate adjustment to reach conservation goals for these species. Aceves-Bueno et al. (2015) suggested that insufficient monitoring and lack of stakeholder buy-in are the main reasons that adaptive management systems fail to reach their intended goals. Citizen science—a collaborative effort between volunteers and scientists to collect data—is a potential tool for overcoming those challenges to adaptive management outcomes (Aceves-Bueno et al. 2015).

Although the term "citizen science" may be fairly new (Bonney 1996), the concept of non-professional and amateur scientists collecting quality avian data has a long history. The National Audubon Society's Christmas Bird Count (CBC), started in 1900, is a classic example of volunteers conducting long-term, large-scale bird monitoring. The North American Breeding Bird Survey (BBS, Robbins et al. 1986) is another example, with professional biologists and trained enthusiasts volunteering their time to collect data following a strict scientific protocol. These kinds of volunteer survey efforts contribute to our understanding of North American bird populations and influence management decisions. Citizen science expands the temporal and spatial scales of research by including networks of non-professionals (Dickinson et al. 2010).

Of course, not all science is suitable as citizen science; the protocols and the data collected must be simple enough to be taught fairly quickly to a large number of volunteers. Monitoring that utilizes identification and counting of species and individuals is a popular form of citizen science. Male woodcock have a conspicuous and predictable spring mating display, making them an excellent focal species for citizen science monitoring. Woodcock have also been considered an umbrella species of young forests (Masse et al. 2015), in which managing for woodcock is a strategy that benefits a suite of other wildlife (Kelley et al. 2008). Because they are considered an umbrella species, woodcock singing-ground surveys are used in part for assessing young forest management for many young forest species (Masse et al. 2015).

Given that much of the WYFP's habitat management is conducted on private properties through collaboration with landowners, the Partnership sees a valuable opportunity to include these landowners in the evaluation stage of their adaptive management framework. The Partnership also recognizes citizen science as a strategy to increase landowners' personal connection and buy-in to young forest management. This inclusion is envisioned as a landowner-based woodcock monitoring program that will help the WYFP evaluate its management efforts, engage landowners with their properties, and provide education on young forest management. Although existing broad-scope citizen science programs like eBird (Sullivan et al. 2009) collect data on woodcock, the WYFP needs a more targeted monitoring approach to evaluate habitat management practices implemented by landowners collaborating with the Partnership. The objective of the WYFP is to create a woodcock monitoring program in which landowners survey their properties with a user-friendly protocol based on counting displaying male woodcock in spring, providing feedback on their adaptive management framework.

A successful citizen science monitoring program must accommodate the goals of research as well as the motivations, preferences, and abilities of citizen scientists (Greenwood 2007). To achieve this balance, Greenwood (2007) recommended clearly defining project goals and determining how best to use citizen scientists by understanding their needs, motivations, and limitations. The objective of this research was to gather landowner feedback about woodcock monitoring through interviews and pilot surveys to inform the creation of a citizen science program that suits the needs of both the WYFP and participating landowners.

## Study Area

The focal area of the WYFP's management effort is a 6-county region in north-central Wisconsin. A pilot citizen science program was designed and implemented with family forest landowners in 4 of those counties; Vilas, Oneida, Lincoln, and Langlade. These landowners owned between ~2 and 16 hectares (5 to 40 acres) of land that had either been managed for young forest habitat in the last 5 years or had management planned for the following year. These young forest management areas were either aspen (*Populus* spp.)-dominated forest or alder (*Alnus* spp.)-dominated shrubland; both are cover types suited for young forest management in the Great Lakes region (Wildlife Management Institute 2009).

## Methods

### DATA COLLECTION

We used evaluation research methods to capture feedback on the barriers to and opportunities for monitoring woodcock in a citizen science program, and employed quantitative and qualitative techniques and purposive sampling (Miles et al. 2014) to gather feedback from a very specific group of Wisconsin landowners. We designed a questionnaire in 2016 to gather landowner preferences for monitoring woodcock and used these preferences in the development of a pilot woodcock monitoring program. In 2017, we asked landowners to participate in woodcock surveys using this pilot protocol. We used semi-structured interview methods to create a post-survey interview guide that prompted landowners to share specific information about their woodcock monitoring experiences, while giving landowners flexibility in how they shared that information. In this manuscript, we present social science data derived from questionnaires and interviews; we use the term "survey" solely in reference to biological woodcock counts and protocols. This research was conducted with approval from the Protection of Human Subjects Review Board at the University of Maine (2016-04-09, "Exploratory Study of Family Forest Landowner Citizen Science Preferences").

*Woodcock monitoring preferences* We used an in-person questionnaire (Table 1) to gather landowner preferences for participating in woodcock monitoring on their own properties. Participants answered questions using a 5-point Likert-style scale (Likert 1932) or by selecting from a list of options. During this in-person meeting, we also gathered basic demographic information about the participants through standardized interview questions about age, gender, working status, and education level.

*Participant recruitment* In May, 2016, we invited landowners or land caregivers (i.e., those family members or friends who tended a particular property in the absence of the landowner) from 21 suitable properties in the study area to participate in this questionnaire. Hereafter, the single term "landowner" includes both actual owners of the land and land caregivers. We spoke with all individuals separately, and in some cases >1 landowner associated with each property responded to the questionnaire (e.g., husband and wife, father and son, etc.). Because our research focused on a very specific subset of landowners collaborating with WYFP, we did not intend to conduct a full statistical analysis with this questionnaire, but rather to use landowner responses to inform the creation of a 2017 pilot woodcock monitoring protocol. For that reason, and given the logistical constraints of data collection and the limited pool of properties with completed habitat management through the WYFP, our target sample size was 20 questionnaires.

*Pilot woodcock survey* In 2017, we created a citizen science woodcock survey protocol and a Midwest Avian Data Center (data.pointblue.org/partners/mwadc/) online entry portal and database for landowners to monitor displaying male woodcock using young forest management areas on their properties. This protocol was adapted from the American Woodcock Singing-ground Survey of the U.S. Fish and Wildlife Service (Seamans and Rau 2016) and incorporated landowner feedback from the 2016 questionnaire. Woodcock surveys were a 6-min stationary count of all individual peenting (a distinctive vocalization) males detected. Observers recorded the time of first detection and estimated the distance to each peenting male detected. We included a target-diagram on the data sheet to differentiate individual male woodcock (see Appendix A). Observers also recorded environmental data (sunset time, cloud cover, wind speed on the Beaufort scale, and noise level) and metadata (date, observer, point ID). Survey points were pre-determined by the WYFP and located centrally within young forest management areas on participating landowners' property.

In early spring of 2017, landowners who were contacted for in-person questionnaires in 2016 were invited to participate in a woodcock monitoring pilot study on their properties. Prior to the survey date, we provided a detailed written woodcock survey protocol to landowners and instructed them to read the protocol prior to the time of a survey. We intentionally withheld in-person training prior to their first survey experience to remove potential variability in training and to test the effectiveness of our written protocol without additional training. Woodcock surveys were conducted using a side-by-side, but independent, 6-min singing-ground survey by an individual landowner (or small group) paired with a trained technician. Upon completion of side-by-side surveys, the technician interviewed each landowner, asking a short series of questions to gather information on their monitoring experience, their thoughts on the survey protocol, and their willingness to participate in woodcock monitoring in the future. The technicians recorded landowner responses as handwritten notes. During and after interactions with landowner(s), technicians used participant-observation strategies (Spradley 1980) to record notes and observations about their perception of the ability of landowners to conduct woodcock monitoring and any issues landowners appeared to have during the 6-min survey. Before completing interactions with landowners, technicians answered landowner protocol questions and made suggestions for improving performance and survey data quality based on their observations of landowners during the pilot survey.

The number of landowners who participated in pilot monitoring and interviews was limited by the targeted nature of our sampling and our research focus. Additional factors affecting the number of landowners able to participate in 2017 pilot woodcock surveys were the evening timing of surveys, the 20-day duration of the survey season, and the availability of 2 field technicians to conduct side-by-side surveys and interviews with landowners. Because of our fairly homogenous sample, we can reasonably expect to reach data saturation—the point where no new themes arise from additional data—at ~12 interviews (Guest et al. 2006).

## Data Analysis

We summarized landowner responses to the 2016 woodcock monitoring preference questionnaire using simple averaging. We incorporated landowner feedback from the questionnaire into the 2017 pilot woodcock survey protocol and coded field notes from 2017 pilot survey interviews and field observations using elemental and affective methods, then pattern coded (Miles et al. 2014) to find reoccurring themes in the woodcock surveying experiences of landowners. We extracted quotations presented in the results from field notes.

## Results

### WOODCOCK MONITORING PREFERENCES (2016)

*Participant demographics* Eighteen landowners completed the 2016 questionnaire (*n* = 4 female, *n* = 14 male). Participants ranged from 32 to 78 years of age, with an average age of 64 years. Four participants were working, 2 were semi-retired, and 12 were retired. Six participants had an associate's degree or no college degree, 7 had a bachelor's degree, and 5 participants held a master's degree.

*Questionnaire results* Fifteen of 18 landowners said they would be willing to monitor displaying male woodcock on their own properties for at least 1 to 3 nights each spring (Table 1). Three participants were unwilling to conduct woodcock surveys on their properties. Landowners reported being slightly more likely, on average, to participate in a woodcock survey on their property if they were with a wildlife professional than without one (Table 1). On average, participants thought they would be as likely to conduct a woodcock survey if they had to walk 100 m into young forest as if they could survey from an easily accessible trail or road, with an average response of 3.8 out of 5 for both scenarios (Table 1). Given the option of estimating distance in meters, feet, or yards, most participants preferred yards (Table 1).

### PILOT WOODCOCK SURVEYS (2017)

*Participant demographics* Between 25 April and 15 May 2017, 13 individual landowners (*n* = 7 male, *n* = 6 female) participated in a side-by-side survey and interview process. These landowners conducted a total of 29 6-min woodcock singing-ground surveys and counted 36 total male woodcock. Twelve participants were >50 years old and 1 participant was <50 years old. Ten of the landowners who participated in woodcock surveys completed the 2016 questionnaire, whereas 3 had not.

### POST-SURVEY INTERVIEWS AND TECHNICIAN OBSERVATIONS

*Landowner confidence and ability* After their first experience monitoring woodcock, landowners reported varying confidence in their ability to complete a woodcock survey. Confidence ranged from "nil," "not really confident: I thought we were looking for the birds not listening for them," to "I have a few questions but I understand the concept," to "fairly confident." Landowners expressed that "being able to hear a woodcock and identify it raised my confidence in doing the survey." When asked about their ability to hear woodcock peent calls, 7 landowner monitors thought they could hear peents "reasonably well." The in-person experience of listening for woodcock, not just hearing a recording, proved to be important for landowners. Landowners expressed that they "didn't know what to listen for at first but once [the technician] pointed it out" they could hear it. Listening in the field helped 1 participant realize they experience hearing issues that might affect their ability to survey; "I could hear them fine but direction takes work because I have one bad ear." Six landowners reported low confidence in being able to hearing woodcock peents: "Question mark there, my hearing is not the best," "I heard it when we got close to it but not again," "losing confidence because my ears are ringing and I'm straining to hear." Trained technicians participating in side-by-side pilot surveys with landowners were confident that 6 of 13 landowners were physically able to hear woodcock peent calls well enough to conduct a survey on their own (*n* = 4 female, *n* = 2 male).

Landowners were asked which parts of the survey were most difficult for them. Three landowners reported having difficulty with "estimating distance" to a peenting woodcock. Others said "hearing and identification" of woodcock were issues and "knowing what to listen for," and "too many other calls, it's hard to focus on the woodcock" were causes for that difficulty. One landowner mentioned the difficulty of "transferring 15 mph wind speed to the 0–5 [Beaufort] scale." Technicians observed several cases of landowners recording wind speeds in miles/hour instead of in the Beaufort scale values described on the data sheet.

*Landowner impressions of survey protocol* Overall, landowners found the survey protocol easy to follow: "on a scale of 1 to 10, 7," "that was easy," "real good, excellent," "it was fine." Several landowners expressed ease in following the protocol overall but had "some specific questions" about parts of the protocol. One landowner thought, "it was a lot to read, lots of words, but straightforward." Six landowners offered specific suggestions for improving the survey protocol. Those suggestions included: 1) making it shorter—"break up the words, make an easy table, the info is good just too long to read;" 2) clarifying the purpose of the distance diagram on the data sheet—"the distance map…how are we supposed to mark it?" and "clarifying that the target diagram is to help with the number of individual birds;" and 3) making the web link to the woodcock sound easier to find —"biggest thing was what do I listen for? It doesn't sound like a peent to me." Suggestions for improving the data sheet included "larger print on the datasheet even if it took 2 pages," and "written instructions on a second sheet to bring into the field" to help remind them of survey protocol while they were surveying.

Other general suggestions by landowners for improving their monitoring experience included: "making the time commitment required clearer to landowners," "before we went out, play the vocalization" as a "refresher of what noise to listen for," and "go through the form before the survey and point out the difference boxes and lines and what info goes where."

**Table 1.** In 2016, 18 Wisconsin landowners implementing young forest management on their properties were asked about their American woodcock (AMWO) monitoring preferences. Participant responses to an in-person questionnaire addressing landowner preferences for woodcock monitoring are shown here. Q1 and Q6 were multiple choice, and Q2–Q5 were answered on a 5-point Likert-style scale where 1 represented very unlikely and 5 represented very likely.

| | **Distribution of Responses by Question** | | | | | |
|---|---|---|---|---|---|---|
| **Response** | **Q1[a]** | **Q2[b]** | **Q3[c]** | **Q4[d]** | **Q5[e]** | **Q6[f]** |
| mean response | N/A | 3.9 | 3.3 | 3.8 | 3.8 | N/A |
| mode response | 1–3 days | 5 | 5 | 5 | 4 | yards |
| 0 nights | 3 | | | | | |
| 1–3 nights | 8 | | | | | |
| 3–5 nights | 7 | | | | | |
| 1, very unlikely | | 2 | 3 | 3 | 1 | |
| 2, unlikely | | 0 | 3 | 0 | 1 | |
| 3, neutral | | 3 | 3 | 4 | 4 | |
| 4, likely | | 5 | 3 | 2 | 7 | |
| 5, very likely | | 8 | 6 | 9 | 5 | |
| meters | | | | | | 1 |
| feet | | | | | | 3 |
| yards | | | | | | 10 |
| feet or yards | | | | | | 3 |
| any unit | | | | | | 1 |

[a] How many nights would you be willing to dedicate to AMWO surveys between April 25 and May 15th?

[b] How likely are you to participate in an AMWO survey on your own property if you are with a wildlife professional?

[c] How likely are you to conduct an AMWO survey on your property without a wildlife professional (you can conduct the survey with family members, friends, neighbors, etc.)?

[d] How likely are you to conduct an AMWO survey from a road or trail, where it is fairly accessible?

[e] How likely are you to conduct an AMWO survey 100 meters (or 328 ft or 109 yards) off a trail or road, into the habitat?

[f] Which system and unit of measurement are you most comfortable using to estimate distance, meters, feet, or yards?

*Future participation in monitoring* Landowners were asked if they would have hesitation in conducting the same woodcock survey on their own in the future. None of the landowners reported disinterest in participating again in the future. Their responses fit into 3 categories: 1) no hesitation, 2) wanting more practice, and 3) hesitation because of hearing. Those who expressed no hesitation felt that they would "give it a shot," they were "happy to" because "it was fun!" and said they might invite company: "I'm gonna do it with my kids." Several thought that if they "had more practice [they] would do it again, 6 minutes [the time it takes to monitor one survey point] is not a big commitment." Others were "not ready to do it on my own yet," but implied with more practice they might be interested. The final group of landowners was hesitant only because of their hearing; "yeah, I would do it. Worst thing would be listening for them. I'd bring someone along," and "The hearing issue, I don't want to give you bad data, otherwise no [hesitation]."

*Landowner preferences for data submittal* Eleven participants said they would be willing to enter their data online, whereas 2 reported a preference to mail in their data sheets with 1 saying "I don't have a computer at home." Of the 11 landowners willing to enter data online, 5 registered to enter their data online and 3 took the step of entering data online. Those who entered data did so accurately.

## Discussion

The WYFP is working to create a monitoring program in which landowners conduct valuable woodcock surveys and that offers education and engagement that help landowners better understand the young forest management outcomes on their properties. From our perspective as researchers, the woodcock data collected must be valid and useful to the specific goal of assessing the impact of WYFP's management efforts. Using citizen science monitoring is a valuable strategy for evaluating and updating management efforts in an adaptive management framework (Aceves-Bueno 2015). Collaborating with citizen scientists can overcome some of the financial and logistic challenges of traditional research by expanding the geographic and temporal scope of research and increasing access to private lands (Dickinson et al. 2010). Leaders of the WYFP appreciate the ecological importance and management implications of monitoring and evaluating efforts on private lands (Gibbs et al. 1999) but have limited financial means to do so. They also appreciate the social benefits of including stakeholders in the adaptive management process (Larson et al. 2013, Aceves-Bueno 2015). The citizen science program they envision creates a compromise between the lower cost and potentially lower skill level of landowners conducting surveys and the benefit of educating and engaging landowners through their participation. Although paid technicians likely provide higher quality ecological data, the cost of their time, along with the added challenge of accessing private lands across a large geographic area, makes them an unrealistic option within the WYFP budget. By taking the time to understand the views, preferences, and limitations of Wisconsin landowners (Greenwood 2007), the WYFP is increasing the likelihood of creating a scientifically rigorous, user-friendly, and engaging woodcock monitoring program that meets its monitoring and outreach objectives.

Other researchers highlight the importance of understanding volunteers (Weston et al. 2003, Greenwood 2007) and creating a sense of community among volunteers and researchers (West and Pateman 2016). Clearly explaining why the research is important and why particular variables are of interest increases volunteer interest and dedication to the project (Rotenberg et al. 2012). In our 2017 pilot survey protocol, we explained how landowner-collected data would be used, and the personal benefits of participating in monitoring: “The data you collect will help the Wisconsin Young Forest Partnership and other natural resource organizations and agencies assess the effectiveness of young forest management strategies, such as those implemented on your property. This will also give you, the observer, an opportunity to learn more about your property and the wildlife it supports.” In-person trainings are an important strategy for increasing volunteer confidence in protocols and help increase data consistency and quality (Newman et al. 2003, Gallo and Waitt 2011, Rotenberg et al. 2012). Our post-survey interviews reflected this need for in-person training, with landowners expressing a desire for additional direction prior to surveying, and several indicating that more practice or training would help encourage them to participate in the future. Reporting findings back to volunteers (Hobbs and White 2012) and giving opportunities for volunteers to provide feedback (West and Pateman 2016) also improves the volunteer experience and long-term interest in the research. The WYFP plans to create an annual report, summarizing woodcock monitoring efforts and findings, for landowners. We encouraged communication and welcomed landowner questions and feedback by clearly listing organizer contact information on our pilot survey protocol.

### RECOMMENDATIONS FOR LANDOWNER WOODCOCK MONITORING

One important way to improve the consistency and quality of woodcock monitoring data is to provide in-person training for all participants (Table 2). We intentionally withheld pre-survey training prior to the pilot monitoring project and only provided landowners with a written protocol before attempting their first survey. Trained technicians conducting surveys alongside landowners were not confident in the consistency and quality of the data landowners were collecting after reading the written protocol alone. A possible supplement or alternative to in-person training would be to create training videos that remind landowners what to listen for and how to complete the data sheet. In a Massachusetts study, participants trained with videos were found to be as successful at identifying invasive plants as those who received in-person training, and better than those who received text and photo-based training (Starr et al. 2014). Based on participant feedback and technician observations, we concluded that gaining experience through practice is key (Table 2). Several landowners conducted pilot surveys on 2 separate occasions. Anecdotally, these landowners seemed more confident and performed better during their second woodcock monitoring experience than their first.

Dickinson et al. (2010) point out the importance of understanding and accounting for observer skill level and experience and recognizing “first-year” effects, with the survey skills of new observers improving over time. The BBS excludes surveys from first-year observers in their population analyses because first-time observer data has been found to artificially increase population trend estimates, as their bird detections increase with survey practice (Kendall et al. 1996). The North American Amphibian Monitoring Program (Weir 2005) requires its volunteers to take a frog call identification quiz (http://www.pwrc.usgs.gov/Frogquiz/) and score above a set threshold before they can participate in monitoring. Birder Certification Online (http://birdcertification.org/) is a similar tool that tests visual and auditory bird identification. Programs like the BBS and CBC provide learning tools and identification resources but do not require a formal evaluation of skill level before volunteers conduct surveys.

Possibly the most important aspect of creating a successful woodcock monitoring program to produce quality scientific data is to make sure that landowners who are collecting data are physically capable of hearing a peenting woodcock from ≥100 m (Table 2). The landowners in the potential pool of citizen scientists for the WYFP are largely retired and over the age of 50. Of the 13 landowners who participated in pilot surveys, 6 self-reported having issues hearing peent calls, and technicians felt that 7 were not able to hear woodcock peents well enough to survey on their own. Farmer et al. (2014) found that hearing and other age-related factors are a source of error in bird monitoring that could bias management decisions. To remove this bias, it is important to have some form of standardized evaluation of participants' abilities to hear peenting male woodcock well enough to conduct a survey on their own, and to continue these hearing checks through time as they continue to collect data in consecutive years. Bergh and Andersen (this volume, Detection probability and occupancy of American woodcock during Singing-Ground Surveys) accounted for differences in survey ability by incorporating the effect of individual observers on woodcock detection.

Developing a standardized evaluation for hearing ability and identifying woodcock will be necessary for the WYFP to meet its goal of creating a citizen science program that produces reliable data. If there is no formal evaluation of hearing ability, there will be no way to separate surveys in which woodcock are absent or undetectable from those in which landowners are physically unable to detect them. Data with such uncertainty cannot be used for making sound management decisions. If landowners are unable to hear woodcock peents to a testable standard, encouraging partner or small group monitoring, where someone who is able to hear well enough partners with someone unable to adequately hear peenting woodcock, is a more inclusive option than barring a landowner from monitoring altogether. The partner monitor(s) could be a family member or friend who is trained to monitor, or even possibly an unassociated trained volunteer who would be granted access to the property for monitoring. This volunteer access strategy could also be used for properties where landowners are uninterested or unable to conduct surveys themselves but are willing to allow access to their properties for someone else to conduct woodcock surveys (Table 2).

**Table 2.** Recommendations for creating a landowner American woodcock monitoring program on private lands. These recommendations are based on landowner feedback from questionnaires, interviews, and pilot surveys conducted in north-central Wisconsin in 2016 and 2017.

| Recommendations for Landowner Woodcock Monitoring |
|---|
| 1. Provide in-person and/or video-based survey training for landowners. |
| 2. Standardize annual evaluation of landowners' ability to hear peenting woodcock from at least 100 m away. |
| 3. Encourage pre-survey practice, as this is important for landowner confidence and data reliability. |
| 4. Consider how first-time observer effects may impact data reliability and quality when conducting and interpreting data analysis. |
| 5. Provide flexible data submittal channels, including both online and paper forms. |
| 6. Require submission of all hard copy data sheets to increase likelihood of receiving all survey data. |
| 7. Develop a network of non-landowner volunteers to survey at properties where landowners are unable or unwilling to survey but willing to grant access for monitoring. |

Flexibility with data reporting methods also appeared important in our pilot project (Table 2). There are many benefits to using online databases in which landowners can enter their observations in a centralized location for storage, organization, analysis, and exploration (Newman et al. 2010, Dickinson et al. 2012, Miyazaki et al. 2015). However, given the older age demographic of the landowners who may monitor woodcock, an option for returning hard-copy data seems necessary to accommodate all computer skill levels and those who may not have access to computers. Given the low rate of online reporting by monitors in our pilot study, monitoring programs may benefit from making the return of hard-copy datasheets a standard practice to ensure that all data collected is received (Table 2). Although we do not fully understand the discrepancy between the 11 landowners willing to enter online data and the 5 who actually did, training may play a role. In our pilot study, landowners were given written instructions for online submission, but we provided no in-person training or demonstration. Including explicit training for data submission procedures and periodic reminders may increase online reporting by landowners.

## FUTURE STEPS FOR WYFP LANDOWNER WOODCOCK MONITORING

The WYFP is currently reviewing its citizen science monitoring objective, using the information gathered in this study, to better align the ability and interest of the landowners with the Partnership's scientific interests. This objective will be evaluated again in the future to determine how well the program is reaching its intended research and participant goals. The next steps will include an update of the survey protocol to reflect the suggestions made by pilot study landowners and the revised program objective. Developing training and outreach materials that 1) clearly and concisely lay out the goals and importance of monitoring, 2) explain the purpose and value of the citizen scientist to the Partnership's evaluation objective, and 3) educate and engage landowners will help maintain landowner interest and participation in woodcock monitoring. Making protocols and training materials available in a centralized and user-friendly online location on the WYFP's website will enhance usability of the program. Systems for clear and simple communication and annual reporting back to landowners, as well as a channel for gathering landowner feedback into the future, will be developed to increase the longevity of participation by landowners.

Revising the WYFP's evaluation objective to be consistent with landowner needs and abilities is key to the successful launch and sustainability of a citizen science-based woodcock monitoring program. The strategies and recommendations from this research will help other land managers decide if a citizen science program is right for them as they create wildlife monitoring and habitat management evaluation programs in the future.

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UMaine 2017 American Woodcock **Landowner Data Sheet**

| | | | | |
|---|---|---|---|---|
| Property Owner/Site: | Point ID: | Month: | Day: | Year: |

| | | | |
|---|---|---|---|
| State: | County: | Visit (circle): 1 2 | Observer: |

*Sunset + Sky Cond Addition =*
**Earliest Possible Start time**:
___:____+____=____:_____
*<Sunset> <15 or 22 min>*
**This survey began at:**
_____ : ________pm

Sky Cond (check one):
0 ☐ clear
1 ☐ 1/4 overcast
3 ☐ 1/2 overcast
5 ☐ 3/4 overcast
Add 22 min to start time
7 ☐ >3/4 overcast --Add 15 min

Estimated Temperature:
°F

Wind (0-5):

Noise Disturbance:

**none** ☐ no effect on count
**low** ☐ slightly affecting count
**moderate** ☐ moderately affecting count
**heavy** ☐ seriously affecting count
Source(s) of disturbance:
*i.e.: frogs, traffic*

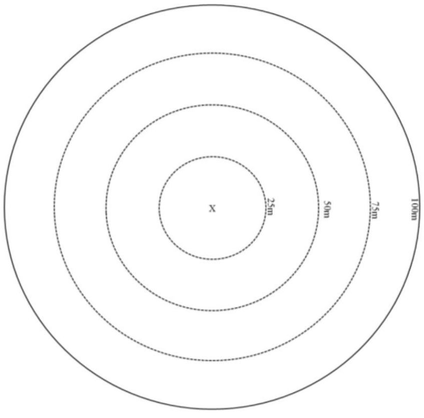
Precip: **none** ☐ **fog** ☐ **mist** ☐ **light rain** ☐ **heavy rain** ☐ **snow** ☐

*Wind*: 0=smoke vertical, 1=smk drift, 2=wind on face, 3=twg constant motion, 4=sm branches move, 5= trees sway

*Disturbance* Examples: *None* = e.g., crow occasionally calling; *Low* = e.g., distant traffic noise; *Moderate* = e.g., intermittent traffic noise, soft chorus of spring peepers; *Heavy* = e.g., continuous traffic, loud chorus of peepers

| Bird ID  | Distance from Observer (yards) | "Peenting" First Detection Time | | | Outside managed patch? **check if true** | Range Finder Used? **check if true** |
|---|---|---|---|---|---|---|
| | | 0 – 2 mins | 2 – 4 mins | 4 – 6 mins | | |
| 1 | | | | | ☐ | ☐ |
| 2 | | | | | ☐ | ☐ |
| 3 | | | | | ☐ | ☐ |
| 4 | | | | | ☐ | ☐ |
| 5 | | | | | ☐ | ☐ |
| 6 | | | | | ☐ | ☐ |
| Total AMWO | | | | | | |

Use the diagram to help keep track of individual peenting male woodcock, 25 yard rings are shown.



OPTIONAL: Other Nocturnal Bird Detections

| Nocturnal Bird Species | Distance from Observer (yards) | First Detection Time | | | Outside managed patch? **check if true** | Range Finder Used? **check if true** |
|---|---|---|---|---|---|---|
| | | 0 – 2 mins | 2 – 4 mins | 4 – 6 mins | | |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |
| | | | | | ☐ | ☐ |

**Notes:**

Remember that surveys begin at calculated start time and continue for no longer than 38 minutes each night.

# Mobilizing Private Landowners to Create American Woodcock Habitat: Lessons Learned in Rhode Island, USA

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**ABSTRACT** Engaging private landowners in the conservation of American woodcock (*Scolopax minor*; hereafter, woodcock) in the northeastern United States is important because most forests in the region are privately owned. For this reason, a consortium of conservation agencies in the region has been encouraging private landowners to create young forest vegetation types. This study summarizes the achievements and lessons learned through 3 components of a collaborative outreach program as practiced in Rhode Island, USA since 2008: 1) providing technical and financial assistance to private landowners to support woodcock habitat creation, 2) developing a woodcock management demonstration area in the Great Swamp Wildlife Management Area to support research and landowner trainings, and 3) conducting research on landowner involvement in the creation of young forest. We found that the financial and technical assistance was an important factor motivating private landowners to create young forest. Furthermore, response to a follow-up questionnaire after our trainings was encouraging; 83% of the participants followed up with forest management on their own properties, and creation of young forest was the most common activity. The woodcock demonstration area strongly supported the training programs by allowing landowners to see regenerating clearcuts of 4 different ages in close proximity, and it was used as a research site to determine how woodcock selected certain-aged young forest patches. Our spatial analysis confirmed that the extent of young forest created in Rhode Island during the 7 years after 2004 was almost double the extent created during the previous 7 years, and that private landowners created more habitat than either government agencies or nongovernment organizations. We conclude that private landowners can play an important role in the conservation of woodcock, and recommend an expanded outreach program to mobilize them.

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**KEY WORDS:** American woodcock, clearcutting, early successional forest, forestry demonstration, private landowners, spatial analysis

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American woodcock (*Scolopax minor*; hereafter, woodcock) populations in the eastern United States have declined by roughly 1% per year since 1968 (Cooper and Rau 2013), a decline linked to the loss of young forest vegetation types (McAully et al. 2005, Kelly et al. 2008). Private landowners are critical to the conservation of woodcock in southern New England, where private ownership of forests is 77% in Connecticut, 79% in Massachusetts, and 85% in Rhode Island (Butler et al. 2011). For this reason, a consortium of federal, state, university, and private conservation agencies in Rhode Island has been collaborating since 2008 to encourage private landowners to create habitat for woodcock and other species that require young forests.

The consortium is led by 4 agencies—the Rhode Island Department of Environmental Management (RIDEM), the University of Rhode Island (URI), the USDA Natural Resources Conservation Service (NRCS), and the Rhode Island Resource Conservation and Area Development Council (RC&D)—and has received valuable support from several other agencies, including the USDA National Institute of Food and Agriculture (through URI Agricultural Experiment Station), the RI Forest Conservators Organization, and the Ruffed Grouse Society. The program has included 3 main components: 1) providing technical and financial support to motivate private landowners to create young forests on their properties, 2) creating a 40-ha woodcock management demonstration area for research and training purposes, and 3) conducting research on landowner involvement in the creation of young forests. The purpose of this manuscript is to document the lessons learned through this integrated program and to offer recommendations for an expanded outreach program to private landowners in the northeastern United States.

## Study Area

Our study area for our larger-scale spatial analyses and for engaging private landowners in forest management included the state of Rhode Island. Our study also focused on the 40-ha woodcock management demonstration area in the Great Swamp Wildlife Management Area, South Kingstown, Rhode Island, USA. The RIDEM Division of Fish and Wildlife initiated forest cutting in 1995 within an area that was formally designated in 2008 as a woodcock habitat demonstration area. RIDEM created this demonstration area to support the Woodcock Conservation Plan for New England/New York, which proposed developing demonstration areas on public lands to showcase exemplary habitat management for woodcock and other young-forest-dependent wildlife (Williamson 2008). RIDEM selected the Great Swamp Wildlife Management Area for this demonstration area because its approximately 1,050 ha of wetland forest and 325 ha of upland forest were largely in older age classes (60 to 100 years old). The stated objectives for the Rhode Island woodcock demonstration area were to: 1) manage young forest vegetation types for woodcock and other wildlife, using Best Management Practices, 2) monitor woodcock and songbird response to habitat management, 3) measure key habitat features, and 4) create educational materials and opportunities for private landowners. Given the importance of this demonstration area for landowner training and research, we briefly describe in the Results how the demonstration area was developed and how it has been utilized.

## Methods

### TECHNICAL AND FINANCIAL SUPPORT TO PRIVATE LANDOWNERS

The consortium organized a number of training events each year for private landowners, including the annual Rhode Island Coverts Workshop, a 3-day event that included classroom and field-based training related to creating young forests. We also encouraged private landowners to apply for technical and financial support from the NRCS Environmental Quality Incentives Program (NRCS 2017) and the URI-NRCS Regional Conservation Partnership Program (URI 2017). In 2014, we conducted a survey of private landowners who created young forests after having participated in a Rhode Island Coverts Workshop between 2008 and 2012 (Buffum et al. 2014). We provide a summary of these survey findings and a follow-up analysis of NRCS technical and financial support targeted to create young forest.

### SPATIAL ANALYSIS OF YOUNG FOREST VEGETATION

Our spatial analysis compared the extent of young forest vegetation created in Rhode Island during 2 7-year periods (1997–2004 and 2004–2011) by private landowners, government agencies, and non-government organizations. We used ArcGIS version 10.4.1 (Environmental Systems Research Institute, Redlands, CA) with datasets and imagery that are publicly available on the Rhode Island Geographic Information System (RIGIS 2017); land use/land cover (1997, 2004 and 2011); conservation status (2014); and imagery (1997, 2004, 2008, 2011, 2016). We identified parcels with an area ≥1 ha that were classified as forest in 2004 and as non-forest in 2011. We used the 2004 and 2011 imagery to confirm that the plots had been clearcut. We used the 2016 imagery to exclude plots that had already been converted to land uses other than young forest by 2016. Finally, we classified the ownership status of the remaining young forest plots into 6 categories of conservation land (state, federal, municipal, land trust, non-governmental organization [NGO], private) and 1 category of non-conservation land. We compared the results to data from a previous study that used a similar approach to assess the extent of young forest vegetation types created between 1997 and 2004 (Buffum et al. 2011).

## Results

### SUPPORT TO PRIVATE LANDOWNERS

Follow up by private landowners after attending our trainings was encouraging—our survey found that 83% of landowners who had attended the Coverts Workshop ≥6months before the survey had already followed up by preparing a management plan or implementing forestry activities on their properties, with the most common activity being the creation of young forest (Buffum et al. 2014). The main factor affecting how quickly they implemented forest management activities after the training appeared to be whether they had completed a forest management plan, a process that can take up to a year. Eighty percent of participants with management plans had already implemented some forest management activities.

The size of forest holdings did not affect the likelihood of follow-up after the training. Participants owning ≥20 ha of forest mentioned several advantages of having larger forest holdings when creating young forest vegetation types: greater flexibility in site selection, fewer conflicts with neighbors who do not like clearcuts near their property boundaries, and greater ability to engage loggers who often prefer larger jobs. Participants with smaller holdings were less likely to be interested in earning income from their forests or to have sold timber or firewood. However, they were equally likely to have conducted forest management before attending the training, and to have followed up after attending the training.

Landowner awareness about the importance of young forests was low. All of our training participants had a strong interest in wildlife, but few were aware before attending the training that so many wildlife species depended on young forests or that this vegetation type was declining in New England. Many viewed clearcutting negatively, and 33% said they probably would not have implemented any clearcuts if they had not attended the training. Financial and technical assistance from NRCS was an important motivating factor; 84% of the landowners who implemented activities after attending the Coverts Workshop received support from NRCS, and 47% said they would probably not have implemented the activities without the financial assistance. However, many participants were not aware about NRCS financial assistance programs before attending our training.

### WOODCOCK DEMONSTRATION AREA

After the plan for the woodcock demonstration area was formally submitted in 2008, RIDEM almost tripled the extent of young forest vegetation to 33.17 ha with 4 more clearcuts in 2012 and 2017 (Table 1 and Fig. 1). The aim was to create a mosaic of young forest stands of different ages adjacent to mature forest and open fields. The planned clearcuts were marked by wildlife biologists and foresters, and offered for sale at open bid to local commercial loggers. The payments from the loggers covered all of the costs of the habitat-creation program. The loggers were instructed to leave 1–2 mast-producing trees per ha as a food source for wildlife and 1–2 standing dead snags per ha as habitat for cavity nesters. All downed woody debris was retained on-site scattered or in small brush piles. As our experience grew, we planned larger patch cuts (>4 ha each) and reduced the stand reentry time to accomplish our original goal of a 25-year rotation for the entire area. For more information about the site, see Timberdoodle.org (2017).

Initially we encountered some opposition to creating these clearcuts, the purpose of which was misunderstood by some citizens who visited the area for recreational purposes. We responded to these complaints through educational presentations about the habitat program, stressing that the clearcuts were necessary to preserve biodiversity within the management area by creating young forests that so many wildlife species depend upon.

RIDEM and URI started a pilot research program in 2008 to examine the impact of the young forest management on woodcock and other bird species (Masse et al. 2013, Masse et al. 2014, 2015). In brief, we captured male woodcock on their singing grounds and fitted them with backpack-style transmitters. The telemetry data included locations, movements, survival, and habitat use by woodcock, expanding knowledge of local woodcock and the impact of the demonstration area. Basic home-range and habitat-use data included dominant forest type used, age class, stem density, overstory density, and earthworm biomass. We also used point-count surveys to assess the impact of habitat management on other high-priority avian species.

We determined that all of the habitat needs of woodcock residing in the Great Swamp Wildlife Management Area during spring through fall could be met because roosting meadows, daytime feeding areas, and singing grounds were available. Some important findings were that

**Table 1.** Timing and combined area of young forest habitat patches produced by Rhode Island Department of Environmental Management Division of Fish and Wildlife as part of the creation of an ca. 40-ha woodcock management demonstration area in the state-owned Great Swamp Wildlife Management Area, South Kingstown, Rhode Island.

| Year | Hectares | Number Plots |
|---|---|---|
| 1995 | 4.63 | 3 |
| 2007 | 8.50 | 3 |
| 2012 | 9.81 | 2 |
| 2017 | 10.24 | 2 |
| Total | 33.17 | 10 |

1) 83% of the daytime feeding areas were located in wetland deciduous forests, 2) average stem density within home ranges was 9,500 stems per ha, and 3) earthworm biomass was significantly higher within home ranges than in other nearby forests. The importance of the habitat management for other avian species was an additional benefit that supported the habitat management program goals, as 39 species of birds were identified using the managed areas, including several species of high conservation concern.

We used the demonstration area to educate university wildlife classes, visiting scientists and symposiums, and private citizen forestry associations, and for targeted private landowner outreach programs such as the Rhode Island Coverts Workshop. The demonstration area allows our team of scientists to communicate directly with private landowners about the impact they can have on wildlife by employing basic habitat management practices on their properties. We plan to install a series of interpretive signs to further educate the public about woodcock habitat requirements. URI graduate students and faculty are working with RIDEM to design interpretive signs with information about woodcock roosting grounds (Fig. S1), singing grounds, feeding grounds, nesting cover, and other topics (Monahan 2012).

### SPATIAL ANALYSIS OF YOUNG FOREST COVER TYPES

The amount of young forest created in clearcuts of ≥1 ha in Rhode Island increased from 37.9 ha/year during the period of 1997–2004 to 73.9 ha/year during the period of 2004–2011 (Table 2). In both periods, most of the young forest was created on privately-owned land without any conservation status, which applies to most landowners who apply for NRCS support. Most of the young forest produced on conservation lands was created by municipal organizations during the first period, and by the State of Rhode Island in the second period. In both periods, most of the young forest that was subsequently converted to other land uses was for residential and commercial construction, with much smaller amounts used for agriculture, gravel mines, and lawns. Most of these conversions took place within a few years; our analysis of the 2016 imagery revealed that only 7% of the young forest created between 1997–2004 that was still forest in 2008 was converted to other land uses by 2016.

These findings on the extent of young forest created on state land are consistent with data compiled by RIDEM, which show that the extent of clearcuts on state land increased considerably after 2004 (Fig. 2). This trend can be expected to continue due to planned clearcuts in 2018 and 2019 at the same level as the 2017 cuts. NRCS support to private landowners for creating young forest in Rhode Island also increased since 2006. The annual extent of young forest created by private landowners with support from NRCS for early successional habitat practices during 2012–2017 was almost 3 times the annual extent during 2006–2011.

## Discussion

Our findings highlight the importance of educating landowners about the value of young forest cover types for wildlife. Awareness of this issue before attending the training was unexpectedly low, considering that the participants already had strong interest in wildlife. This applied to several participants who had already prepared forest management plans before attending the training, which suggests that their consulting foresters did not stress the importance of creating young forest during the process of plan preparation. Thus, we believe that consulting foresters as well as landowners could benefit from training about the ecological importance of young forests. This is especially important considering that many landowners have negative perceptions about clearcutting (Berlick et al. 2002).

Our findings also suggest an opportunity for outreach programs in southern New England to target landowners with small forest holdings. Other studies have reported correlations between larger forest holdings and more active forest management (Rickenbach and Kittredge 2009) and greater participation in forestry programs (Poudyal and Hodges 2009, Ma et al. 2012). However, our participants with smaller holdings were equally likely to

**Table 2.** Amount of young forest created in Rhode Island between 1997–2004 and 2004–2011 by fee ownership type based on clearcuts of ≥1 ha that had not been converted to non-forest land use 5 years after the end of the period.

| Fee Ownership | Conservation Status | 1997–2004 |  | 2004–2011 |  |
|---|---|---|---|---|---|
|  |  | Ha | % of total | Ha | % of total |
| State | Conserved | 7.4 | 3 | 55.4 | 11 |
| Federal | Conserved | 0.0 | 0 | 2.7 | 1 |
| Land Trust | Conserved | 8.6 | 3 | 7.0 | 1 |
| Municipal | Conserved | 81.4 | 31 | 49.3 | 10 |
| NGO | Conserved | 0.3 | 0 | 20.1 | 4 |
| Private | Conserved | 3.6 | 1 | 3.6 | 1 |
| Private | Non-conserved | 164.1 | 62 | 378.9 | 73 |
| Total |  | 265.3 | 100 | 517.0 | 100 |
| **Total per year** |  | **37.9** |  | **73.9** |  |

follow up with management practices on their properties after the training. We believe that landowners with small holdings can make a valuable contribution by creating woodcock singing grounds, which can be achieved with clearcuts as small as 0.2 ha (Kelley et al. 2008), although cuts ≥0.6 ha would also provide suitable habitat for many shrubland bird species (Askins et al. 2007). Landowners with small holdings can also support wildlife species such as New England cottontail (*Sylvilagus transitionalis*) that require much larger habitat patches if their properties are near existing patches of young forest (Buffum 2016).

The financial and technical assistance offered by NRCS was an important motivating factor for the landowners who attended our training sessions. We agree with Daniels et al. (2010), who reported that profit was not the primary objective of many landowners, but that the financial incentives increased the area of forest owners were willing to manage. We strongly endorse the current NRCS program of providing financial support for the preparation of forest management plans, an important first step in creating wildlife habitat. We recommend that these important technical and financial assistance programs be promoted more widely, and that simpler descriptions of NRCS forestry programs and application procedures be developed.

The woodcock demonstration area has been extremely valuable for our outreach program because it allows landowners to see regenerating clearcuts of 4 different ages in close proximity, which makes them much more comfortable with the idea of clearcutting. The scale of habitat management in the demonstration area can be intimidating for some private landowners, but our training sessions also include visits to private landowners who have implemented smaller-scale habitat-creation activities. Several authors have emphasized the benefits of peer-to-peer learning as an effective approach to motivate landowners (Rickenbach and Kittredge 2009, Ma et al. 2012). We believe that exposing participants in our training sessions to both small- and large-scale habitat management activities is an effective strategy, and the feedback from those who attended training sessions has been highly favorable.

We are far from creating the amount of young forest in Rhode Island that wildlife biologists have recommended to stabilize populations of woodcock and other species that require this vegetation type. For example, Dettmers and Rosenberg (2000) proposed addressing population objectives for priority shrubland bird species by maintaining young forest on 10% of forests in southern New England, which is almost double the current extent in Rhode Island (Buffum et al. 2011). The 2008 Woodcock Conservation Plan proposed an even more ambitious program of maintaining shrubland and young forest on 27% of forests in Rhode Island, which would require a greatly increased amount of clearcutting. Nevertheless, we were encouraged to see that the amount of young forest created per year in Rhode Island doubled after 2004, and that most of this increase was due to the efforts of private landowners. We cannot attribute all of this increase to the efforts of our consortium, but we are confident that our integrated program has made a positive contribution and that further increases are possible if we intensify our efforts. It is also clear that private landowners can play an important role in the conservation of woodcock in our region and elsewhere, and we recommend an expanded outreach program to mobilize them.

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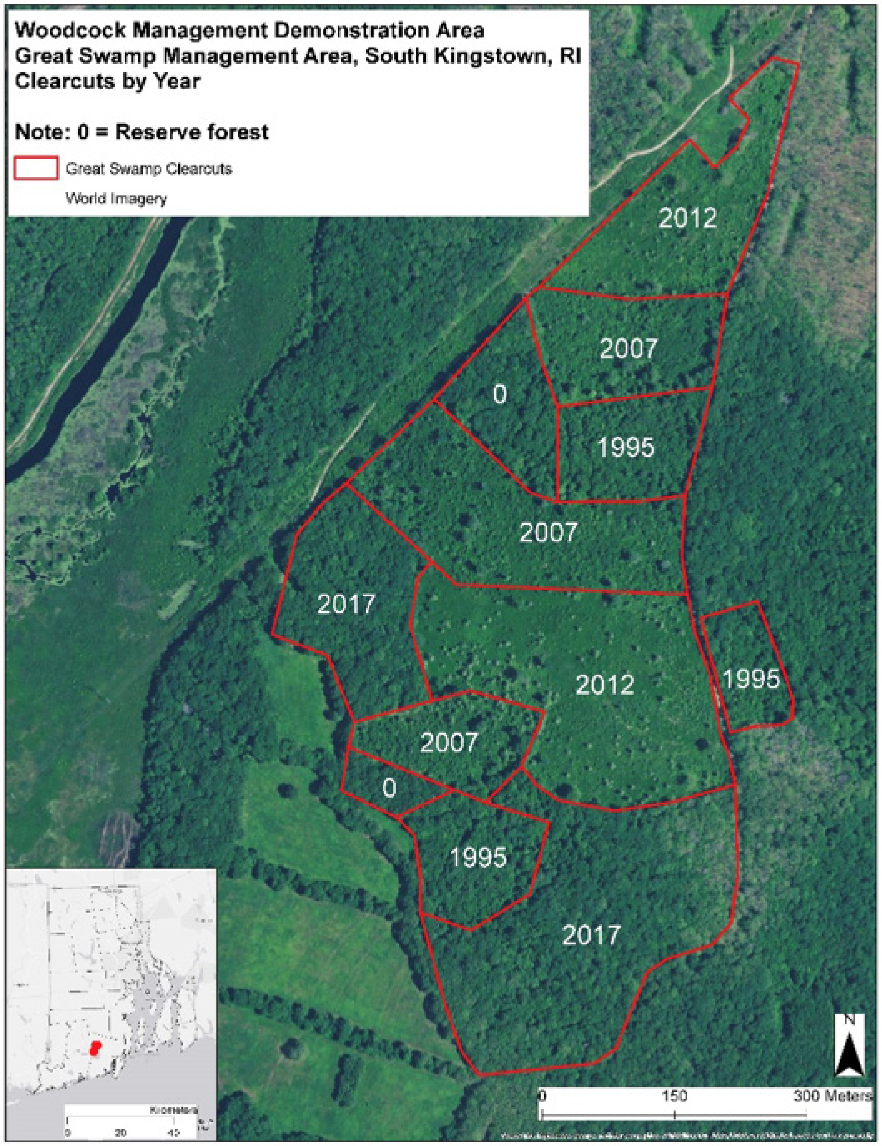


**Figure 1.** Location of young forest patches produced by the Rhode Island Department of Environmental Management Division of Fish and Wildlife during 1995 to 2017 as part of the creation of an ca. 40-ha woodcock management demonstration area in the state-owned Great Swamp Wildlife Management Area, South Kingstown, Rhode Island, USA.

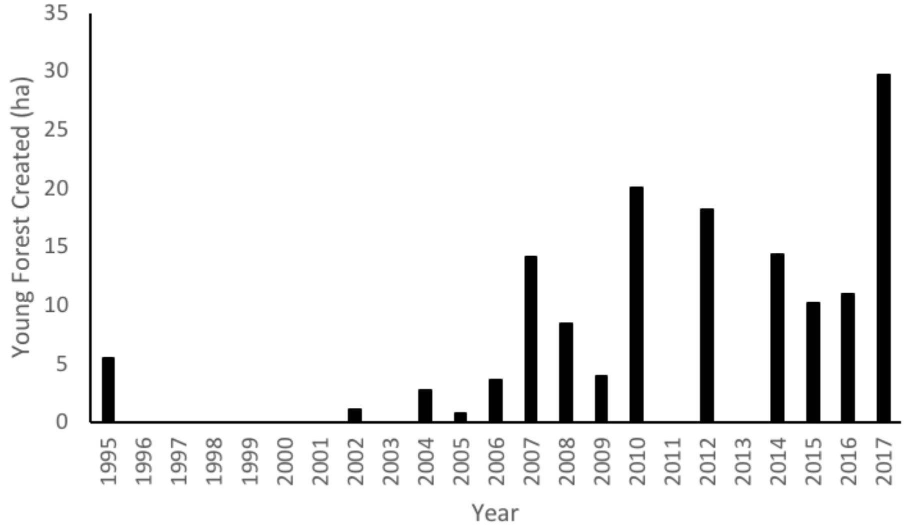
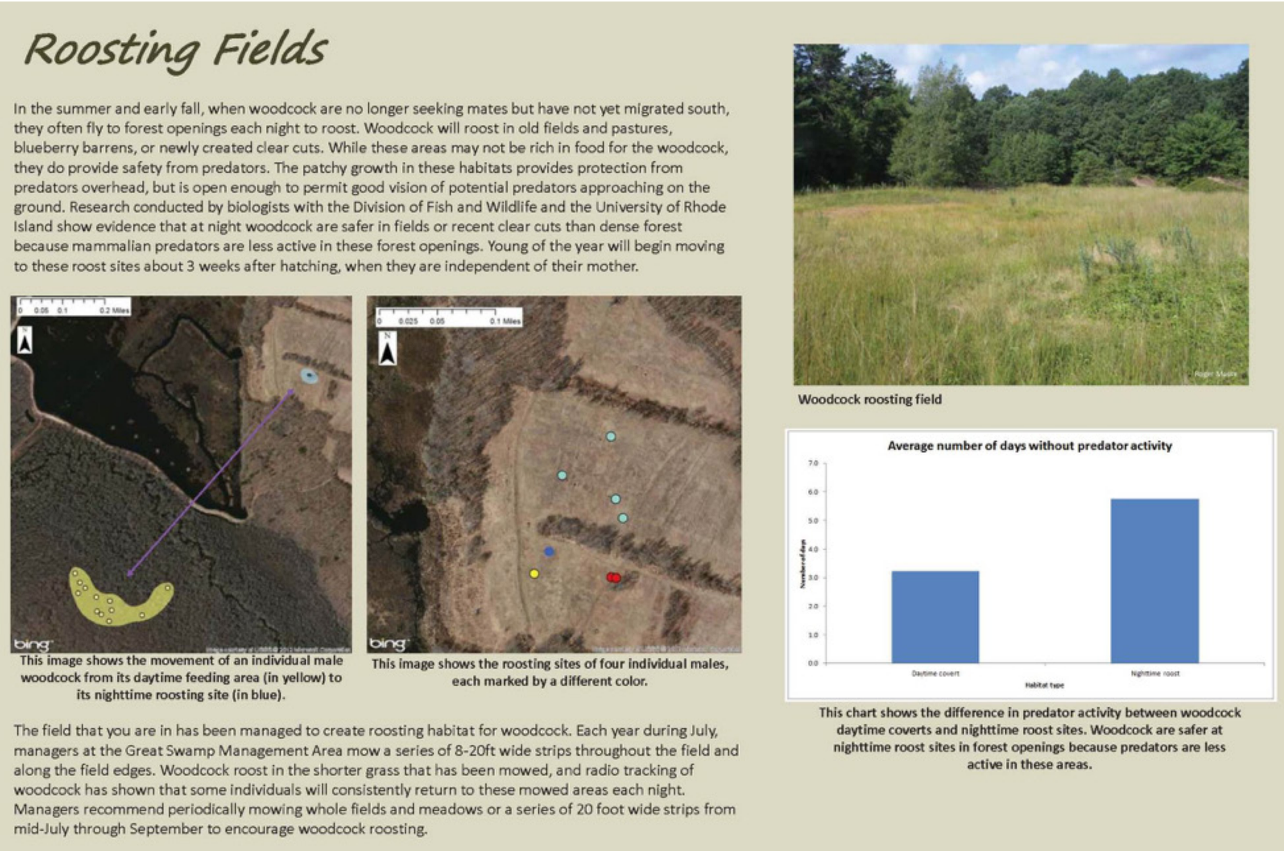


**Figure 2.** Total amount (ha) of young forest produced by Rhode Island Department of Environmental Management Division of Fish and Wildlife on state-owned land during 1995 to 2017 in Rhode Island, USA.



Roosting Fields

In the summer and early fall, when woodcock are no longer seeking mates but have not yet migrated south, they often fly to forest openings each night to roost. Woodcock will roost in old fields and pastures, blueberry barrens, or newly created clear cuts. While these areas may not be rich in food for the woodcock, they do provide safety from predators. The patchy growth in these habitats provides protection from predators overhead, but is open enough to permit good vision of potential predators approaching on the ground. Research conducted by biologists with the Division of Fish and Wildlife and the University of Rhode Island show evidence that at night woodcock are safer in fields or recent clear cuts than dense forest because mammalian predators are less active in these forest openings. Young of the year will begin moving to these roost sites about 3 weeks after hatching, when they are independent of their mother.

This image shows the movement of an individual male woodcock from its daytime feeding area (in yellow) to its nighttime roosting site (in blue).

This image shows the roosting sites of four individual males, each marked by a different color.

Woodcock roosting field

Average number of days without predator activity

This chart shows the difference in predator activity between woodcock daytime coverts and nighttime roost sites. Woodcock are safer at nighttime roost sites in forest openings because predators are less active in these areas.

The field that you are in has been managed to create roosting habitat for woodcock. Each year during July, managers at the Great Swamp Management Area mow a series of 8-20ft wide strips throughout the field and along the field edges. Woodcock roost in the shorter grass that has been mowed, and radio tracking of woodcock has shown that some individuals will consistently return to these mowed areas each night. Managers recommend periodically mowing whole fields and meadows or a series of 20 foot wide strips from mid-July through September to encourage woodcock roosting.

**Figure S1.** Design of an interpretive sign for the woodcock management demonstration area in the state-owned Great Swamp Wildlife Management Area, South Kingstown, Rhode Island, USA.

# Woodcock is Not a Dirty Word! Using Interest in Wildlife to Engage Private Forest Landowners

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**ABSTRACT:** Over the last half century, Wisconsin's young (or early successional) forest cover has decreased in extent and declined in quality as habitat for associated wildlife. Consequently, many wildlife species have seen population declines. A majority of Wisconsin's forests are privately owned, and the majority of forest owners report having no management plan. The Wisconsin Young Forest Partnership (WYFP) is a group of agencies, organizations, and businesses that have come together to enhance young forests across ownerships. Together we have developed a program that uses concern for and interest in wildlife species to begin a dialogue with landowners who currently are not actively managing their forests. Over the past 5 years, we have learned what does—and does not—work when trying to begin a dialogue with forest landowners in north-central Wisconsin. The goal of the WYFP is to increase the managed area of aspen (*Populus* spp.), alder (*Alnus* spp.), and associated young forest cover to reflect the habitat conditions that American woodcock (*Scolopax minor*), ruffed grouse (*Bonasa umbellus*), golden-winged warblers (*Vermivora chrysoptera*), and other species associated with early successional forest experienced in the 1970s and 1980s. We connect landowners to resources such as natural resource professionals, trained consulting foresters, and, in many cases, habitat funds to pay for plan writing and habitat management. The end result is landowners who are excited about forest management, are actively engaged in forestry practices to improve wildlife habitat, and who have a written plan to help them continue management on their property into the future.

***Proceedings of the American Woodcock Symposium 11: 93***

**KEY WORDS:** American woodcock, forest cover, forest management, private forest landowners

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# Factors Influencing American Woodcock Hunter Satisfaction in Canada

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**ABSTRACT:** From 1991 to 2005, we surveyed American woodcock (*Scolopax minor*; hereafter, woodcock) hunters in 3 Canadian provinces to assess hunter satisfaction. Across all submitted reports, 42.0% of the respondents reported a 'poor' experience, 35.2% of the hunters reported an 'average' experience, and 22.1% of the hunters reported a 'good' experience. We analyzed hunter satisfaction rate with an ordered logistic regression that included province, Singing Ground Survey Population Index (SGS index), number of woodcock harvested, hunting effort (hours hunted), environmental conditions before and during the nesting and brood-rearing periods (i.e., prior to the hunting season), precipitation during the post-fledging period, and year as explanatory variables. We also included a random effect for each individual hunter, to account for repeated answers, and for year, to account for short-term irregular perturbations in hunter satisfaction. Hunters from Nova Scotia were on average more satisfied than hunters from Ontario. Hunter satisfaction was positively correlated with the SGS index and the number of woodcock harvested by the hunter during a hunting trip. Hunter satisfaction was negatively correlated with the amount of precipitation during the nesting period and positively correlated with the amount of precipitation during the post-fledging period. However, there was considerable variation in individual hunter response, with 27.7% of the hunters more satisfied than average and 22.8% less satisfied than average. In fact, the individual hunter response accounted for approximately 75.0% of the variability observed in the model, indicating that accounting for hunter satisfaction would require further investigation. In the meantime, promoting woodcock habitat conservation in southern Canada could increase woodcock populations, harvest opportunity, and, by extension, hunter satisfaction.

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**KEY WORDS:** American woodcock, hunter satisfaction, hunter success, hunter survey, human dimensions

A fundamental goal of wildlife management is to maintain sustainable game populations while, at the same time, providing hunters with quality recreational opportunities (Vaske et al. 1986, Andersen et al. 2014). Whereas the North American model of conservation has provided guidance to wildlife managers in terms of how resources

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should be allocated and managed to successfully manage wildlife resources, it has provided little guidance in terms of human-wildlife dimensions (Geist et al. 2001, Gigliotti et al. 2009). Consequently, wildlife managers have acquired substantial knowledge on game species (e.g., life history, habitat use, etc.), but their understanding of hunter motivations and behavior has lagged (Decker et al. 1980, Anderson et al. 2007, Gigliotti et al. 2009). Part of the problem is that because of the strong hunting tradition in North America, hunter numbers largely have been taken for granted in management decisions. The persistent decline in hunter numbers, in spite of good hunting opportunities in recent years for many species, has forced managers to reconsider their approach and increase their effort into assessing hunter satisfaction and identifying the factors that drive their motivation (Enck et al. 2000, Vrtiska et al. 2013).

Harvest of game can affect hunter satisfaction, which in turn is one factor that can influence future intentions to hunt (Frey et al. 2003, Brunke and Hunt 2008). In Canada, both the total harvest of American woodcock (*Scolopax minor*; hereafter woodcock) and the number of migratory gamebirds hunters show a long-term decline (Gendron and Smith 2017). Few studies have addressed the motivation and satisfaction of small game hunters in North America (but see: Hayslette et al. 2001, Frey et al. 2003), with most of the research focused on ungulates and waterfowl (Decker et al. 1980, Vaske et al. 1986, Hammitt et al. 1990, Schroeder et al. 2006, Brunke and Hunt 2008). Applying prior findings to woodcock hunters in Canada is complicated by the variability in hunter attitudes and preferences and by the factors found to drive hunter satisfaction (Decker et al. 1980, Hammitt et al. 1990, Frey et al. 2003). Currently, little published information exists on woodcock hunter satisfaction in Canada, but from 1991 to 2005, the Canadian Wildlife Service conducted a mail questionnaire targeting woodcock hunters to gauge their hunting habits and level of satisfaction. While the survey was restricted to hunters in Ontario, New Brunswick, and Nova Scotia, and response was voluntary, the responses gathered provide some insight into the motivation of woodcock hunters in Canada.

Our objectives in this paper were to quantify the satisfaction of woodcock hunters in Canada who answered the questionnaire, and to assess variation in their responses over space and time. Based on previous hunter-satisfaction studies, we included year, province, and specific questionnaire data, namely the number of woodcock harvested and hours hunted as declared by the hunter (Guttery et al 2016, Andersen et al. 2014, Schulz et al. 2010, Brunke and Hunt 2008, Frey et al. 2003). We included the Singing Ground Survey population index (SGS; Seamans and Rau 2016) as a proxy for the abundance of adults in the fall, and environmental variables in the spring and summer as proxies for number of juveniles in the fall (i.e. productivity; Roy et al., *in press*, Schulz et al. 2010). We did not consider changes in hunting regulations in our analysis because the daily bag limit (8 woodcocks per day) remained constant throughout the study period.

## Methods

### HUNTER SATISFACTION

Between 1991 and 2005, data from the Canadian National Harvest Survey (Gendron and Smith 2017) was used to identify woodcock hunters. Each year, wing envelopes were mailed to approximately 450 woodcock hunters. Hunters were randomly selected based on whether they

**Table 1:** Explanatory variables included in the ordered logistic regression model to explain the satisfaction level of woodcock hunters in Canada surveyed between 1991 and 2005 by province where the hunting trip occurred.

| Variable | Expected effect on Woodcock Population | Expected effect on Hunter Satisfaction |
|---|---|---|
| Province | | None |
| Year | | None |
| Singing Ground Survey (SGS) Population Index | High SGS index indicates a high breeding population | High SGS population index increases satisfaction |
| Declared harvest | | Harvest increases satisfaction |
| Declared effort | | Increased effort decreases satisfaction |
| Spring snow cover | Late snow cover decreases female productivity | Late snow cover decreases satisfaction |
| Precipitation before the nesting period | High precipitation decreases female productivity | High precipitation decreases satisfaction |
| Precipitation during the nesting and brood rearing periods | High precipitation decreases female productivity and juvenile survival rate | High precipitation decreases satisfaction |
| Precipitation during the post-fledging period | High precipitation increases juvenile and adult survival rates | High precipitation increases satisfaction |

had participated in the Canadian National Harvest Survey during the previous year and demonstrated an interest in woodcock hunting. The National Harvest Survey does not address the number of woodcock hunters directly, so hunters had to declare an interest in hunting non-waterfowl game species (e.g., woodcock, rails, coots, etc.) and successfully harvested ≥1 woodcock in the previous year to be considered. The survey was limited to hunters residing in Ontario, New Brunswick, and Nova Scotia. The hunters selected were asked to send in 1 wing from each woodcock they harvested and to provide details about each of their hunting trips on a report card. Hunters were asked to report the number of woodcock they flushed, the numbers of hours they hunted, and the number of woodcock they harvested personally, and to rate their hunting experience as 'poor', 'average,' or 'good.' Hunters were asked to file a report card for each of their hunting trips, and could request additional report cards throughout the hunting season. To increase sample size, report cards were sent to hunters who had participated in the survey the previous year in addition to the ~450 hunters surveyed each year. Hunters were dropped from the survey if they did not submit a report card during an entire year, or if they requested to be removed from the survey.

### ENVIRONMENTAL VARIABLES

We downloaded the Snow Cover Extent from the National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Information website (ncei.noaa.gov/data/snow-cover-extent/access/). The database consists of weekly gridded data (1.0° x 1.0° grid cells) documenting the occurrence of snow on the ground for the northern hemisphere, and is based on Robinson et al. (2012) methodology. For each year, we calculated the average week at which snow cover permanently disappeared in each province (i.e., averaged over each of the 1.0° x 1.0° grid cells within each province). For Ontario, we restricted the extraction of the snow cover values below 51.75°N to avoid including areas that are not part of the woodcock breeding range (McAuley et al. 2013). Within each province, we centered the average week at which the snow cover permanently disappeared after extraction to capture years of "early" and "late" snowmelt.

We used the NOAA Precipitation Reconstruction over Land dataset to represent the amount of precipitation that occurred during each year. The dataset consists of monthly precipitation between 1850 and 2014 on a 1.0° x 1.0° grid. The dataset was constructed according to methodology in Chen et al. (2002). We calculated the total amount of precipitation in each province (i.e., summed over each of the 1.0° x 1.0° grid cells) before the start of the nesting period (April), during the nesting and brood-rearing periods (May and June), and during the post-fledging period (July). Similar to the snow cover index, we restricted the extraction of the data below 51.75°N in Ontario and centered the data during the survey period to identify "dry" and "wet" years within the periods of interest. We did not expect a linear relationship between precipitation and satisfaction, but rather expected the effect of precipitation to level off with increasing amount of precipitation. We therefore log transformed the precipitation data prior to centering them.

## Data Analysis

We analyzed the hunter satisfaction rating (i.e., 'poor', 'average', or 'good') with an ordered logistic regression that was parametrized via the mean (η) and cut points (κ). The cut points define the limits between different categories on the logistic scale, and values of the observed variable (i.e., hunter satisfaction) therefore depend on whether the predicted mean has crossed a particular threshold:

$$\text{satisfaction}_i = \begin{cases} 1 - \text{logit}\,(\eta_i - \kappa_1) & \text{if satisfaction}_i = \text{Good} \\ \text{logit}\,(\eta_i - \kappa_1) - \text{logit}\,(\eta_i - \kappa_2) & \text{if satisfaction}_i = \text{Average} \\ \text{logit}\,(\eta_i - \kappa_2) & \text{if satisfaction}_i = \text{Poor} \end{cases} \qquad \text{eq. 1}$$

$$\eta_i = \mu_i + \varepsilon_{hunter_i} + \varepsilon_{year_i} \qquad \text{eq. 2}$$

where $\eta_i$ is the predicted mean of the observation $i$ on the logistic scale, $\mu_i$ is the predicted effect of the explanatory variables, $\varepsilon_{\text{hunter}}$ is a hunter-specific random effect to account for the fact that some hunters returned >1 report cards, and $\varepsilon_{\text{year}}$ is random effect to account for short-term irregular perturbations in hunter satisfaction. Both random effects were drawn from a normal distribution with a mean 0 and a shared variance parameter (i.e., either $\sigma^2_{\text{hunter}}$ or $\sigma^2_{\text{year}}$). The predicted effect of the explanatory variables is defined as:

$$\boldsymbol{\mu} = \mathbf{X}\boldsymbol{\beta} \qquad \text{eq. 3}$$

where **X** is a matrix holding the explanatory variables (Table 1) and **β** is a vector holding the parameter to be estimated. We included, Year, Province, number of woodcock harvested by the hunter (declared on the report card), number of hours hunted (declared on the report card), annual provincial SGS population index, the week at which the snow cover disappeared in the province, and total precipitation before and during the nesting, brood-rearing, and post-fledging periods within the province as explanatory variables. We used Ontario as the reference class in the model. For the Year effect, we included both a linear term and random effect to distinguish the prevailing trend from the short-term irregular perturbations. We did not include the number of woodcock that the hunter declared to have flushed during each hunt in the analysis because this variable was highly correlated with the number of woodcock harvested (r = 0.8).

We did not expect a temporal trend in hunter satisfaction or regional differences among hunters in the 3 provinces *a priori* for woodcock hunters, but included those variables because previous analysis demonstrated that there has been some temporal and spatial variation of success for woodcock hunter in Canada (Roy et al., *in press*). We expected both the number of woodcock harvested and the SGS index to have a positive influence on hunting satisfaction (Schulz et al. 2010). Given that spring and early summer weather conditions affect woodcock productivity and juvenile survival rates (Rabe et al. 1983, Sepik et al. 1983, Daly et al. 2015) and are correlated to woodcock harvest in the fall (Roy et al. *in press*), we included explanatory variables related to spring and early summer conditions. Specifically, we included the week at which the snow cover disappeared within the province and the total precipitation before the nesting period (April), during the nesting and brood-rearing periods (May–June), and during the post-fledging period (July). We expected high amounts of precipitation before the nesting period and during the nesting and brood-rearing periods to have a negative effect on woodcock productivity (Rabe et al. 1983, Daly et al. 2015), to decrease harvest (Roy et al. *in press*), and therefore to affect hunter satisfaction negatively.

We also expected dry conditions during the post-fledging period to have a negative effect on juvenile survival rate (Sepik et al. 1983), to decrease harvest (Roy et al. *in press*), and therefore to affect hunter satisfaction negatively. We fitted the model using Stan version 2.14.1 called via the RStan package in R (R Core Team 2016, Stan Development Team 2016). Stan implements Bayesian inference using a variant of the Hamiltonian Monte Carlo algorithm (Carpenter et al. 2016). Each variable was centered prior to analysis. We used non-informative priors for all parameters of the model (Appendix 1). We ran 4 chains, each of 500 iterations for the adaptation phase (discarded), followed by a further 1,000 iterations for inference. We checked for convergence by visual inspection, and by using the Gelman-Rubin diagnostic test (Gelman et al. 2013). We assessed the effects of explanatory variables using Bayesian credible intervals, where we were certain of real effects if the 95% credible intervals did not include zero. We also considered variables for which there was some evidence of effects, but more uncertainty, by determining if 90% credible intervals contained zero.

We derived variance partition coefficients (VPC) from the posterior distribution to assess the proportion of the variance that was associated with the model ($\sigma^2$), the explanatory variable ($\sigma^2_\beta = \boldsymbol{\beta}\mathrm{cov}(\mathbf{X})\boldsymbol{\beta}$), individual hunters ($\sigma^2_{\mathrm{hunter}}$), and individual years ($\sigma^2_{\mathrm{year}}$; Long 1997, Browne et al. 2005). The model variance is fixed in the parametrization of the model we used to ensure cut points can be identified, so we used the value of $\pi^2/3$ for the calculation (Browne et al 2005, Gelman and Hill 2007). For example, the VPC for hunter is defined as:

$$\mathrm{VPC}_{\mathrm{hunter}} = \frac{\sigma^2_{\mathrm{hunter}}}{(\sigma^2 + \sigma^2_\beta + \sigma^2_{\mathrm{hunter}} + \sigma^2_{\mathrm{year}})} \qquad \text{eq. 4}$$

## Results

We received 1,555 report cards from 207 hunters (~3.3% response rate) during the survey but 31.9% (N = 496) of those report cards were incomplete, with either the satisfaction rating or information about the hunting trip missing, and were discarded from the analysis. Due to a clerical error, no report cards from 1996 were included in the database. In total, 166 hunters filled ≥1 report card with 60.8% (N = 101) from Ontario, 22.3% (N = 37) from New Brunswick, and 16.9% (N = 28) from Nova Scotia. On average, a hunter submitted 6 report cards, but this number was highly variable (SD = 7.9), with 1 hunter submitting 66 report cards. Yearly return rate ranged from 26 (1991) to 160 (1993) and averaged 81 returned cards per year (SD = 41.7). Hunters harvested ≥1woodcock during 65.3% (N = 691) of the hunting trips they reported. On average, hunters harvested 2 (SD = 2) woodcock per hunting trip.

Overall, 42.0% of all report cards (responses) indicated a 'poor' experience during the hunting trip, 35.2% reported an 'average' experience, and 22.1% reported the experience as 'good.' Compared to hunters from Ontario, hunters from Nova Scotia were more satisfied (β = 3.03; 95% BCI = 0.65 –5.45; Fig. 1) and there was some tendency for the hunters from New Brunswick to be more satisfied than those from Ontario (β = 1.45; 95% BCI = -0.77 – 3.57; Fig. 1). There was a tendency for a weak, long-term decline in hunter satisfaction during the survey period (β =-0.31; 95% BCI = -0.64 – 0.03). Hunter satisfaction was positively correlated with the SGS population index (β = 2.13; 95% BCI = 1.05 – 3.12; Fig. 2) and the number of woodcock harvested by the hunter (β = 0.22; 95% BCI = 0.09 – 0.35; Fig. 2). The amount of precipitation during the nesting and brood-rearing periods (β = -3.16; 95% BCI = -5.06 – -1.23; Fig. 3) was negatively correlated with hunter satisfaction, whereas the amount of precipitation during the post-fledging period (β = 2.25; 95% BCI = 0.67 – 3.83; Fig. 3) was positively correlated with hunter satisfaction. There was also a weak negative correlation between hunter satisfaction and spring snow cover (β =-0.55; 95% BCI = -1.22 – 0.09). Hunter effort (β = 0.06; 95% BCI = -0.13 – 0.25) and the amount of precipitation before the nesting period (β =-0.73; 95% BCI = -2.58 – 0.97) did not substantively influence hunter satisfaction.

There was considerable variation in individual hunter satisfaction, with 27.7% (N=46) of the hunters more satisfied than the average and 22.8% (N=38) less satisfied than the average (Fig. 4). The variance partition coefficient estimates indicated that variability among hunters accounted for 76.0% (95% BCI = 63.6 – 84.9 %) of the variability accounted for in the model, whereas the explanatory variables, short-term variability due to years, and residual error accounted for 10.4% (95% BCI = 5.1 – 18.1 %), 8.2 % (95% BCI = 3.0 – 18.1 %), and 5.4% (95% BCI = 3.7 – 7.6) of the variability, respectively. Although the individual hunter effect was large, it did not buffer completely against the effect of the other explanatory variables. In other words, based on model predictions, it was possible to have a small proportion of the most dissatisfied hunters report their experience as 'good', albeit only under the best circumstances (e.g., high SGS population index, full daily bag limit, and excellent conditions during the spring). In cases where hunters returned more report cards than average, the credible interval associated with the individual effect was smaller but there was no obvious correlation between the numbers of report cards submitted and satisfaction.

## Discussion

Overall, most survey participants reported low satisfaction during their hunting trip. Hunter satisfaction was positively associated with hunter success, the size of the breeding population, and environmental factors during spring and early summer. However, the most important output of our model was the wide variability observed in the response among hunters.

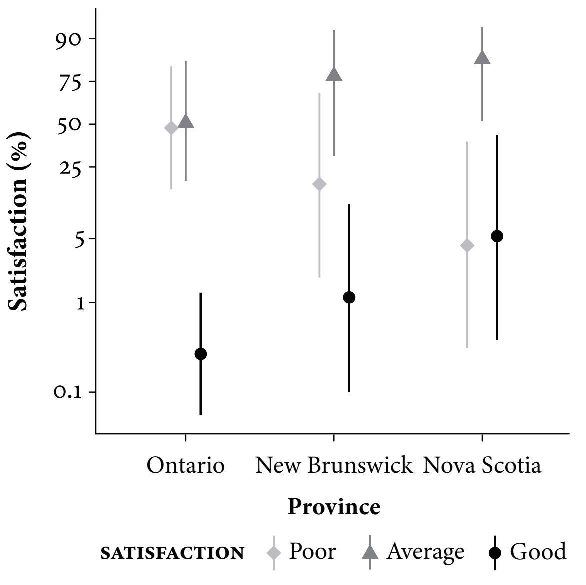

**Figure 1:** Predicted satisfaction of woodcock hunters in Canada, surveyed between 1991 and 2005, about their hunting trip. Hunter satisfaction was self-reported as either Poor, Average or Good in the survey. The results are presented according to the province where the hunting trip occurred. The dots represent the averages and the bars represent the 95% credible intervals. Note that the y-axis is on the logistic scale for ease of presentation.

The number of woodcock harvested had a positive effect on hunter satisfaction in our study, but only to a limited extent. Based on predictions from our model, even with a full daily bag limit of 8 woodcock, only about 1.5% of hunters would report their satisfaction as 'good' during an average year (i.e., when we isolate the effect harvest and controlled for all other variables). This finding might seem surprising, but it has been noted before that consumptive users, such as hunters, are less likely to describe their experience as 'perfect' unless they encounter exceptional circumstances (Vaske et al. 1982, 1986) and that other factors can supersede harvest success as a motivation for hunting (see discussion below). From a management perspective, our results indicate that increasing the daily bag limit would have a positive effect on hunter satisfaction, but that that effect would only be marginal at best, and that other factors might more substantively increase hunter satisfaction.

The SGS population index in the spring also had a positive effect on hunter satisfaction. Schulz et al. (2010) suggested that a high abundance of woodcock in the spring should carry over to the fall, give hunters an increased amount of harvest opportunities, and therefore increase hunter satisfaction. The state of the spring population is also likely to be noticed by hunters, which could make them prone to believe that it is either a 'good' or 'bad' year for hunting, which in turn would affect their satisfaction. Our model predicted only 6.0% of hunters would report their satisfaction as 'good' at peak abundance in the SGS population index (i.e., when we isolate the effect of the SGS population index and controlled for all other variables), which is only a modest increase. Nevertheless, comparing the predictions of the individual hunter declared harvest and the SGS population index on hunter satisfaction indicates that the effect of the SGS population index was more important than the effect of harvest itself. A similar pattern has been reported for other small game species in areas where target species abundance was low (Hayslette et al. 2001, Frey et al. 2003). However, the SGS population index in our analysis provided a province-level index for hunting opportunity rather than an index at a local hunting-trip scale, and may not be a reliable indicator of hunter experience during their hunting-trip.

The continued decline of the SGS population index in Canada suggests woodcock hunter satisfaction will continue to decline. The reasons for the decline in the woodcock breeding population in Canada remain obscure, and further work would be required to identify if breeding-ground factors are the cause of the decline (Roy et al., *in press*). Recent analyses suggested that the distribution of the SGS is biased towards southern Canada and that this coverage bias may result in inaccurate population estimates by not surveying substantial populations in northern Ontario and Quebec (Sullins et al. 2016). The observed decline in the south could thus be caused in part by a redistribution of the woodcock population during the breeding period (Roy et al. *in press*, Sullins et al. 2016). However, given the relationship we found between the SGS population index and hunter satisfaction, it seems that hunters are attuned to how woodcock populations are faring in southern Canada, where most Canadian hunters live. If that is the case, the state of northern breeding populations might not be of relevance to Canadian wildlife managers to maintain hunter satisfaction and, therefore, human dimension efforts should be concentrated in southern Canada where hunter density is the highest.

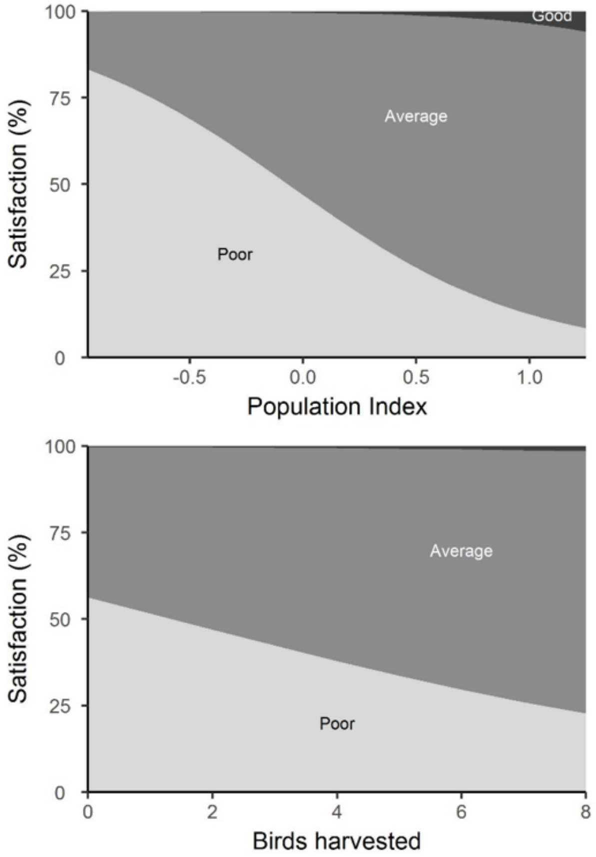

**Figure 2:** Mean predicted satisfaction of woodcock hunters in Ontario, Canada about their hunting trip as a function of the American Woodcock Singing Ground Survey Population Index in the spring (top), and the number of woodcocks harvested by the hunter (bottom). Hunters were surveyed between 1991 and 2005. Hunter satisfaction was self-reported as either Poor (light grey), Average (dark grey) or Good (black) in the survey.

Our results indicating an effect of precipitation during the spring and summer on hunter satisfaction support the contention that perceived hunter trip quality is tied in part to the quality of the nesting period for woodcock (Schulz et al. 2010). It has already been demonstrated that precipitation can limit the survival of juveniles during the brood-rearing period, that summer drought can increase mortality for both adults and juveniles (Rabe et al. 1983, Sepik et al. 1983, Daly et al. 2015), and that woodock harvest in Canada is correlated with spring conditions (Roy et al., *in press*). The number of woodcock flushes declared

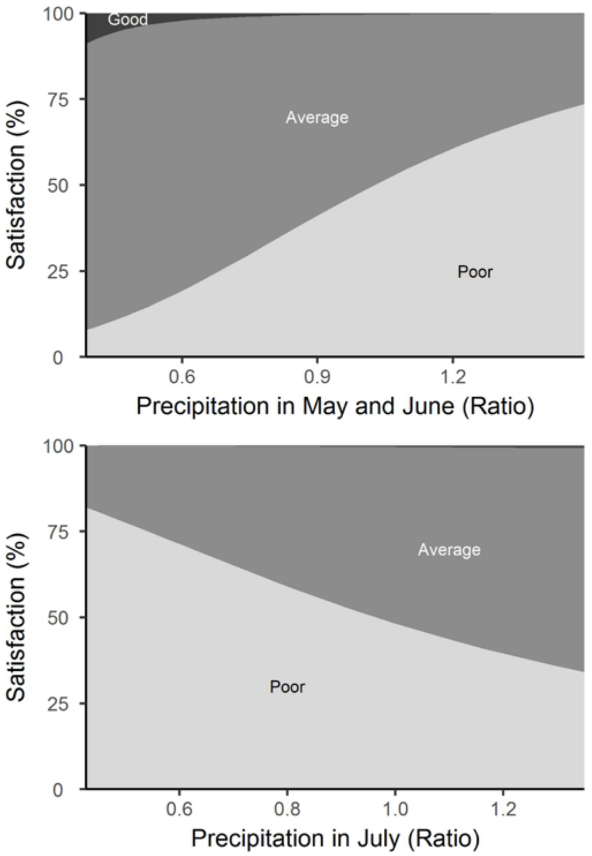

**Figure 3:** Mean predicted satisfaction of woodcock hunters in Ontario, Canada, about their hunting trip as a function of the amount of precipitation during the nesting and brood rearing periods (top) and the post-fledging period (bottom). Hunters were surveyed between 1991 and 2005. Hunter satisfaction was self-reported as either Poor (light grey), Average (dark grey) or Good (black) in the survey. The x-axis represents the ratio of precipitation compared to the average level of precipitation during the survey period (i.e., 0.5 = half the average precipitation, 1 = average precipitation, 2 = double the average precipitation).

by hunters during their hunting trips were also weakly correlated with the environmental conditions in the spring and the summer (C. Roy *unpublished data*). The likely explanation for our findings is that abundant precipitation during the nesting period results in a decline in nesting success and survival rates of juveniles during the brood-rearing period whereas dry conditions during the post-fledging period decrease fledgling survival by negatively impacting their ability to feed (Roy et al., *in press*). Both of these scenarios would decrease the abundance of juveniles, which are usually more vulnerable to harvest than adults and represent a greater proportion of the harvest in the fall (Reynolds 1987, Zimmerman et al. 2010), and would thus negatively impact fall flush rates and hunting success and hunter satisfaction. Although the full mechanism that ties spring conditions to hunter satisfaction in the fall remains to be formally tested, we argue that our findings reinforce the notion that the overall conditions of the population can influence hunter satisfaction.

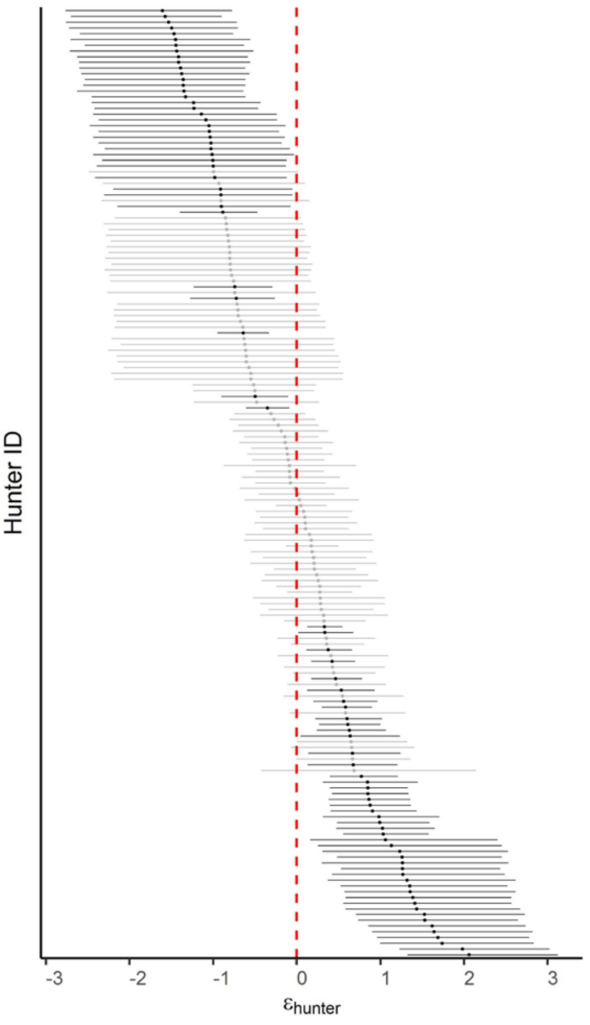

**Figure 4:** Individual hunter effect ($\varepsilon_{\text{hunter}}$) in a model that predicts the satisfaction of woodcock hunters in Canada surveyed between 1991 and 2005. Negative number indicates that the hunter is less satisfied than average whereas a positive number indicates than the hunter is more satisfied than the average. Dots represent the mean and bars represent the 95% Bayesian credible intervals. Black is used when the 95% credible intervals of the estimates do not include zero. Individual hunter labels for each hunter on the y-axis have been removed for clarity and anonymity.

Overall, the variables we included in our analysis tended to have a limited effect on woodcock hunter satisfaction compared to the high variability observed among the sample of hunters that we surveyed. The variability among hunters accounted for 76.0% of the predicted variation in hunter satisfaction, whereas our explanatory variables explained only 10.5%. There was a strong dichotomy between hunter satisfaction in our survey, with nearly one quarter of the hunters being either substantively more or less satisfied than average. Because we controlled for hunter success and large-scale drivers of hunting opportunity, our results indicate that there are still some important drivers of hunting satisfaction that were missing from our analysis. These results reinforce the notion that there are many other determinants affecting hunter satisfaction than hunter success or the size of game populations (Decker et al. 1980, Hammitt et al. 1990, Frey et al. 2003). Apart from successfully seeing and harvesting game, experiencing nature (Hammitt et al. 1989, Wynveen et al. 2005, Schroeder et al. 2006) and spending time with friends and family (Decker and Connelly 1989, Guttery et al. 2016) have also been cited as important drivers of satisfaction. Without formally assessing the factors that drive woodcock hunter satisfaction it will be difficult to formulate a proper hunter retention strategy. Given the variation we observed among provinces and hunters, a more thorough survey of woodcock hunters in Canada would give us a better understanding of their motivation and the factors that drive their satisfaction. Such a survey should also undertake a broader approach that seeks to identify the multiple factors (i.e., being outdoors, being with friends, connecting with nature, etc.) that lead a hunter to characterize a hunting trip as 'successful' and would help classify the hunters as a function of their attitudes and preferences. This approach is particularly enticing because it could allow managers to seek alternative paths, such as mentorship programs or access to crown lands, rather than simply targeting hunting success to retain and recruit woodcock hunters (Vaske et al. 1986).

The implications of our survey are limited in part by the methodology used to select the hunters for the survey. The hunters selected for this survey were randomly selected from the pool of hunters who had participated in the Canadian National Harvest Survey during the previous year and had successfully harvested ≥1 woodcock. Consequently, our results are only applicable to hunters who had been successful in the previous year. Another major limitation of our survey was that it depended on the hunter's willingness to submit a report card. However, no data were compiled on the number of hunters that refused to answer the survey, or why a hunter stopped responding, which also limits our ability to draw broad inferences from our results. For example, the strong dichotomy we observed in hunter individual responses could be an artifact of the voluntary response of hunters to participate in the survey. Hunters that had a strong feeling about the state of the woodcock population could be more likely to return report cards than those that were indifferent.

## Management Implications

Although it would be theoretically possible to maintain or increase hunter satisfaction by trying to increase the woodcock population or daily bag limits, our results suggest that such gain would be minimal, and based on the current trend of the SGS population index, which is still low on the woodcock breeding ground in Canada (Seamans and Rau 2016), such strategies do not seem likely. Increasing the breeding population in the spring could help increase hunter satisfaction, but it would require identifying the cause of the decline in the SGS population index on breeding grounds in Canada, a task that has not been done yet (Roy et al., *in press*). Given that habitat manipulation to improve woodcock breeding habitat might be difficult to achieve, some resources could be dedicated to understanding the high variability in hunter satisfaction that we observed in our study. Identifying the factors that drive hunter motivation could help managers design strategies to improve the hunting experience of woodcock hunters in Canada and, by extension, improve hunter retention and recruitment.

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## APPENDIX 1: STAN CODE FOR THE ANALYSIS OF THE SATISFACTION OF WOODCOCK HUNTERS IN CANADA, SURVEYED BETWEEN 1991 AND 2005, ABOUT THEIR HUNTING TRIP.

```
data {
 int<lower=2> K;
 int<lower=0> N;
 int<lower=1> D;
 int<lower=1, upper=3> Y[N];
 row_vector[D] X[N];
 int Nhunters;
 int hunter_id[N];
 int NYears;
 int year_id[N];
}
parameters {
 vector[D] beta;
 ordered[K-1] cutpoints;
 real<lower=0> sigma_hunter;
 real<lower=0> sigma_year;
 vector[Nhunters] epsilon_hunter;
 vector[NYears] epsilon_year;
}
model {
 cutpoints ~ normal(0,5);
 beta ~ normal(0,5);
 sigma_hunter ~ student_t(4,0,1);
 epsilon_hunter ~ normal(0,1);
 sigma_year ~ student_t(4,0,1);
 epsilon_year ~ normal(0,1);
for (n in 1:N)
 Y[n] ~ ordered_logistic(X[n] * beta +
 sigma_hunter*epsilon_hunter[hunter_id[n]] +
 sigma_year*epsilon_year[year_id[n]], cutpoints);
}
```

# Promoting Wildlife Habitat and Conservation Partnerships Through State-Funded Grant Programs

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**ABSTRACT:** As hunter numbers decline nationally, state wildlife agencies look for new conservation funding avenues. With the assistance of conservation groups and engaged citizens, the Michigan Department of Natural Resources (MI DNR) was able to secure the passage of a restructured license package, which took effect in 2014. Included in the restructuring was a simplification of the available hunting licenses and a promise to give more back to state citizens for the resulting fee increases. Following up on this promise, the MI DNR Director directed the Wildlife Division to develop and initiate a grant program that would increase wildlife habitat through grant funds given to conservation partners. The Wildlife Habitat Grant Program awarded funds to the first round of successful applicants in spring of 2014, and this competitive grant program is now in its fourth cycle, with projects completed from Iron County in the western Upper Peninsula to Lenawee County in the southeastern Lower Peninsula. The Wildlife Habitat Grant Program has awarded >$4.6 million and has improved or restored wildlife habitat on approximately 3,235 hectares (8,000 acres). As young forests are of high priority, a number of these projects have been focused on American woodcock (*Scolopax minor*) and ruffed grouse (*Bonasa umbellus*) habitat, and are often associated with Grouse Enhanced Management Sites (GEMS). Project collaborators have included the Ruffed Grouse Society and American Woodcock Society, U.S. Forest Service, Beaver Island Wildlife Club, National Wild Turkey Federation, Wildlife Management Institute, Soil and Water Conservation Districts, Michigan United Conservation Clubs (MUCC), and private landowners.

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**KEY WORDS:** conservation funding, grants, habitat, wildlife conservation

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## CHAPTER FOUR

# Habitat Dynamics

# Association between American Woodcock Seasonal Productivity and Landscape Composition and Configuration in Minnesota

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**ABSTRACT** The effects of landscape composition and configuration on productivity of most bird species, including American woodcock (*Scolopax minor*), are largely unknown. Understanding landscape components and cover-type configurations associated with productivity can be useful in developing more effective management strategies that increase recruitment. We used data on nest and juvenile survival rates of American woodcock from northern Minnesota from 2011 and 2012 to inform logistic exposure models of survival and predict productivity through the period when juveniles are capable of sustained flight (~15 days post-hatch). We used those models to link landscape features with nest survival rate and juvenile survival rate, predict spatially explicit productivity across our study area, and identify areas of high productivity within our study landscape. Lastly, we used simulations to explore the consequences of potential management actions aimed at improving productivity and the effects of long-term succession of young-forest cover types. We found that associations between land-cover composition and different components of productivity (i.e., nest and juvenile survival rates) were scale-specific. Generally, our models suggested stand-level composition (i.e., the amount of each cover type within 250–500 m of the nest) influenced nest survival rate, with mature forest having a small but mostly positive association with nest survival rate in most landscape contexts. Conversely, our models predicted lower nest survival rates in landscapes with greater amounts of grassland and upland shrubland. The amounts of wetland shrubland and upland shrubland at stand- (i.e., 250–500 m) and landscape-level (i.e., 1,000 m) scales were positively associated with juvenile survival rate. Our findings demonstrate that the effects of management actions depend on the context and configuration of cover types within the surrounding landscape and that spatially explicit models of productivity may be useful for informing management strategies. Furthermore, our results suggest that relationships between survival and specific land-cover types may change throughout the reproductive cycle in American woodcock.

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**KEY WORDS:** juvenile survival, landscape composition, landscape structure, nest success, productivity surface, *Scolopax minor*

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Productivity (i.e., producing young that survive to reach a biological milestone) is a crucial component of population dynamics and a key element in models of population growth. Productivity differs from recruitment in that it is a measure of the within-season production of young, whereas recruitment usually refers to the addition of new individuals to subsequent breeding populations (i.e., necessarily incorporating survival during migration and the nonbreeding period in the case of migratory birds; Braun 2005). Estimating effects of landscape composition and configuration on productivity is important for informing and implementing successful management plans. For example, a primary goal of land managers is to manipulate landscapes in a way that minimizes features comprising sink habitats or ecological traps to increase population growth rate (Leopold 1933, Battin 2004). Incorporating accurate estimates of vital rates (e.g., adult female survival rate, nest survival rate, juvenile survival rate) into population models is important for understanding the influences of different life stages on population trends (Van Horne 1983, Connelly et al. 1988, Derleth and Sepik 1990, Wisdom and Mills 1997). In birds, including both nest and juvenile survival rates in models of productivity is important because the relationships among survival and landscape components may be stage-specific and/or change over time (e.g., Connelly et al. 1988, Roberts et al. 1995, Streby et al. 2014b). Additionally, many bird species require or select different cover types for rearing juveniles than for nesting (Klebenow 1969, Holbrook et al. 1987, Rotella and Ratti 1992, Streby and Andersen 2011).

Previous studies outline species-specific relationships between edge (Horn et al. 2005), forest fragmentation (Robinson and Wilcove 1994, Faaborg et al. 1995, Bayne and Hobson 1997, Lloyd et al. 2005), urban development (Ausprey and Rodewald 2011), and population growth rates or individual aspects of productivity such as nest success rate or juvenile survival rate. Management strategies that do not include information on the relationships among landscape structure and demographic rates across multiple life stages may lead to the creation of low-production landscapes or ecological traps (Schlaepfer et al. 2002, Streby and Andersen 2011). Nest failure and juvenile mortality are primarily driven by predation in most avian systems (Martin 1993); thus, landscape factors that influence the composition of the predator community may affect population demographic rates (Hoover et al. 1995, Brawn and Robinson 1996, Chalfoun et al. 2002). Furthermore, predators may respond (i.e., behaviorally or numerically) to landscape variation at different spatial scales than breeding birds and, consequently, some aspects of the landscape may influence the survival rates of nests and juveniles more than others (Stephens et al. 2005). Therefore, consideration of landscape components at biologically meaningful scales is required to inform predictions of productivity across a spatial extent relevant for population-level management (Levin 1992).

American woodcock (*Scolopax minor*; hereafter "woodcock") are a migratory, upland-breeding shorebird game-species that breed in diverse forest cover types throughout the eastern U.S. and southeastern Canada. Woodcock population trends vary regionally, with eastern breeding populations generally exhibiting declining trends and populations breeding in the western Great Lakes region exhibiting numerically stable trends based on standardized breeding-grounds surveys of singing males conducted since the mid-1960s (Seamans and Rau 2016). Additionally, juvenile/adult female ratios measured from wing-collection surveys of hunters imply declines in recruitment of juveniles into the fall population (Seamans and Rau 2016). These declines in apparent abundance and recruitment of juveniles into the fall population are purportedly linked to habitat loss and alteration of landscapes critical to woodcock reproduction (Dwyer et al. 1988, Gregg 1984, Sauer and Bortner 1991, Kelley et al. 2008). In an attempt to stabilize and ultimately increase woodcock populations, efforts have been made to develop and apply regional Best Management Practices for creating and sustaining woodcock habitat (BMPs; Kelley et al. 2008, Wildlife Management Institute 2010).

The implementation of woodcock BMPs is intended to increase the amount and availability of high-quality woodcock habitat at a landscape scale (~200–800 ha), thus increasing woodcock vital rates. Specifically, woodcock BMPs call for creation or maintenance of young-forest cover through clear-cutting, timber harvest, shearing of brush and small trees, and prescribed burning to create patchy and diverse forests (Wildlife Management Institute 2009). The application of woodcock BMPs on a stand- or landscape-scale aims to create a mosaic of diverse forest cover types, including young regenerating forested areas for breeding, nesting, brood-rearing, and diurnal feeding habitat for woodcock. Additionally, woodcock BMPs call for the maintenance or creation of open grassy or cleared areas used for courtship displays and nocturnal foraging (Wildlife Management Institute 2009). Woodcock populations are known to increase following targeted vegetation management (Dwyer et al. 1988, McAuley et al. 1996), and previous research suggests microhabitat structure and composition have small or nonexistent effects on survival rates of woodcock nests and juveniles (Daly 2014); the influence of large-scale landscape components and their configuration on woodcock productivity, however, is largely unknown.

We used the methods outlined by Peterson et al. (2016) to assess relationships between landscape structure and composition and the productivity of woodcock breeding in northwestern Minnesota. We created spatially explicit models of productivity and used those models to predict productivity over our study area. Our models combine estimates of nest survival rate and juvenile survival rate, each as a function of landscape structure and composition, to predict productivity from nest initiation through the period ending when juvenile woodcock are capable of sustained flight (~15 days post-hatch). Finally, we used our models to investigate whether common management strategies for woodcock are likely to be effective in increasing productivity at managed sites.

## Methods

### STUDY AREA

We relied on data from a study of woodcock population ecology (Daly 2014) at Tamarac National Wildlife Refuge (NWR), Becker County, Minnesota, USA (47.0°N, 95.6°W) from 2011–2012. Tamarac NWR encompassed >17,000 ha dominated by forested cover types with interspersed lakes, rivers, marshes, swamps, and tallgrass prairie. Tamarac NWR falls in the transition zone at the confluence of 3 major biomes: the northern boreal forest, eastern hardwood forest, and western tallgrass prairie. Forests covered 60% of Tamarac NWR and dominant tree species included aspen (*Populus* spp.), jack pine (*Pinus banksiana*), red pine (*P. resinosa*), balsam fir (*Abies balsamea*), paper birch (*Betula papyrifera*), red oak (*Quercus rubra*), white oak (*Q. alba*), sugar maple (*Acer saccharum*), and basswood (*Tilia americana*). Over the past 30 years, portions of the refuge were harvested (i.e., logged), burned, and sheared to create and maintain early successional forest and provide breeding, nesting, and brood-rearing habitat for woodcock and associated species (Boyle et al. 2010).

### DEMOGRAPHIC DATA COLLECTION

We used nest and survival data from adult female and juvenile woodcock captured and marked from April–June during 2011–2012 (Daly et al., this volume, Evaluating techniques for estimating post-breeding-season age ratios). Daly (2014) captured adult female woodcock using mist nets and attached radio-transmitters using a glue-on, backpack-style harness (≤3% of their total body mass; ~4.8 g, model A5410, Advanced Telemetry Systems, Isanti, MN; McAuley et al. 1993a, 1993b). As part of the study, radio-marked female woodcock were tracked to nests, and nest locations were recorded using handheld Global Positioning System (GPS) units (GPSMAP 76 or eTrex Venture HC Global Positioning System, Garmin Ltd., Schaffhausen, Switzerland), averaging 100 points to ensure <5 m accuracy (Daly et al., this volume, breeding season survival of woodcock). Nests were monitored at 2–3-day intervals until they failed (i.e., depredation or abandonment) or succeeded (i.e., evidence that ≥1 egg hatched; see Daly [2014] for detailed descriptions of nest-fate determination). We derived estimates of juvenile survival rate (i.e., post-hatching, pre-fledged young) based on the status of juveniles in broods of radio-marked adult females, and from data resulting from radio-marking and tracking a subset of juveniles within the broods of radio-marked females. Daly et al. (this volume, Evaluating techniques) also found recently hatched (≤5 d) broods of unmarked adult female woodcock using trained pointing dogs and captured and radio-marked juveniles in these broods. Juvenile woodcock are precocial but tend not to exhibit daily movements >100 m during the first week post-hatching, and they generally use a constrained area during this period, so we are confident that these juveniles were close to their nest site (Gregg 1984, Steketee and Robinson 1995). Juvenile woodcock were outfitted with a custom-fit micro-transmitter (BD-2NC or BD-2C, Holohil Systems Std., Carp, ON; Blackburn Transmitters, Nacodoches, TX) using an elastic collar that expanded as they grew. All transmitter and harness packages were ≤3% of the marked individual's mass, and there was no indication of an effect of transmitters on the survival rate of juvenile woodcock (Daly et al. 2015). Additionally, Daly et al. (2015) found no evidence of dependence among juvenile woodcock in the same brood (reanalyzed in Breeding Season Survival of Woodcock, Appendix II, page 62), and we therefore treated the fate of all juveniles in our sample as statistically independent. Daly et al. (this volume, Evaluating techniques) attached radio-transmitters to 1–4 randomly selected juveniles per brood (Fig. 1) that were subsequently monitored ~3 times per week (based on 4–7 attempts per week to relocate individuals either by relocating radio-marked juveniles or females) to eval-

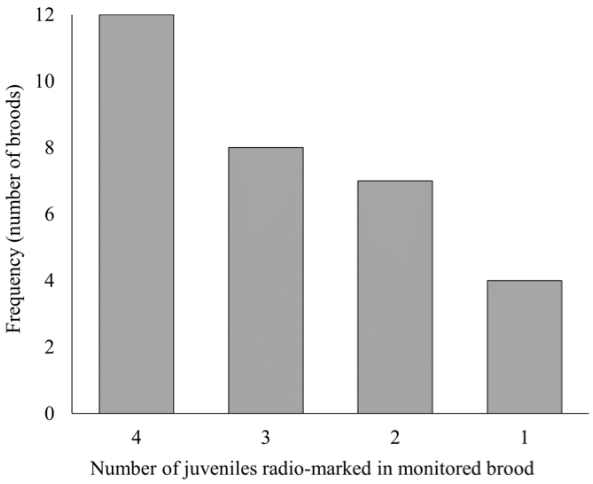

**Figure 1.** Frequency distribution of the number of radio-marked juvenile American woodcock in each monitored brood at Tamarac National Wildlife Refuge, Minnesota, USA from 2011–2012.

uate survival rate of both marked and unmarked juveniles within the same brood.

We considered juveniles within the same brood as independent experimental units in our study because there was no evidence of intra-brood dependence among juveniles based on Winterstein's (1992) third Chi-squared goodness-of-fit test (average *P* = 0.32; Breeding Season Survival of Woodcock, Appendix II, page 62). Thus, the survival of a juvenile woodcock was not statistically linked to the survival of broodmates, making it appropriate to treat each juvenile within a brood as an individual sample. Determining the appropriate experimental unit (e.g., colony, nest, brood, individual) for wildlife species that exist within groups is important because violating the independence assumption may lead to a biased survival rate estimate and to improperly drawn inferences regarding habitat-survival relationships (Winterstein 1992). On the other hand, if there is no evidence of dependence among juveniles from the same brood, treating juveniles as individual samples can increase effective sample sizes for estimating survival rates and improve resolution of habitat-survival relationships. Our treatment of woodcock juveniles as independent samples differs from other studies that found evidence of intra-brood dependence (e.g., Winterstein 1992, DeMaso et al. 1997), highlighting the importance of testing for independence among broodmates in different species.

### LANDSCAPE ATTRIBUTES

We followed the methods and definitions used by Peterson (2014) and Peterson et al. (2016) to model the effects of landscape composition and configuration on the productivity of golden-winged warblers (*Vermivora chrysoptera*) at Tamarac NWR during the same study period. Woodcock and golden-winged warblers co-occur broadly across their breeding distributions and are associated with similar dynamic forest systems with diversity in vegetation age and structure. These 2 species are often described as having similar habitat requirements and are regularly touted as surrogate species for one another, or as umbrella species for young- and early-successional forest communities (Bakermans et al. 2015, Masse et al. 2015). We categorized 6 cover types at Tamarac NWR using 1-m resolution digital aerial photographs (2009; Minnesota Department of Natural Resources) in Arc 10.1 Geographic Information System software (Environmental Systems Research Institute, Redlands, CA). We confirmed the cover types classified from aerial photographs using >2,500 locations visited at our study site. We classified cover types into 5 broad categories (deciduous forest, upland shrubland, forested wetland, grassland, and wetland shrubland) based primarily on vegetation structure that we believed influenced the predator community most likely to depredate woodcock nests and juveniles (e.g., mesopredator mammals and raptors; Storm et al. 1976, Boal et al. 2005). We defined mature forest as stands with canopies >20 m and average canopy closure >60% (Brohman and Bryant 2005). Most mature stands in our study area contained a patchy and dense shrub layer (vegetation <2 m tall) and understory (vegetation between 2 m and ~15 m tall) of a variety of species.

We classified areas dominated by vegetation from 1–3 m tall as shrublands. In our study area, these stands ranged from 5–15 years post-harvest, were 1–30 ha in extent, and were composed of shrubs, forbs, grasses, and patches of saplings. We differentiated between wetland and upland shrublands in our study because previous research in the same system identified differences in golden-winged warbler productivity between wetland and upland shrublands (Peterson 2014, Peterson et al. 2016). Wetland shrublands were similar in structure to upland shrublands, but were dominated by willow (*Salix* spp.), alder (*Alnus* spp.), sedges, grasses, and hazel (*Corylus* spp.) shrubs. We classified less common cover types including forested wetlands of tamarack (*Larix laricina*) or black ash (*Faxinus nigra*), grasslands (without differentiating between wetland or upland), and roads and other small areas of human occupation (e.g., houses, buildings, lawns). Tamarac NWR had open water (i.e., lakes and rivers) that we did not consider as an important cover type for breeding woodcock in our study.

We investigated the importance of edge density (i.e., length of edge within a specified area) by identifying edges between mature forest (i.e., deciduous forest and forested wetland) and shrubland (i.e., upland shrubland and wetland shrubland). We included edge density in addition to the 5 other cover types because edge is known to be important to woodcock in habitat selection (Hudgins et al. 1985) and generally influences avian nest survival (Rudnicky et al.1993, Manolis et al. 2002, Meunier et al. 2006) and juvenile survival (Peterson et al. 2016) rates. We characterized the relationship between each landscape component and nest survival rate and juvenile survival rate using >600 exposure days for each period (Table 1).

We used a two-step approach in modeling the effects of landscape components on nest and juvenile survival rates in woodcock. First, we used linear models to identify the radius at which different cover types were most associated with period-specific survival rates. To do this, we explored the relationship between cover type and survival rate at different spatial scales by modeling the impact radius for each of the 6 model covariates described above following the methods described in Peterson (2014) and Peterson et al. (2016). The impact radius represented the scale at which each landscape variable was most strongly supported in univariate models of nest and juvenile survival rate. We determined the impact radius for each landscape variable by buffering each nest location with circles with different radii (Fig. 2). We used the landscape composition and configuration surrounding nests to inform models of both nest survival and juvenile survival rates because adaptive nest-site selection (i.e., selection of nest sites that maximizes productivity) needs to account for survival rates during both the nesting stage and the juvenile stage (Refsnider and Janzen 2010, Streby et al. 2014a). We explored the relationships between cover types and nest survival rate at radii of 25, 50, 100, 250, and 500 m. We tested some of the same, and larger radii (100, 250, 500, 750, and 1,000 m) in our exploration of factors influencing juvenile survival rate to account for the mobility of juveniles (Daly 2014). The

**Table 1.** Scale and polynomial function of landscape-scale variables used in predicting productivity for 2 survival-rate periods in American woodcock monitored at Tamarac National Wildlife Refuge, Minnesota, USA, during 2011–2012. Variables that were not included in both survival-rate periods are indicated by "N/A".

| | **Nest Survival Rate (*n* = 48 nests; *n* = 630 exposure days)** | | **Juvenile Survival Rate (Day 1–15) (*n* = 90 individuals; *n* = 1,014 exposure days)** | | |
|---|---|---|---|---|---|
| **Landscape Variable** | **Scale (m)** | **Polynomial function** | **Scale (m)** | **Polynomial function** | **Relationship with survival rate** |
| Mature Forest | 500 | Linear | 500 | Linear | Mature forest is the most common cover type present on the landscape in northern Minnesota. Mature forest is purported to be used infrequently by American woodcock (Kelly et al. 2008), and long-term succession of young forests without additional disturbance or management is thought to be a cause of declines in woodcock populations. We included mature forest as a covariate in both nest survival rate and juvenile survival rate models because some woodcock nested within mature forest and the amount of mature forest on the landscape may influence the predator community and the survival rate of nests and juveniles. |
| Grassland | 500 | Linear | N/A | N/A | Grassland is reportedly important to woodcock for display and mating. We included grassland in models of nest survival rate because grassland is relatively uncommon on the landscape and may be associated with different predator communities resulting in tradeoffs between nesting near grassland and survival rate as observed in other young-forest species (Peterson et al. 2016). |
| Upland shrubland | 500 | Linear | 1,000 | Linear | We included upland shrubland in our models as American woodcock are believed to be a young-forest specialist species and most management plans call for the creation of more upland shrubland to increase productivity and abundance. |
| Wetland shrubland | N/A | N/A | 250 | Linear | Wetland shrubland is structurally similar to upland shrubland, but may have different predator populations and a differential effect on survival rate in juvenile woodcock. Although woodcock rarely nest in wetland shrublands, they often nest nearby, and proximity may be important to the survival rate of juvenile woodcock as wet areas are often associated with diurnal feeding areas in adult woodcock. |

smallest and largest radii do not necessarily represent the minimum or maximum distances that juveniles could or did travel from the nest site during the first 15 d post-hatching. Instead, these radii represent the scale at which cover types might generally be available to juvenile woodcock during the first 15 d post-hatching as the quantity, composition, and configuration of cover types surrounding the nest site may affect the survival rate of juveniles by influencing the ability of juveniles to escape detection by predators (e.g., Spears et al. 2007), and/or by influencing the local predator community (e.g., Sovada et al. 2000).

We summed the total area (ha) for each cover type and the total linear distance of edge (km) contained within each buffer zone around each nest location and modeled the relationships between landscape variables and survival rate at each scale (i.e., impact radii). We constructed linear models (including those with quadratic and cubic parameters) relating landscape components and survival rate using a logistic exposure function (Shaffer 2004) and the glm function in R (R Core Team 2016). We ranked models of nest survival rate and juvenile survival rate using Akaike's Information Criterion adjusted for sample size

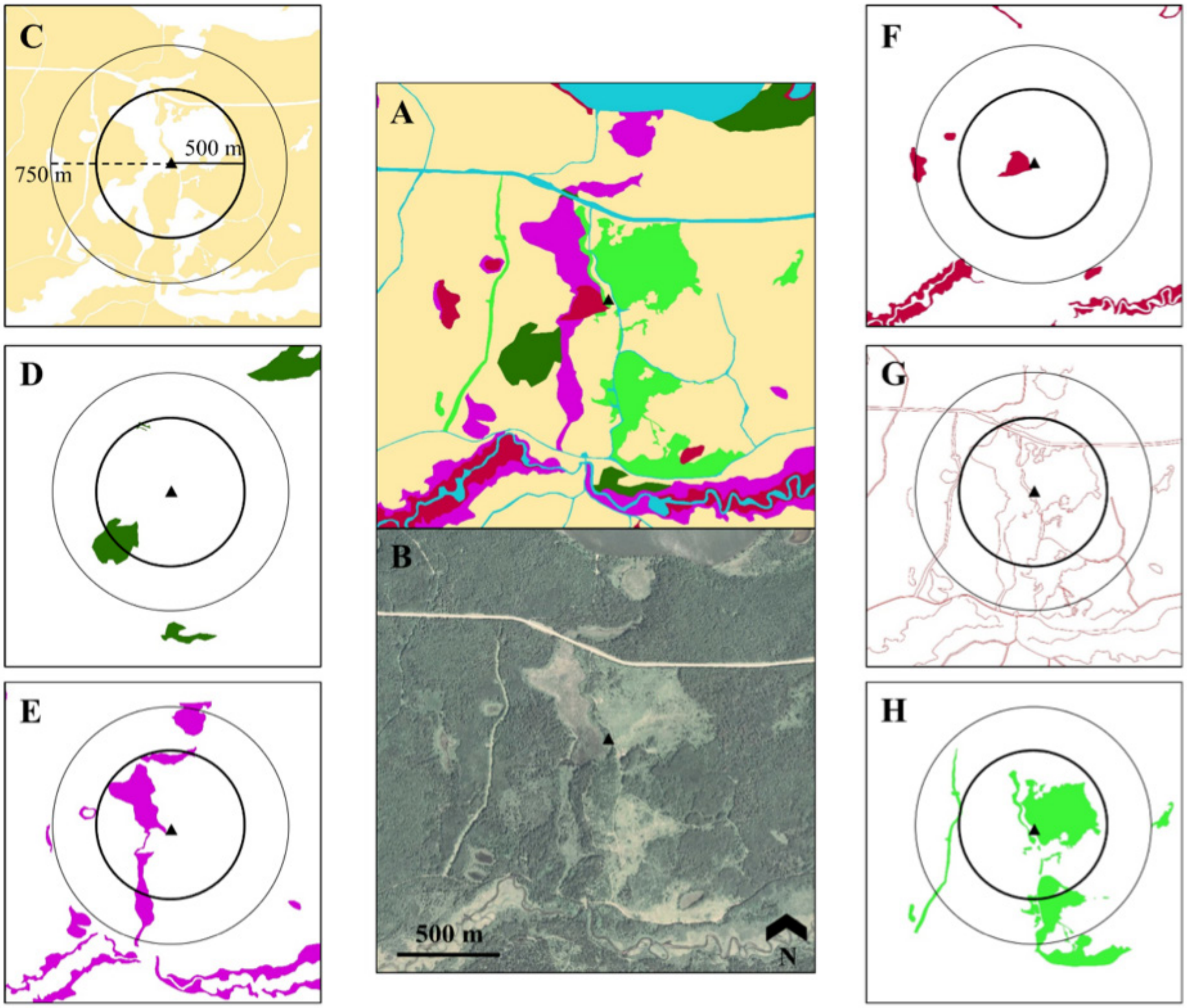

**Figure 2.** Example of digitized landscape (A) derived from satellite imagery (B). An American woodcock nest is located near the center of all images and denoted by a black triangle. Panels C–H demonstrate the process of isolating and quantifying the amount of landscape variables at different impact radii surrounding nests. In this example, we investigated the amount of mature forest (C), forested wetland (D), wetland shrubland (E), grassland (F), shrubby edge (G), and upland shrubland (H) within 500 and 750 m of a nest. We extracted the area of each of these cover types at different radii and used generalized linear models to determine if 1 impact radius best explained juvenile and nest survival rates for each cover type.

($AIC_c$; Burnham and Anderson 2002). We used a combination of $AIC_c$ rankings, the consistency of model rankings (i.e., whether stand- or landscape-scale radii [>250 m] consistently outperformed micro-scale radii [<250 m] and vice versa), and biologically informed predictions to select cover types and impact radii to include as covariates in productivity models (Peterson 2014, Peterson et al. 2016; presented in Kramer 2017).

The second step of our modeling approach involved using the covariates (i.e., cover types and associated impact radii) identified in the first step to build logistic-exposure survival-rate models (Shaffer 2004) for each potential combination of important landscape components at their determined impact radius. We applied these models to each pixel (1 $m^2$) on the digitized landscape such that the survival rate estimate at any pixel was informed by the specific landscape composition and configuration within the previously determined impact radius specific to each landscape component. Following the methods of Peterson (2014) and Peterson et al. (2016), we estimated daily survival rate ($S$) within each period for each observed combination of landscape structure and composition ($_l$) and survival-rate period ($_p$) as:

$$S_{lp} = exp(\alpha_{lp} + \beta_{1lp}x_{1lp} + \beta_{2lp}x_{2lp} + \beta_{3lp}x_{3lp} \ldots) / (1 + exp(\alpha_{lp} + \beta_{1lp}x_{1lp} + \beta_{2lp}x_{2lp} + \beta_{3lp}x_{3lp} \ldots))$$

where $\alpha$ is the estimated intercept and $\beta_1$ is the estimated coefficient for the landscape variable $x_1$.

To estimate survival rate over the entire period (i.e., nest and juvenile survival rates) we raised the estimate of daily survival rate to a power equal to the number of days in the period (i.e., 25 days for the nesting period, 15 days for the juvenile period). We applied this logistic-exposure survival-rate equation to the landscape for each survival-rate period (i.e., nest, juvenile; [$_p$]) based on the surrounding landscape composition and structure ($_l$). At each pixel on the landscape, we used the amount of each landscape variable surrounding that pixel at the predetermined impact radius and the $\beta$-coefficients for the logistic-exposure survival-rate equations for the appropriate landscape model to predict nest success (i.e., survival rate from laying to hatching) and juvenile survival rate (i.e., from hatch day to day 15) of woodcock.

We predicted nest productivity (i.e., number of juveniles hatching; NP) given the assumed ability for 1 renesting attempt (i.e., 1 additional nesting attempt following previous nest failure; McAuley et al. 1990), using a mean hatched brood of 4 juveniles,

$$NP = (NS + (1 - NS) * NS) * 4$$

where NS is nest success rate. We calculated productivity to day 15 post-hatch (i.e., the number of young raised to day 15; P15) as,

$$P15 = NP * JS$$

where JS is juvenile survival rate (from hatch day to day 15). We applied these equations to the digitized landscape and produced surfaces containing values for NP, JS, and P15 of theoretical woodcock nests placed within each pixel (1 $m^2$) of our study area. We used these models to identify areas of high and low productivity on the landscape and predict the effects of management actions on the productivity of woodcock breeding at Tamarac NWR.

### APPLICATION OF SPATIALLY-EXPLICIT MODELS OF PRODUCTIVITY

We predicted the effects of 3 realistic land-cover management scenarios on the productivity of woodcock at Tamarac NWR to investigate the relationships among cover types and period-specific survival rates and resulting productivity. In ArcGIS, we applied hypothetical management on landscapes within our study area to illustrate (1) the effect of grassland succession into upland and wetland shrubland, (2) the effects of creating a ~16 ha (40-acre) upland shrubland clear-cut surrounded by mature forest, and (3) the effects of succession without further management or disturbance on a heterogeneous landscape containing patches of shrubland, grassland, and mature forest. We constrained our models to areas we expected woodcock might use for nesting based on field observations of woodcock nest locations. Thus, we considered roads, open water, grassland, and any cover types >300 m from upland or wetland shrubland to be areas unused by woodcock and omitted those areas from our analysis. We averaged each pixel in our productivity surface with all pixels within a 25-m radius to smooth visualizations of landscape productivity.

We selected 3 distinct areas of our study site to test the effects of potential management on the productivity of woodcock by altering the input values of landscape parameters into our spatially explicit models. First, we predicted the change in productivity following the conversion of non-nesting habitat (grassland) into upland shrubland and wetland shrubland. These scenarios (Scenario 1a and Scenario 1b; Table 2) investigated the relative productivity of woodcock in upland and wetland shrubland cover types while controlling for the surrounding landscape structure and composition. The effects of grassland on nest and juvenile productivity of woodcock is not well understood, although grasslands are purported to be a crucial landscape component for breeding woodcock as males use open areas to display and attract females (Wildlife Management Institute 2010). Our second scenario (Scenario 2; Table 2) predicted the effects of clear-cutting a section of extensive, mature forest to create a 16-ha (40-acre) patch of upland shrubland surrounded by mature forest. Lastly, we investigated how productivity of a heterogeneous landscape changes over time by simulating succession of all cover types (i.e., grassland to shrubland, shrubland to mature forest) in the absence of further disturbance or the maintenance of disturbed areas (Scenario 3; Table 2). We chose an area with a patchy and irregular distribution of diverse cover types that reasonably represented a non-managed landscape. We investigated the difference between productivity in each scenario by averaging productivity across all potential nesting sites in the study area. We also accounted for the change in available nesting cover types by multiplying the area available for nesting in each scenario by the mean productivity of the resulting landscape.

Federal and State permits for capture, banding, and radio-marking woodcock as part of the study by Daly (2014) were granted by the U.S. Geological Survey Bird Banding Laboratory (Permit # 06258, Wayne Brininger, USFWS), and the Minnesota Department of Natural Resources (Permit #s 17377 and 17973, W. Brininger, USFWS). Animal welfare and handling protocols in Daly's (2014) study were approved by the University of Minnesota Institutional Animal Care and Use Committee under Protocol #1103A97333.

## Results

Daly (2014) and Daly et al. (this volume, Evaluating techniques) monitored 48 nests and 90 juveniles at Tamarac NWR from 2011–2012. Of the 48 nests and 90 juveniles monitored, 21 nests (44%) and 25 juveniles (28%) were depredated. We created 14 logistic exposure models (Table 3) predicting survival rate across 2 periods (nesting and juvenile survival from hatching to day 15). Our spatially explicit models of nest and juvenile survival rates explained more variation than the null (intercept-only) models (nest survival, $\Delta AIC_c$ from null = -4.69; juvenile survival, $\Delta AIC_c$ from null = -9.66; Fig. 3). We did not detect a correlation between nest survival rate and juvenile survival rate ($r$ = -0.09, $P$ = 0.50). However, nest survival rate explained more variation in productivity than juvenile survival rate ($AIC_c$ = 82.63 and $AIC_c$ = 137.50, respectively).

### EFFECTS OF ALTERING INPUT COVER TYPE VALUES ON PREDICTED PRODUCTIVITY

Altering the input values for underlying landscape parameters of our study area resulted in biologically significant changes in predicted productivity of woodcock. Altering the input landscape parameters to reflect conversion of a large grassland to upland and wetland shrubland (Scenario 1a; Table 2) increased the area available for nesting by 8% (4.5 ha). Converting grassland to upland shrubland increased the predicted mean productivity (i.e., the mean number of juveniles surviving 15 days post-hatching from breeding attempts at a random pixel [1 $m^2$]) by 128% from 0.59 juveniles/breeding female (SD = 0.23) to 1.35 juveniles/breeding female (SD = 0.28; Fig. 4C). After accounting for the increase of available nesting cover, the estimated productivity of the upland-shrubland landscape increased by 147%. When we altered the input landscape parameters to indicate conversion of the grassland to wetland shrubland (Scenario 1b; Table 2), the predicted mean productivity increased by 190% from 0.59 juveniles/breeding female (SD = 0.23) to 1.71 juveniles/breeding female (SD = 0.54; Fig. 4D). After accounting for the increase of appropriate nesting cover, converting grassland to wetland shrubland increased the productivity of woodcock on this landscape by 213%.

Changing the underlying landscape parameters to reflect clear-cutting and subsequent succession of a 16-ha mature deciduous forest stand to upland shrubland (Scenario 2; Table 2) increased predicted mean productivity 52% from 0.88 juveniles/breeding female (SD = 0.26) to 1.34 juveniles/breeding female (SD = 0.51; Fig. 5). We assumed that woodcock would nest throughout the intact patch of mature forest prior to management in this scenario, and therefore our estimate of productivity is not

**Table 2.** Cover type input values (ha) used in models to predict the number of juvenile American woodcock surviving to 15 d post-hatching produced under different management scenarios at Tamarac National Wildlife Refuge, Minnesota, USA. See text for descriptions of scenarios.

| | Amount (ha) of cover type pre-management | | | | Amount (ha) of cover type post-management | | | |
|---|---|---|---|---|---|---|---|---|
| | Mature forest | Upland shrubland | Wetland shrubland | Grassland | Mature forest | Upland shrubland | Wetland shrubland | Grassland |
| Scenario 1a | 45.0 | 14.0 | 0 | 4.7 | 45.0 | 18.5 | 0 | 0.2 |
| Scenario 1b | 45.0 | 14.0 | 0 | 4.7 | 45.0 | 14.0 | 4.5 | 0.2 |
| Scenario 2 | 60.2 | 2.2 | 0 | 0 | 45.2 | 0 | 18.7 | 0 |
| Scenario 3 | 76.6 | 14.8 | 0 | 3.5 | 92.0 | 3.5 | 0 | 0 |

dependent on the available amount of nesting cover types. Only ~10% of female woodcock Daly (2014) monitored nested in expansive stands of mature forest >200 m from other cover types. Therefore, if we assume only 10% of the mature forest in this landscape (6.2 ha) was appropriate for nesting woodcock, then the amount of available nesting habitat following clear-cutting increased by 90% and productivity of the landscape increased by 1,430%.

Finally, altering the input landscape parameters to represent forest succession of a diverse and patchy forest matrix of upland shrubland, mature forest, and grassland (Scenario 3; Table 2) resulted in an estimated 19% decline in woodcock productivity from 1.01 juveniles/breeding female (SD = 0.56) to 0.82 juveniles/breeding female (SD = 0.23; Fig. 6). When we accounted for the change in available nesting habitat following succession of grasslands to shrublands, and shrublands to mature forest, we found the area available for nesting on the landscape increased by 3.8% (3.5 ha) following management, which slightly mitigated declines in productivity of the entire landscape that we estimated to be -16%.

## Discussion

We constructed spatially explicit models and predicted the nest survival rate and number of juveniles surviving to 15 days after hatching of American woodcock across a diverse landscape in northwestern Minnesota, following the methods outlined by Peterson (2014) and Peterson et al. (2016). Our models related structural and composition characteristics of cover types across a varied and complex landscape to survival rates of woodcock nests and juveniles. These models allow for identification of areas of high- and low-productivity (based on the location of the nest site) and simulation of effects of potential management scenarios across this and similar landscapes. Because the results of any management action are dependent on the existing landscape mosaic, these models do not provide generalized rules for managers, but instead offer a tool to (1) assess the predicted, spatially explicit productivity of existing landscapes to aid in determining whether management is warranted, (2) identify low-productivity areas (i.e., sinks), and (3) test different management scenarios to optimize the resulting productivity of the managed area given the unique abundance and distribution of site-specific landscape components. Like all statistical models of complex biological processes, our models should be interpreted considering their limitations and may not provide reliable predictions in other portions of the woodcock breeding distribution. The relatively small sample sizes and relatively data-driven method of arriving at final models prevented us from reasonably subsetting our data as required for k-fold cross-validation techniques used by others to test these and similar models (Boyce et al. 2002, Peterson 2014, Peterson et al. 2016). However, for the purposes of our study, these models provide a means of evaluating relative productivity across our study area.

Overall, our models generally corroborated the findings of other studies reporting no relationship between woodcock nest success and the cover type or vegetation structure immediately surrounding the nest (e.g., McAuley et al. 1996). Daly et al. (this volume, Breeding season survival of woodcock) reported similar stem density at woodcock nests over their 2-year study period, suggesting female woodcock selected nest sites with similar micro-scale features regardless of the composition of the greater landscape. We found that composition and configuration of cover types influenced woodcock nest survival rate at the landscape-scale (i.e., within 500-m radius of the nest). Based on the observed nesting behaviors of woodcock in our study and other portions of the species' range, woodcock appear to be capable of finding structurally similar nest sites with relatively low basal area (i.e., ~9 m$^2$/ha) and high stem densities (i.e., >12,000 stems/ha) in a variety of landscape contexts (e.g., mature forest, upland shrubland, wetland shrubland; McAuley et al. 1996, Daly et al. (this volume, Breeding Season Survival of Woodcock). If female woodcock choose nest sites with similar micro-scale characteristics, it is logical that the greater surrounding landscape may be more likely to influence the survival rates of nests and juveniles and that females may select nest

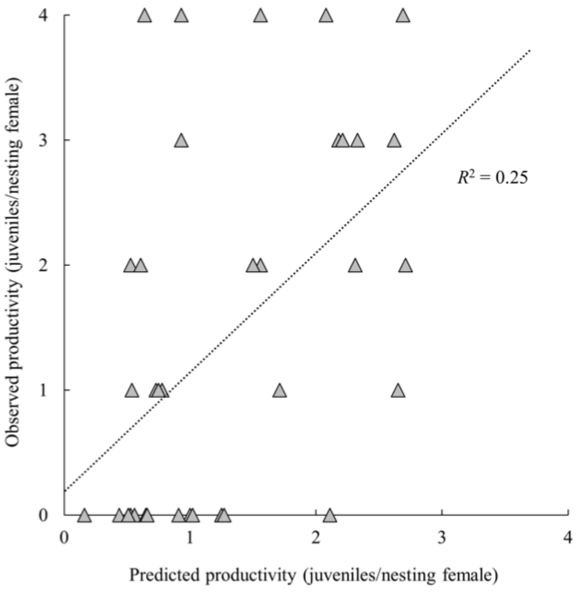

**Figure 3.** Predicted versus observed productivity (i.e., number of juveniles surviving to day 15) of American woodcock at Tamarac National Wildlife Refuge, Minnesota, USA. Slope of regression line is significantly different from zero ($\bar{x}$= 0.96, $t$ = 3.44, $P$ =0.001).

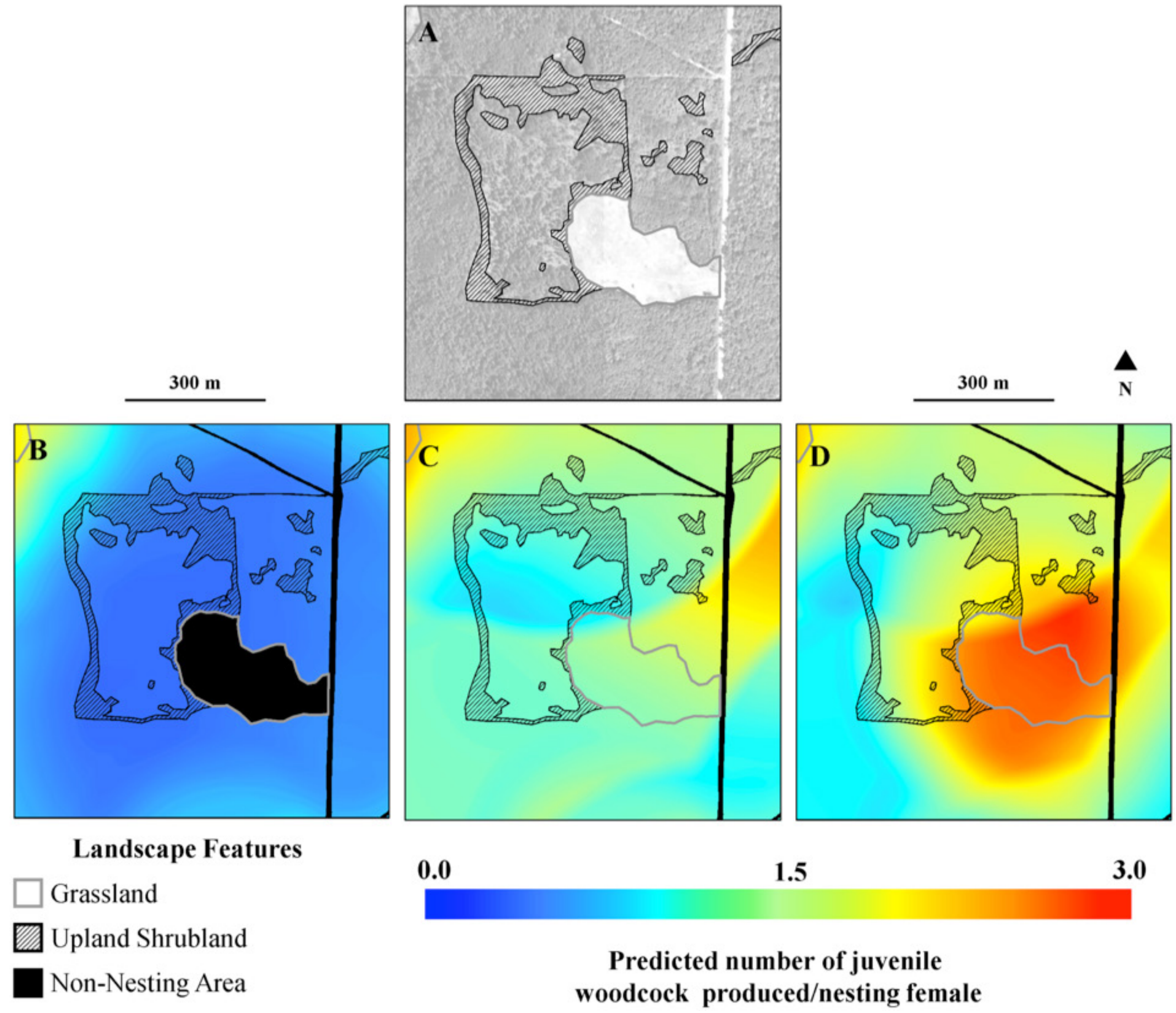

**Figure 4.** Aerial photograph (A) of a portion of Tamarac National Wildlife Refuge, Minnesota, USA, with a mix of cover types. Upland shrubland is delineated by hatched lines and grassland is marked with a thick gray border. Panel (B) shows the predicted productivity (i.e., number of juveniles produced reaching 15 days of age) of the landscape in (A), with cooler colors representing lower productivity and warmer colors representing higher productivity. Panel (C) shows the productivity of the landscape if the main grassland area at the center of the map is replaced with upland shrubland. Panel (D) shows the predicted productivity of the same landscape if the grassland area at the center of the map is transformed into wetland shrubland. See main text for definition of land cover types.

sites that are nearer to cover types and landscape components that confer greater juvenile survival rates (Streby et al. 2014a). As such, management intended to increase the amount or quality of breeding habitat for woodcock may be most effective when managers fully account for the context of the surrounding landscape. Managing an area (e.g., a refuge or property) to contain all the landscape components that are required for highly productive woodcock populations may not be necessary, nor may it always be the best course of action. The inverse relationships between influential cover types (e.g., grassland and wetland shrubland) and the abundance of these cover types on the surrounding landscape may influence whether a manager creates more grassland, or allows a shrubland to mature depending on the context of the surrounding landscape. Our models can be used to help aid in these predictions.

We did not account for weather variables in our models, although other studies suggest links between inclement weather and the timing of nest initiation (Roboski and Causey 1981, Dwyer et al. 1988, Whiting 2006), precipitation and survival rates of juvenile woodcock (Sheldon 1971, Owen 1977, Daly et al. 2015), weather-related stress

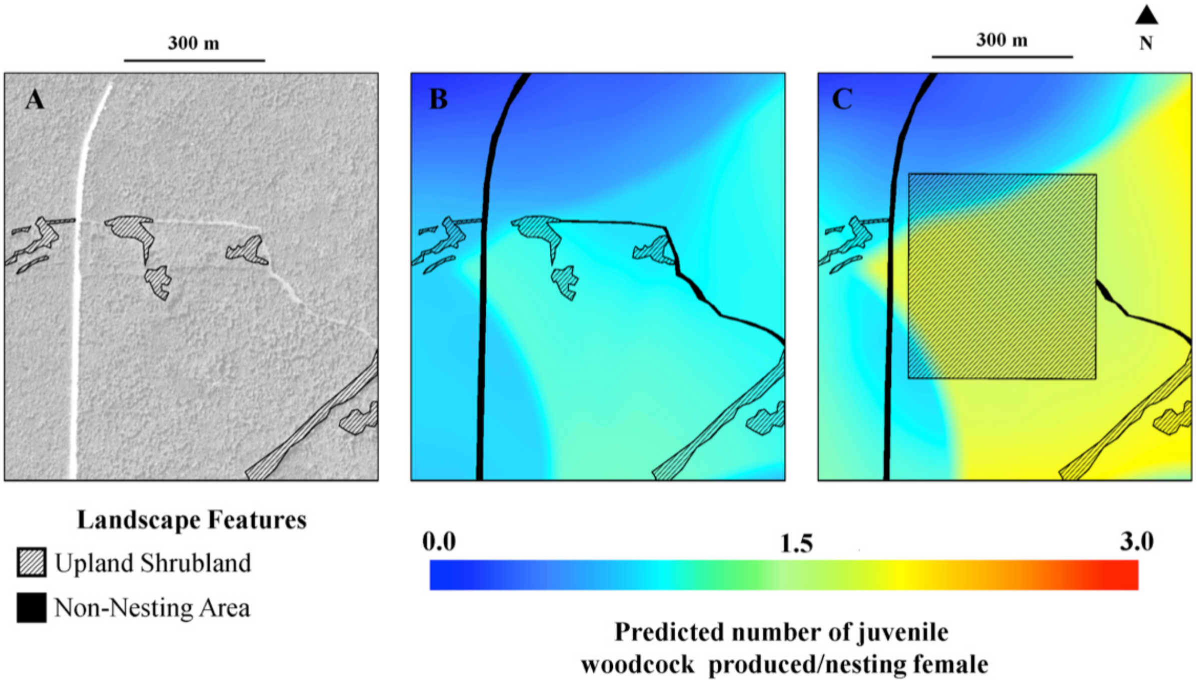

**Figure 5.** Aerial photograph (A) of a portion of Tamarac National Wildlife Refuge, Minnesota, USA, composed primarily of mature forest with several small patches of upland shrubland (hatched lines). Panel (B) shows the predicted productivity (i.e., number of juveniles produced reaching 15 days of age) of the landscape in (A), with cooler colors representing lower productivity and warmer colors representing higher productivity. Panel (C) displays the predicted productivity following alteration of input landscape parameters to represent clearcutting a 16.2-ha (40-acre) patch of mature forest and upland shrubland resulting in only upland shrubland in the clearcut area. See main text for definition of land cover types.

and juvenile woodcock growth rates (Rabe et al. 1983), and overall woodcock recruitment (Sepik et al. 2000). Weather may influence reproductive success of woodcock, especially at northern breeding latitudes or relatively high elevations (McAuley et al. 2010, Daly 2014), but our primary goal was to determine the effects of different landscape compositions and configurations on the productivity of woodcock at our site. Determining the proximate cause of death (e.g., predation versus exposure and subsequent consumption by a predator) was challenging for radio-marked juveniles in Daly's (2014) study; therefore, it is unclear how weather and predation may have interacted to influence juvenile mortality events. Additionally, some land-cover types may be more or less suitable to woodcock during inclement weather events and our models may include some effect of the interaction between weather and cover type. Future research may continue investigating the effects of weather on populations of woodcock with long-term telemetry studies as changes in climate and weather patterns may lead to more precipitation and severe weather, especially during the spring when woodcock nest (International Panel on Climate Change 2014).

Overall, our models and predictions of productivity generally align with the BMPs developed for woodcock in the upper Great Lakes region (Wildlife Management Institute 2010). The BMPs for the upper Great Lakes region recommend a landscape-level approach to managing woodcock in stands 200–400 ha. The impact radii of our models reflect this landscape scale (a 500-m impact radius includes ~78.5 ha), and therefore could be useful for predicting the effects of management prior to its implementation and for planning the most effective management strategy for unique landscapes. The woodcock BMPs also call for management units centered around shrubby or forested wetlands with surrounding upland shrubland (Wildlife Management Institute 2010). Our models generally suggest these wetlands may confer greater productivity by increasing juvenile survival rate in woodcock nesting within 250 m of these wetlands. The BMPs call for the creation of roosting fields and singing grounds (i.e., grasslands or other open areas) that amount to ≤20% of the overall landscape. Our models demonstrated a negative relationship between grassland and survival rate of woodcock nests and, therefore, an upper limit closer to 5% of

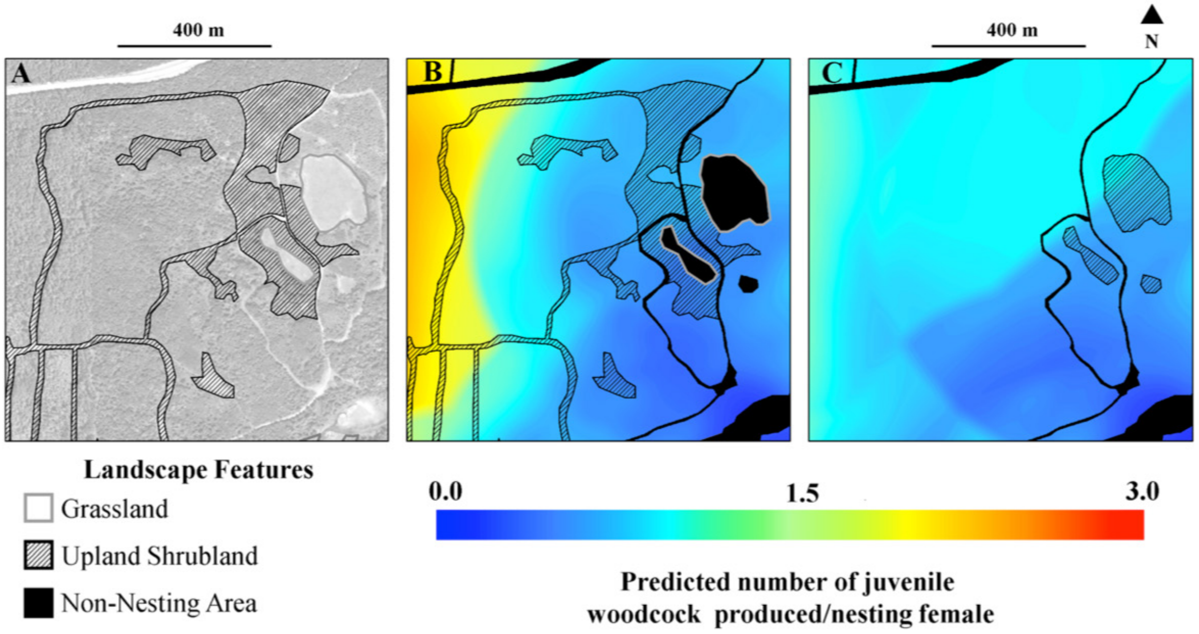

**Figure 6.** Aerial photograph (A) of a portion of Tamarac National Wildlife Refuge, Minnesota, USA, composed of a variety of land cover types with a complex and varied configuration. Upland shrubland (hatched lines) is present in large patches, and also small linear firebreaks. Grassland (solid gray lines) is also present on the landscape. Panel (B) shows the predicted productivity (i.e., number of juveniles produced reaching 15 days of age) of the landscape in (A), with cooler colors representing lower productivity and warmer colors representing higher productivity. Panel (C) displays the predicted productivity following the alteration of input landscape parameters to represent succession of the landscape without any additional disturbance and/or management. In this scenario, our models allowed upland shrubland to succeed to mature forest, and grassland to succeed to upland shrubland. See text for detailed description of land cover types.

the landscape (e.g., 2 ha for every 40 ha managed) might lead to greater nest productivity in the region we studied. Woodcock are known to be territorial during the breeding period, with a single male often dominating a display area (i.e., peenting site; Weeks 1969). Woodcock are also known to use small clearings for displays, so limiting the amount of grassland on the landscape is unlikely to inhibit the ability for woodcock to display and attract mates (Gutzwiller and Wakeley 1980). However, in addition to serving as areas to display, open fields and grassland areas are known to be used by woodcock for foraging and roosting during the breeding and nonbreeding periods (Krohn 1971, Berdeen and Krementz 1998). Therefore, it may be informative to experimentally investigate the effects of the abundance of grassland cover on the occupancy and density of singing males, productivity of nesting females, and space use of nonbreeding, post-breeding, or migratory woodcock throughout the annual cycle to determine the relative importance of grassland cover for woodcock.

To maintain a diverse landscape suitable for woodcock, the BMPs call for a 40-year rotation (depending on soil type and regeneration rates) of stands such that 25% of the landscape is comprised of forest in each of 4 age classes: 0–10, 11–20, 21–30, and 31–40 years post-harvest. As such, our models may be used to assess the geometry and configuration of managed stands through time to ensure that stand rotation continues to provide landscapes associated with high woodcock productivity. It is also critical to account for how the implementation of management may create landscapes that, at first, do not contain the desired or appropriate vegetation structure or land-cover type or contain cover types that are associated with low predicted productivity (e.g., clear-cutting does not immediately result in a dynamic shrubland; see Streby et al. 2018). This may result in infrequent use of these sites by woodcock and/or lower predicted productivity until the desired cover type or vegetation structure is achieved. Similarly, the value of particular landscapes for woodcock may peak and then decline as vegetation succeeds, which influences how managers might implement management to maximize the value of the management as the rates at which vegetation grows and matures is likely to be dependent on the region, climate, vegetation types, and soil types at a given site.

Our models are informed by data collected over 2 years; additional data would thus likely be necessary to validate and improve our models. Data from additional years would likely help account for variation in woodcock survival rate and reproduction and improve the predictive power of our models. However, even in the absence of nest and juvenile survival rate data from additional years, our models provide a useful tool that may help implement and guide management for woodcock in northern Minnesota and similar landscapes in the upper Great Lakes region. These types of models might be useful for investigations of woodcock productivity in other portions of the breeding distribution with woodcock-cover type relations different than those we observed. Comparing models of productivity of woodcock from other portions of their breeding distribution may also provide information on population-specific cover-type relationships and aid in improving and implementing management strategies tailored for individual woodcock populations.

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# American Woodcock Migration Ecology: Factors Influencing Departure Rates and Habitat Selection at Cape May, New Jersey

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**ABSTRACT:** Migration may expose birds to hazards at intensities greater than those during any other life stage, and effective conservation of migratory species requires an understanding of space use during migration. From 2010 to 2013 we conducted a radio-telemetry study of American woodcock (*Scolopax minor*) on the Cape May Peninsula, New Jersey, which is an important stopover site for migratory woodcock in the eastern flyway. Our research objectives were to 1) describe diurnal cover-type characteristics used by woodcock, 2) evaluate second-order habitat selection during the fall migration period, 3) evaluate drivers affecting timing of departure of woodcock from stopover sites, and 4) determine age- and sex-specific departure rates. We nightlighted fields to capture birds and attach VHF radio-transmitters. Over 4 years we radio-marked 271 woodcock and collected 1,949 GPS point locations from these birds (Range = 0–21 points per individual). We used GIS and resource selection functions in the form of generalized linear mixed models to compare land cover-type attributes at the marked locations (used) to attributes at random locations distributed across our study landscape (available). Our model shows a strong negative effect on selection as distance from fields increases, avoidance of large contiguous forest, and selection for forested wetlands. We used results from this analysis to develop a predictive model of habitat distribution at Cape May. To complete objective 3 and 4 we used a CJS survival analysis framework, where results from objectives 1 and 2, as well as weather and astrological variables, were used as covariates to model timing of departure. Our study improves understanding of American woodcock habitat selection during this critical life stage and provides a predictive model for understanding timing of departure from a migratory stopover. Furthermore, our results may identify important habitats for other short-distance migrants that rely on early successional habitat.

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**KEY WORDS:** American woodcock, habitat selection, migration ecology, New Jersey, predictive model

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# Landscape Context Matters When American Woodcock Select Singing Grounds: Results from a Reciprocal Transplant Experiment

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**ABSTRACT:** The multiscale nature of habitat selection during the breeding season for migratory birds means that core-use areas (e.g., breeding territories) are selected based on their local habitat features, but these may also be influenced in some way by features within a larger-scale landscape. We conducted a reciprocal transplant experiment to test the hypothesis that habitat selection and movements of male American Woodcock (*Scolopax minor*) in core-use areas during the breeding season depend on the perceived quality of the surrounding landscape. We captured second-year male woodcocks ($n = 19$) at high- or low-likelihood-of-use landscapes in Rhode Island, USA, affixed each with a radio transmitter, relocated them to the opposite type of landscape, and then determined if they returned to their original site of capture or remained in the landscape to which they were relocated. Birds captured in high-likelihood landscapes and moved to low-likelihood landscapes generally returned to their original high-likelihood landscape (5/7, 71%), but birds captured in low-likelihood landscapes and moved to high-likelihood landscapes rarely returned to their original low-likelihood landscape (1/12, 8%). These results support the hypothesis that woodcock assess their surroundings relatively rapidly and subsequently make critical settlement decisions based on landscape composition. Given that woodcock choice is predicted by the woodcock-specific resource selection function, these results also provide support for the use of this tool to guide forest management for woodcock.

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**KEY WORDS:** American woodcock, landscape context, singing ground, telemetry

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# Evaluation of Habitat Characteristics and the Appropriate Scale for Evaluating Diurnal Habitat Selection of Wintering American Woodcock in Louisiana

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**ABSTRACT:** Migratory bird species pose serious management challenges because it is difficult to determine habitats utilized during their entire life cycles. As American woodcock populations have experienced long-term declines, wintering habitat management has become increasingly important. Past studies on woodcock have relied predominantly on Very High Frequency (VHF) telemetry, which require an observer to manually track them to gather location information. Our study employed both Global Positioning System (GPS) and VHF tags on woodcock to gather high resolution movement data in order to evaluate habitat use and compare VHF and GPS approaches to habitat sampling. We simulated a VHF approach to tracking the same individuals from the GPS tag data (spanning 252 bird-days) and utilized vegetation samples from our VHF tracked birds to evaluate use and random paired location sampling. We found that many random locations fell within the Minimum Convex Polygons (MCP) as defined via the GPS tags (average diurnal MCP size was 0.04 ha). Overall, our results suggest that evaluating resource selection by woodcock requires discerning the appropriate scale(s) of habitat selection via the identification of the spatial and temporal components underlying individual movement ecology.

***Proceedings of the American Woodcock Symposium 11: 124–129***

**KEY WORDS:** American woodcock, habitat use, radio telemetry, spatial ecology, vegetation sampling

In managing for a particular wildlife species it is vital to consider its full annual life cycle, as selective pressures driving demography and population dynamics are often differentially influenced at various life cycle stages. This is particularly true with migratory bird species because demography varies significantly between time spent on the breeding grounds, during migration, and on the wintering grounds (Sillett and Holmes 2002, Rotics et al. 2017). While survival on breeding habitat is important for migratory bird populations (Peron et al. 2012), the impact of habitat quality during migration and winter is not as clearly defined. However, wintering habitat can impact success across the full annual cycle (Marra and Holmes 2001, Rushing et al. 2016, Ruiz-Sanchez et al. 2017).

The American Woodcock (*Scolopax minor*; hereafter woodcock) is a migratory game bird that breeds primarily in the northern midwestern and northeastern states of the United States and southeastern Canada and winters in the southeastern United States. Woodcock are managed by the United Stated Fish and Wildlife Service (USFWS) and the Canadian Wildlife Service (CWS) as two distinct populations, the Central and Eastern populations (Seamans and Rau 2017). The Central population is thought to migrate generally along the Mississippi River corridor while the Eastern population follows the Atlantic coast, although crossover between populations occurs regularly (Moore and Krementz 2017). Both populations of woodcock utilize primarily early successional forests with dense under-

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growth throughout their breeding range (Straw et al. 1994, Dessecker and McAuley 2001, McAuley et al. 2005), but use a wide variety of upland and bottomland hardwoods, mixed pine-hardwoods, and managed pine forests on the wintering grounds as long as understory vegetation is adequate (Dyer 1976, Krementz and Pendleton 1994, Straw et al. 1994). Population monitoring data indicate declines in both regions (Seamans and Rau 2017), and these declines have been attributed primarily to the loss of early successional habitat on breeding grounds (Dessecker and McAuley 2001).

As woodcock populations have declined, focus on wintering habitat management has become increasingly important, particularly in the Lower Mississippi Alluvial Valley (LMAV), where adult female survival rates may be particularly low (Pace 2000). Furthering our understanding of how woodcock select and use habitats during the wintering period has also been identified as a priority information need for woodcock by the Association of Fish and Wildlife Agencies Migratory Shore and Upland Game Bird support task force (Case and Associates 2010). Usable habitat types must occur regularly within some larger landscape because woodcock are thought to travel relatively short distances between diurnal and nocturnal sites (Berdeen and Krementz 1998, Masse et al. 2013)

Past studies on woodcock have relied predominantly on Very High Frequency (VHF) telemetry that required an observer to manually approach woodcock to determine location (Hudgins et al. 1985, McCauley et al. 1993, Krementz and Pendleton 1994). Paired sampling, wherein habitat data are collected at the located position as well as at a random location, is typically used to distinguish between use and available areas (Dyer 1976) in avian studies employing VHF telemetry. Vegetative conditions at use areas can then be compared to overall available vegetative conditions to determine if particular resources are used in proportion to their availability (Manly et al 2002).

The advent of Global Positioning System (GPS) tag technology facilitates the assessment of common vegetation sampling techniques. Woodcock habitat evaluations typically occur at the scale of the stand (Myatt and Krementz 2007) or in relation to where individuals are flushed (Dyer 1976). However, without knowledge of the daily use area of woodcock, our concern is that that without a well-defined daily utilization distribution, random locations (availability component; Manly et al. 2002) could potentially fall in the use region, leading researchers to unknowingly compare use locations to use locations. GPS tags have the ability to collect and store data at programmable intervals, allowing large quantities of high-resolution spatial data to be recorded. We used daily movement GPS data to evaluate the assumption that paired random vegetation points are not used by the woodcock and to provide some direction on refining the appropriate spatial and temporal scale for evaluating woodcock habitat selection.

## Study Area

We conducted our research in the Mississippi Alluvial Valley (MAV) and the West Gulf Coast Plains regions of Louisiana (Figure 1). Focal public lands included the Tensas River National Wildlife Refuge (32,350 ha) and the Dewey Wills (25,859 ha), Sherburne (17,800 ha), Bayou Pierre (895 ha), and Richard K. Yancey (28,250 ha) Wildlife Management Areas (WMAs). We also utilized private land near the towns of Palmetto, Deridder, and Boyce, LA, during this study. Most lands were dominated by bottomland hardwoods (all public tracts and 1 private tract). Upland pine (mostly loblolly pine *Pinus taeda*) was the predominant habitat type on 2 private tracts. Active forest management, including single tree selection, group selection, and small clearcutting, resulted in forests with a variety of age classes on all public lands, while small clearcutting occurred on the private lands Boyce study site. Open, wet fields (either fallow or harvested row-crops) within close proximity to woodlands were present within each site to varying degrees.

## Methods

### WOODCOCK CAPTURE, TAGGING, AND TRACKING

We captured woodcock in October 2015 – February 2016 and November 2016 – February 2017. We located woodcock at night via spotlighting from all-terrain vehicles in fields and captured them using a dip net (45 cm

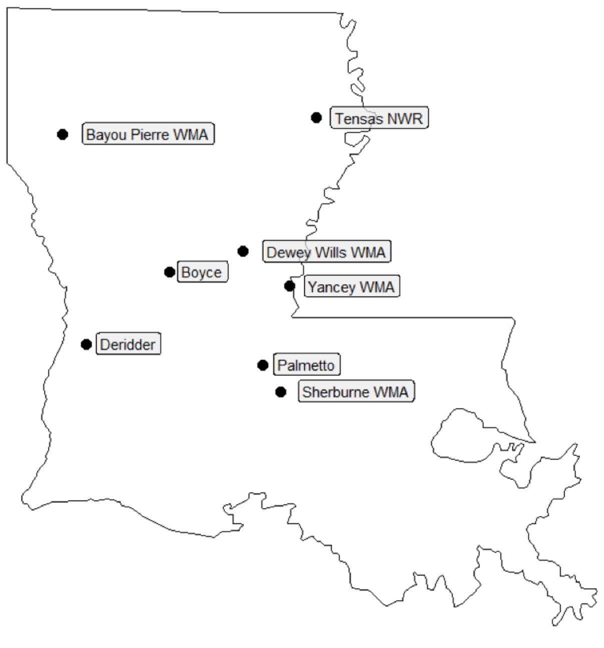

**Figure 1.** Site locations across Louisiana, USA.

in diameter) attached to a 3-m pole. Upon capture, we banded woodcock with U. S. Geological Survey aluminum bands (BBL Permits 23578 and 06669). We also classified each individual by age and sex.

We utilized VHF and combined GPS-VHF Pinpoint (hereafter Pinpoint) tags on woodcock for our work. VHF transmitters weighed 4.5 g (Lotek Wireless, Newmarket, Ontario) and were glued to the back of each woodcock using livestock tag cement and then secured with a coated metal belly band and aluminum crimp (McAuley et al. 1993). Pinpoint tags were 5.5 g and stored GPS locations on-board. We deployed Pinpoint tags using a modified leg-loop attachment (Rappole and Tipton 1991, Mallory and Gilbert 2008) secured with an elastic harness (Stretch Magic Clear Bead Cord, 0.7 mm diameter) and soft PVC tubing (Pony Bead Lacing, 2 mm diameter) to disperse pressure from the harness. We programmed each Pinpoint tag to take GPS fixes at an interval between 1 to 1.5 hours which, depending on tag battery size, would last between 3 and 18 days. We programmed the VHF component to emit a signal between the hours of 0900 and 2100 after GPS data were collected to assist with recovery. Upon recovery, Pinpoint tags yielded up to 300 spatial locations per deployment.

We radio-tracked VHF-only-tagged woodcock weekly. If an individual was relocated within three days of its capture, we noted its status (i.e., alive or dead) but did not utilize the location in subsequent vegetation sampling. When individuals were located, we homed in, flushed the individual, and recorded their locations. Pinpoint-tagged woodcock were not VHF tracked until after the scheduled GPS fixes were completed and the VHF beacon was enabled. Once the VHF beacon was active, we searched for individuals at night and, if an individual was located, we attempted recapture via spotlighting. When successful, we removed the transmitter and released the woodcock at the capture site. We also recovered Pinpoint-tagged woodcock using a shotgun or air rifle under Louisiana State University IACUC A2015-07, Louisiana Department of Wildlife and Fisheries Scientific Collection Permit 078 and U.S. Fish and Wildlife Service Scientific Collecting Permit MB20705C-0. Additional units were recovered via Louisiana hunter harvest during the woodcock hunting season in Louisiana.

### VEGETATION SAMPLING

For VHF-tagged woodcock we used the flush location and a random paired point 20 m away as vegetation sampling locations (Dyer 1976). At each location, we measured the following vegetation characteristics: (1) canopy cover using a concave spherical densiometer, (2) basal area (ha) using a 10-factor basal area prism, (3) vegetative density using a cover board (Nudds 1977), and (4) ground cover using a Daubenmire frame (0.5 $m^2$) constructed from PVC (Daubenmire 1959). For the Daubenmire frame, we classified ground cover to the nearest 10% into the following categories: litter, bare ground, herbaceous-grass cover, and woody cover.

We used GPS data to develop daily measures of space used for Pinpoint-tagged individuals by generating Minimum Convex Polygons (MCPs) using R package adehabitatHR (Calenge 2006) separately for each day and night period, beginning the day after the individual was captured, when there were sufficient location data (>5 locations). Next, we buffered each daily MCP by 20 m and overlaid a 10 m x 10 m point grid for vegetation sampling (Geospatial Modelling Environment Version 0.7.3.0). In support of other project goals, we conducted vegetation sampling at all flush and randomly paired points, all points within the MCP, and every other point within the MCP buffer. Bird-specific MCPs were later modified into aggregated period MCPs for further analyses.

### METHOD COMPARISON

In order to evaluate the efficacy of the paired random vegetation sampling scheme utilized with our VHF-tagged individuals, we simulated the paired use and availability approach using data obtained from Pinpoint tags. For each day a bird was monitored, we randomly selected one diurnal use point to represent daily tracking of a tagged woodcock. We then generated a random available location to simulate a paired point sampling scheme (Dyer 1976, Straw et al. 1986). For 1,000 simulations we generated three random locations for comparison to available locations for each selected daily location using the following distance categories: 10, 20, 30, 45, 60, 75, and 100 m.

Using GPS data from Pinpoint tags, we next evaluated the frequency of randomly selected non-use spatial locations occurring within use areas over time. We suggest it is likely that woodcock moved outside the boundary of a daily MCP because our GPS data were recorded only once per hour. As such, we combined nearby MCPs into aggregated period MCPs (Figure 2). On average, within a daily (0800–1600) range (excluding movements exceeding 100 m), GPS-tagged woodcock moved <20 m/hr; we thus conservatively selected 20 m as the cutoff defining nearby MCPs. If MCPs from the same bird fell outside of this 20-m range, they were considered separate MCPs rather than being incorporated into a single aggregated period MCP (Figure 2). We then evaluated the frequency of non-use habitat sampling locations that fell into aggregated period MCPs, which defined known use over the study period, and we estimated the proportion of occurrences of randomly located available points within the known use polygons.

## Results

We captured and banded 273 individuals over the course of our study (143 M, 130 F); of these, 65 were tagged with

VHF transmitters (37 M: 28 F) and 63 were tagged with pinpoint transmitters (37 M: 26 F). For VHF-tagged individuals which were subsequently relocated (*n* = 38), the habitat was comprised of a mean basal area of 34.61 sq.m/ha (SD = 23.49), mean canopy cover was 54.55% (SD = 25.59), and mean vegetation density was 49.56% (SD = 26.63). For the randomly selected paired vegetation points (*n* = 38), the mean basal area was 43.68 (SD = 18.07), mean canopy cover was 73.04% (SD = 14.64), and mean vegetation density was 30.53% (SD = 29.75). Mean canopy cover and mean vegetation density at use points were 25% less (t = 3.8664, *P* = 0.0002) and 62% greater (t = -2.9378, *P* = 0.0044), respectively, than at random points. Mean basal area was similar (t = 1.89, *P* = 0.06).

We recovered 33 of the deployed Pinpoint tags and they recorded 3,760 location points spanning 252 bird-days. The number of days an individual was monitored ranged from 1 to 18 (median = 10). Average diurnal MCP size was 0.04 ha (range: <0.01–0.59 ha; *n* = 247) and average aggregated MCP size was 0.27 ha (range: <0.01–3.54 ha; *n* = 67). MCP size varied substantially across sites. While no pattern differentiated pine-dominated sites from bottomland hardwood sites, we note the Sherburne WMA site had substantially larger diurnal MCPs on average than the other sites (Table 1). Average daily movement was ~94 m (range: <1 m – 4707.87 m). Tagged woodcock demonstrated moderate fidelity to diurnal use areas, returning to the same aggregated period MCP 33% of the time. Based on 1,000 simulated pairs of bird-random locations, random paired locations fell within the aggregated period MCP at a rate of 2.5% at 100 m, 4.7% at 75 m, 6.9% at 60 m, 11.8% at 45 m, 21.7% at 30 m, 35.2% at 20 m, and 50.6% at 10 m.

## Discussion

Our results indicate that wintering woodcock across Louisiana utilized habitat with lower canopy cover and higher vegetation density than the randomly sampled locations, corroborating previous findings in the state (Dyer 1976). However, based on our simulation results, we found the paired sampling scheme may not allow for differentiation of habitat selection by woodcock since our samples were separated by 20m. On average, woodcock utilized a daily area of 0.04 ha (20*20 m), Consequently, with a paired sample 20 m away, our random samples would fall into a known woodcock use area over 35% of the time.

The frequency of available locations which fall within an individual's area of use may bias vegetation and habitat comparisons, as it conflates the sampling process

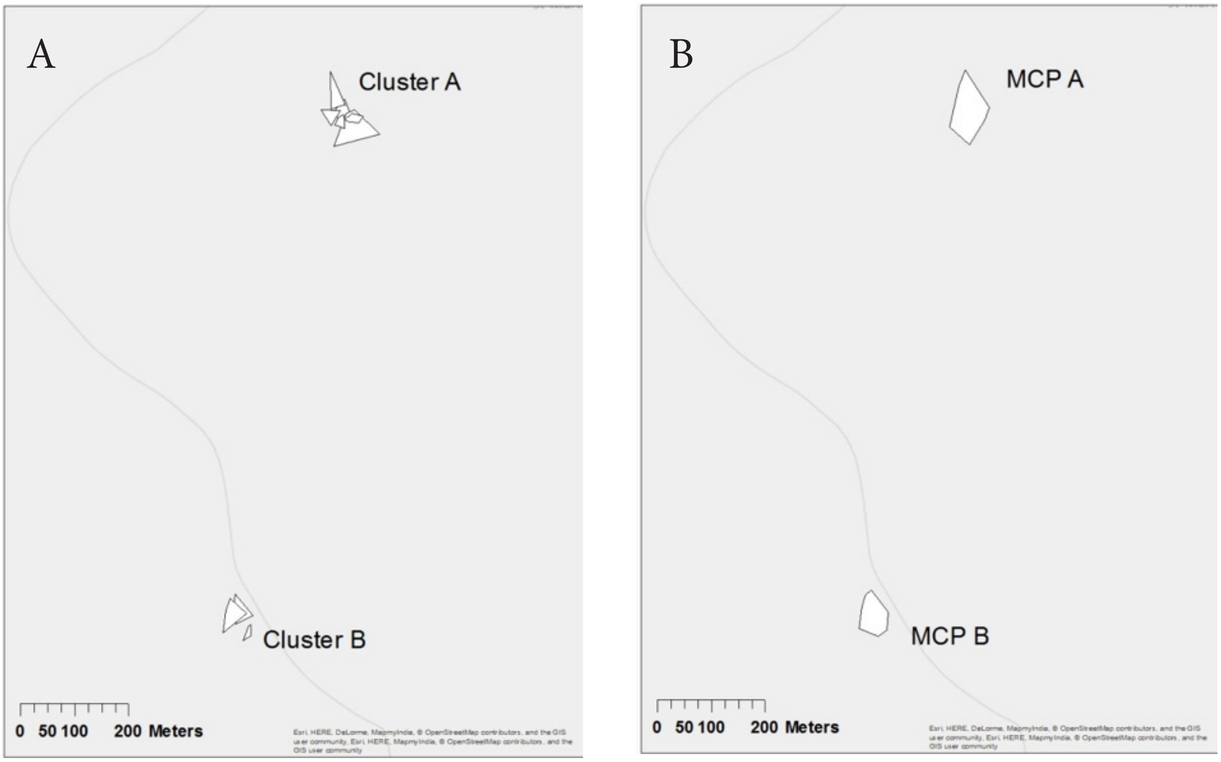

**Figure 2.** A cluster of MCPs generated for 10 days of one individual (A) and the aggregated daily MCPs generate from the individual MCPs (B).

underlying the comparison of use to available. Comparing sampling point within the daily or weekly range of a woodcock might be relevant at the micro-habitat level. However, inference at any higher level will risk the comparison of used habitat to more used habitat. Hence, any results indicating selection, either positive or negative, may not be yielding biologically appropriate inferences at the scale at which woodcock habitat management should be conducted. Woodcock represent a unique challenge in regards to evaluating habitat selection. They regularly make large movements across the landscape in the form of nocturnal flights to open fields; once they select a diurnal or nocturnal area, however, movement distances are significantly reduced. Standard definitions of available habitat to an individual should, in theory, include much of the surrounding landscape, as woodcock may utilize habitat within several kilometers of their capture site. However, once in a diurnal or nocturnal use area, woodcock are likely selecting based on microhabitat characteristics such as soil moisture, vegetative cover, or forage availability (Doherty et al. 2010, Masse et al. 2013). Proximity to fields and clearings may also play a large role in the selection of diurnal habitat. While it is well established that woodcock often utilize agricultural fields at night (Blackman et al. 2011, Krementz et al. 2014), woodcock may use a wide variety of other fields and clearings which may be more difficult to quantify on the landscape (Berdeen and Krementz 1998, Masse et al. 2013).

Given these challenges, in situations in which vegetation metrics at paired samples are taken for comparison to habitat for individual woodcocks, we recommend that a minimum buffered radius of 43 m from the flush location, or an unsampled area covering approximately 0.58 ha (equivalent to our largest diurnal MCP) centered on the flush location, would ensure minimal overlap between areas likely used and random locations. However, we note 2 difficulties using this approach: 1) this will not account for inter-individual variation, and 2) the random point for one individual could easily fall directly in the range of other local individuals. MCP overlap was common in woodcock (Elizondo 2018). As distance needed to ensure sample independence between use and random locations increases, the likelihood of transitions between general habitat classes increases as well, thus necessitating a well-defined habitat sampling frame. We also recommend that any inferences drawn from the approach we used are restricted, as they can only reliably predict at small scales—for instance daily woodcock movements within their diurnal use areas. While useful, these inferences will have limited application in a context of landscape management until stronger linkages between woodcock daily and period movements and space utilization are better defined.

**Table 1:** Diurnal Minimum Convex Polygon area by site.

| Site | Number of GPS tags recovered | Broad Habitat Classification | Mean MCP area (ha) |
|---|---|---|---|
| Sherburne WMA | 9 | Bottomland Hardwood | 0.20 |
| Richard K. Yancey WMA | 2 | Bottomland Hardwood | 0.02 |
| Tensas River NWR | 11 | Bottomland Hardwood | 0.03 |
| Deridder | 7 | Upland Pine | 0.09 |
| Bayou Pierre WMA | 1 | Bottomland Hardwood | 0.02 |
| Boyce | 3 | Upland Pine | 0.03 |

As microhabitat characteristics are fairly well established for woodcock, we suggest a focus on larger scale landscape variables in future research. The classification of the landscape may be made within a broadly defined use area established by the movements of many individuals within a particular system (see Masse et al. 2013) or an area that encompasses at least several square kilometers around the areas the woodcock utilize. Woodcock can travel >2 km in search of a nocturnal field, both on the breeding grounds (Masse et al. 2013) and on the wintering grounds (Elizondo 2018) and are capable of movements >4 km in a single day while settled on the wintering grounds. Thus, all of the habitat within this range is easily available to them, and areas which they fly over when returning to the forests from nocturnal fields are actively selected against. Lastly, we strongly recommend considering the mosaic of forest and potential nocturnal fields in assessing diurnal woodcock habitat use. The quality of nocturnal fields likely plays a largely unexplored role in woodcock diurnal habitat use. This quality may pertain to food availability, likelihood of depredation, or suitability for display. In particular, we recommend making effort to include "non-traditional" clearings that woodcock may use, i.e. smaller areas which may be clearcuts or small forest openings.

## Acknowledgments

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# Enhancing Nocturnal Habitat for the American Woodcock on Louisiana Wintering Grounds

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**ABSTRACT** American woodcock (*Scolopax minor*; hereafter, woodcock) have experienced long-term population declines across much of their breeding distribution since 1968. Previous research suggests that nocturnal habitat availability on the wintering grounds is important to wintering woodcock survival. We compared 4 different land management techniques: mowing, burning, disking, and a mow/burn combination for enhancing nocturnal habitat for woodcock in south-central Louisiana. From 2011–2013, we monitored study plots during overcast nights throughout winter months. We detected woodcock most frequently in both the burn and mow treatments and least frequently in the disk treatment. The total numbers of woodcock we captured and flushed were 13 times greater in the burn treatment than in the disk treatment. We captured 24 times more juvenile woodcock in the mow and burn treatments than in the disk treatment. We captured 12 times more female woodcock in the burn treatment than in the disk treatment, whereas we captured 9 times more male woodcock in the mow treatment than in the disk treatment. Our results suggest that suitable nocturnal habitat for woodcock on the wintering grounds in south-central Louisiana can be enhanced by burning and/or mowing.

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**KEY WORDS:** American woodcock, habitat, modeling, nocturnal, *Scolopax minor*, wintering, Louisiana

The American woodcock (*Scolopax minor*; hereafter, woodcock) is migratory game bird in eastern North America, and is managed on the basis of 2 regions, Eastern and Central (Seamans and Rau 2016). Long-term population declines on large portions of the breeding grounds have been documented since the beginning of singing-ground surveys in 1968 (Seamans and Rau 2016). Due to these long-term declines, woodcock are currently listed as a species of high concern by the U.S. Shorebird Conservation Plan (U.S. Shorebird Conservation Plan 2001), and as a game bird below desired population size by the U.S. Fish and Wildlife Service (U.S. Fish and Wildlife Service 2004). These population declines are believed to be largely due to habitat loss created by current agriculture and societal land-use practices resulting in a reduction in adequate early successional forest vegetation types (Kelley et al. 2008). Low winter period survival rates of 72 ± 5% may partially explain the long-term declines in woodcock populations (Pace 2000). Suitable nocturnal habitat availability, not hunting mortality, is suspected to play the largest role in woodcock survival on the wintering grounds (Krementz et al. 1994, Pace et al. 2000, Pace 2000, Glenn et al. 2004, but see Berdeen and Krementz 1998). This low winter survival suggests that placing a greater emphasis on providing or enhancing nocturnal habitat for woodcock on the wintering grounds may be warranted.

To manage for woodcock, appropriate diurnal and nocturnal habitat must be provided within 700 m of each other (Berdeen and Krementz 1998). Woodcock use forests for diurnal and nocturnal cover, whereas early suc-

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cessional openings provide foraging grounds for wintering woodcock at night (Dyer and Hamilton 1974, Straw et al. 1994, Berdeen and Krementz 1998, Krementz 2000, Kelley et al. 2008). Although habitat preferences of woodcock have been studied elsewhere, there is little research available concerning woodcock response to management practices designed to create early successional nocturnal habitat on the wintering grounds (Krementz 2000, Welch et al. 2001, Glenn et al. 2004; Berry et al. 2006). Welch et al. (2001) examined woodcock response to manipulated, early successional cover types within the Eastern Management Region and concluded that some manipulative practices, namely burning and herbicide application, could be used to create woodcock habitat. However, the Welch et al. (2001) study was limited in scope and additional research on winter habitat management techniques is needed. Therefore, we examined woodcock response to 4 management practices designed to create early successional nocturnal cover as woodcock habitat on the wintering grounds within the Central Management Region.

## Study Area

We conducted our study on the Sherburne Wildlife Management Area (SHWMA) located in the Morganza Flood Way system of the Atchafalaya Basin in south-central Louisiana. SHWMA is comprised of 17,276 ha of state (SHWMA) and federal lands (Atchafalaya National Wildlife Refuge and U.S. Army Corps of Engineers land) and lies within Pointe Coupee, St. Martin, and Iberville parishes. SHWMA is managed by the Louisiana Department of Wildlife and Fisheries (LDWF 2019).

SHWMA was largely comprised of bottomland hardwood forest dominated by cottonwood-sycamore (*Populus deltoides – Platanus occidentalis*), oak-gum-hackberry-ash (*Quercus* spp. – *Nyssa* spp. – *Celtis laevigata – Fraxinus* spp.), overcup oak-bitter pecan (*Quercus lyrata – Carya aquatica*), and willow-cypress (*Salix nigra – Taxodium distichum*) tree species associations (Eyre 1980). There were about 100 ha of fallow fields located within the north-central portion of the area. Our study site was a 25.9 ha fallow field centrally located within the larger fallow field complex and surrounded by mature trees separating it from other nearby fallow fields (Fig. 1). Our study site had not been treated for several growing seasons and was dominated by saplings. The site contained even-aged early successional tree species dominated by cottonwood-sycamore-Chinese tallow (*Triadica sebifera*; 2–5 cm in diameter and 3–5 m tall), grasses, and forbs.

## Methods

We selected 4 treatments to create nocturnal habitat: mow, burn, disc, and a mow/burn combination. We also con-

**Figure 1.** American woodcock nocturnal habitat study site at Sherburne Wildlife Management Area, Pointe Coupee Parish, Louisiana, USA.

sidered a control treatment; however, due to the diameter of existing trees within the study area, we elected to reset succession within the entire study area as existing trees had already reached the capabilities of available equipment necessary to conduct the management. We replicated each treatment 4 times, thus creating 16 0.81-ha study plots. The 16 study plots were arranged in a 4 x 4 grid pattern located near the center of the 25.9-ha study site. The arrangement of treatments was randomly selected for the northern-most row of plots. We rotated treatments for subsequent rows of plots so that similar treatments would not be adjacent to each other, thus preventing plot juxtaposition from becoming a potential woodcock selection factor (Berdeen and Krementz 1998). Treatment applications within plots were not altered between years and remained the same for both study years.

We created the study plots in the fall of 2011 by disking a ca. 5-m border around each of the 16 plots. We applied treatments in October of each year (2011 and 2012). We set the mower deck height to 35–40 cm for the mow treatments, which resulted in even-height vegetation throughout the treatment. We created disk treatments by initially mowing followed by a thorough and deep (≥10 cm) disking, resulting in no standing woody vegetation. We applied Reward© (Syngenta), a herbicide with diquat, at a concentration of 1.33 l/0.40 ha to all treatments requiring a burn (burn and combination of mow/burn treatments) before burning to increase fuel load. We conducted controlled burns in late October of both seasons.

We captured woodcock by night-lighting (Rieffenberger and Kletzly 1967) from an ATV in our study plots from mid-November through mid-February of 2011–2012 and 2012–2013. We sexed, aged (Martin 1964, Artmann and Schroeder 1976), and fitted each captured bird with a United States Geological Survey (USGS) aluminum leg band. We searched study plots by completing 2 passes at a constant speed through each row of study plots. If we captured a marked woodcock twice on the same night, we excluded the second capture in our analysis. When woodcock flushed and were not captured, we recorded flushes in the plot they flushed from. We recorded all detections by treatment type.

We measured the vegetative composition of all plots to characterize vegetative structure of each treatment but not to reflect woodcock selection of specific vegetative composition. We characterized the vegetative structure for each treatment type by measuring vegetation using a 0.5 x 1 m frame at 5 locations within each study plot. We measured vegetation during the third week of February of each year. We randomly selected the starting location on the west end of the plot, then recorded data every 10 m moving easterly from there. In each frame, we visually estimated percent live grass, dead grass, herbaceous vegetation, bare soil, standing woody vegetation, non-standing woody vegetation, and vine. We took 5 measurements of the height of woody stems, dead grass, and vines to the nearest cm. We used SAS version 9.1 for all data analysis (SAS 2003). We ran PROC GLM with year as a random variable to examine for possible interaction between captures and flushes,

**Table 1.** American woodcock nocturnal habitat treatment (Mow, Burn, Mow/Burn, and Disk) selection results at Sherburne Wildlife Management Area, Pointe Coupee Parish, Louisiana, USA, during winters of 2011–2012 and 2012–2012. *Post-hoc* analysis was performed using the Tukey HSD test with α = 0.05, and variables with the same letter (Post-hoc) are not statistically significantly different from one another.

| | | **Mow** | | **Burn** | | **Mow/Burn** | | **Disk** | |
|---|---|---|---|---|---|---|---|---|---|
| **Variable** | ***P*-value** | ***n*** | **Post-hoc** | ***n*** | **Post-hoc** | ***n*** | **Post-hoc** | ***n*** | **Post-hoc** |
| **2011–2013** | | | | | | | | | |
| Capture[a] | 0.023 | 100 | AB | 135 | A | 68 | AB | 13 | B |
| Flush | <0.001 | 117 | AB | 170 | A | 55 | BC | 8 | C |
| Adult | 0.068 | 16 | AB | 38 | A | 25 | AB | 4 | B |
| male | 0.217 | 7 | A | 12 | A | 10 | A | 2 | A |
| female | 0.034 | 9 | AB | 26 | A | 15 | AB | 2 | B |
| Juvenile | 0.027 | 84 | A | 97 | A | 43 | AB | 9 | B |
| male | 0.006 | 49 | A | 38 | AB | 20 | AB | 4 | B |
| female | 0.084 | 35 | AB | 59 | A | 23 | AB | 5 | B |
| All males | 0.009 | 56 | A | 50 | A | 30 | AB | 6 | B |
| All females | 0.039 | 44 | AB | 85 | A | 38 | AB | 7 | B |

[a] All captured woodcock regardless of sex or age.

and by sex and age class. We used a Tukey post-hoc analysis to examine differences in woodcock use among treatment types.

## Results

We captured 316 woodcock (Table 1), 5 of which were recaptures from a previous year or a separate night, and we flushed 350 woodcock. Most captures (*n* = 233) were hatch-year (HY or juvenile) woodock. We captured 142 male woodcock, of which 31 were after-hatch-year. We also captured 174 female woodcock, of which 52 were after-hatch-year.

We captured woodcock more often in the burn treatment (*n* = 135; 42.7% of captures; Table 1) than in the disk treatment (*n* = 13; 4.1% of captures). There were no statistically significant differences in the number of woodcock captured in the mow (*n* = 100; 31.6% of captures) and mow/burn (*n* = 68; 21.5% of captures) treatments compared with the number captured in the other treatments ($F_{7,\ 24}$ = 2.93, *P* = 0.023). We also flushed more woodcock in the burn (*n* = 170; 48.6% of flushes) and mow (*n* = 117; 33.4% of flushes) treatments than in the disk (*n* = 8; 2.3% of flushes) treatment, and the number of woodcock flushed in the burn treatment was greater than the number flushed in the mow/burn (*n* = 55; 15.7% of flushes) treatment ($F_{7,24}$ = 6.68, *P* < 0.001; Table 1). There was a treatment-by-year effect (*P* = 0.0029) for 1 combination of treatments, with significantly more woodcock flushed in the mow treatment in 2012 than in 2013.

The number of adult woodcock we captured did not differ among treatments ($F_{7,24}$ = 2.23, *P* = 0.068; Table 1). We captured more juvenile woodcock in the burn (*n* = 97; 41.6% of captures) and mow (*n* = 84; 36.1% of captures) treatments than in the disk (*n* = 9; 3.9% of captures) treatment. The number of juvenile woodcock captured in the mow/burn (*n* = 43; 18.5% of captures) treatment did not differ from the number captured in the other treatments ($F_{7,24}$ = 2.83, *P* = 0.027). We captured more male woodcock in the mow (*n* = 56; 39.4% of captures) and burn (*n* = 50; 35.2% of captures) treatments than in the disk (*n* = 6; 4.2% of captures) treatment, whereas the number of woodcock we captured in the mow/burn (*n* = 30; 21.1% of captures) treatment did not differ from the number captured in the other treatments ($F_{7,24}$ = 3.60, *P* = 0.009). We captured more female woodcock in the burn treatment (*n* = 85; 48.9% of captures) than the disk treatment (*n* =7; 4.0% of captures). The number of female woodcock we captured in the mow (*n* = 44; 25.3% of captures) and mow/burn (*n* = 38; 21.8% of captures) treatments did not differ from the number we captured in the burn or disk treatments ($F_{7,24}$ = 2.59, *P* = 0.039). The number of adult male woodcock we captured did not differ among treatments (*n* = 31; $F_{7,24}$ = 1.49, *P* = 0.217). We captured adult female woodcock more often in the burn (*n* = 26; 50.0% of captures) than in the disk (*n* = 2; 3.4% of captures) treatment. The number of adult female woodcock we captured in the mow (*n* = 9; 17.3% of captures) and mow/burn (*n* = 15; 28.8% of captures) treatments did not differ from the number we captured in the burn or disk treatments ($F_{7,24}$ = 2.66, *P* = 0.034). We captured juvenile male woodcock more often in the mow (*n* = 49; 44.1% of captures) than in the disk (*n* = 4; 3.6% of captures) treatment. The number of juvenile male woodcock we captured in the burn (*n* = 38; 34.2% of all captures) and mow/burn (*n* = 20; 18.0% of all captures) did not differ from the number we captured in the mow and disk treatments ($F_{7,24}$ = 3.82, *P* = 0.006). The number of juvenile female woodcock we captured did not differ among treatments ($F_{7,24}$ = 2.09, *P* = 0.084).

The burn treatment was characterized by tall (3.8 m) woody vegetation and dead clump grasses with patches of bare soil (53%). The mow treatment likewise had vertical structure that consisted of dead clump grasses and patches of bare soil (15%). The mow/burn treatment had considerably more bare soil (42%) than did the mow treatment, but lacked vertical structure. Likewise, the disk treatment was characterized by bare soil (58%) with little vertical structure (Figs. 2 & 3).

## Discussion

Our results suggest that both burn and mow treatments are suitable for enhancing nocturnal woodcock habitat in south-central Louisiana. We found that woodcock avoided treatments with little structural cover (i.e., disk and mow/burn treatments) and favored treatments with vertical cover and patches of bare soil (i.e., burn and mow treatments). Although the mow treatment only consisted of 15% bare soil, apparently this was sufficient for foraging; probe holes were commonly found within this treatment. Berdeen and Krementz (1998) reported that woodcock in the Georgia Piedmont used fields with bare soil and high foliar volume in the 0.8–2.0-m stratum. In contrast, Glenn et al. (2004) found woodcock in eastern Texas used nocturnal sites with bare soil and overhead cover in the 0.26–0.75-m stratum. Both our burn and mow treatments provided patches of bare soil and overhead cover. Although mow treatments did not provide foliar volume above 0.5 m, woody debris both standing and on the ground and dead clump grasses likely provided adequate vertical cover while also allowing feeding. Studies in Virginia (Krementz et al. 1995), North Carolina (Stribling and Doerr 1985, Blackman et al. 2013), and Arkansas (Krementz et al. 2014) have reported woodcock use of agricultural fields with ridge/furrow topography and residual vegetation that likely provides a better vertical cover component than did our disk treatment.

Vegetative structure in the burn plots was noticeably different than vegetative structure in the mow plots, with greater woody vegetation height and more bare soil in the burn than mow plots. As did Glenn et al. (2004) and Berdeen and Krementz (1998), we found woodcock also used treatments with taller woody vegetation. Woodcock selection of nocturnal sites may be dependent on earthworm abundance (Dyer and Hamilton 1974, Blackman et al. 2012), microclimate (Stribling and Doerr 1985, Blackman et al. 2012), protection from predators (Berdeen and Krementz 1998, Glenn et al. 2004), or some combination of these factors. Although we did not measure earthworm abundance, we think it is unlikely that earthworm abundance differed among treatments, at least for the burn, mow, and mow/burn treatments. Treatments were all created in the same 25.9-ha study area and with the exception of the disk treatment there was little if any soil disturbance when treatments were applied. The major difference among treatments was the amount and structure of cover available. Woodcock at our study site may be selecting habitats based on thermal cover and protective cover from predators. Although burn, mow, and mow/burn treatments typically did not differ significantly in terms of number of woodcock captured, there was a general trend for a greater percentage of woodcock captures in both the burn (range: 34.2%–48.9%) and mow plots (range: 17.3%–44.1%) than the mow/burn (range: 15.7%–32.25) plots. This could be because the mow/burn plots tended to have less vegetative cover than either the mow or burn plots.

Our study site consisted a 25.9-ha fallow field with replications of 4 treatments within this fallow field. Future studies should consider replicating treatments at sites that are geographically separated to avoid possible confounding results due to pseudoreplication.

## Management Implications

Both mow and burn treatments were used more frequently by woodcock than mow/burn and disc treatments. The combination of vertical structure and bare ground likely provides protection from predators while still allowing woodcock to forage. However, annual application of either treatment will likely result in loss of important vertical cover. Repeated annual mowing typically results a reduction of woody cover and increased grass cover (Harper 2007), likely increasing woodcock exposure to predators and reducing foraging opportunities. If mow treatments are implemented, implementation should be on a ≥2-year rotation with deck height set ≥40cm. Whereas both mow and burn treatments can offer high-quality woodcock habitat, sustainable habitat will most likely be achieved using both mow and burn treatments on a rotational basis. For example, a field can be mowed one fall, allowed to remain fallow the next fall, and then burned the third fall. This rotation should reduce the intrusion of grasses while maintaining woody cover. Management suggestions discussed here should be coupled with those of Krementz (2000), ensuring nocturnal habitat is created within 700 m of suitable diurnal habitats.

**Figure 2.** Percent cover of dead grass, soil, and standing woody vegetation at woodcock nocturnal habitat treatments at Sherburne Wildlife Management Area, Pointe Coupee Parish, Louisiana, USA. *Post-hoc* analysis was performed using the Tukey HSD test with $\alpha = 0.05$, and variables with the same letter (Post-hoc) are not statistically significantly different from one another.

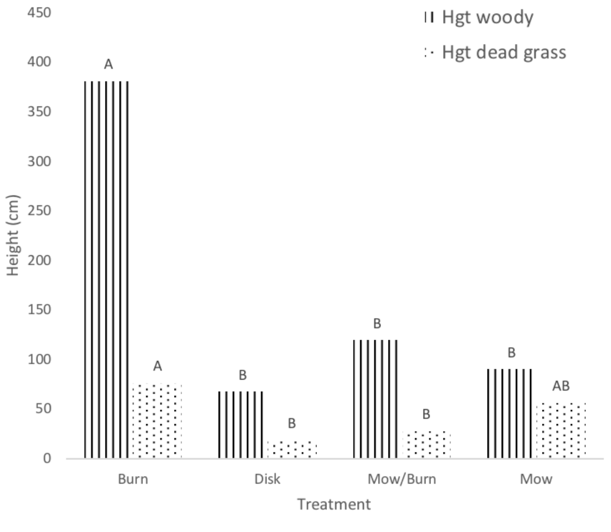

**Figure 3.** Height (cm) of standing woody vegetation and dead grass at woodcock nocturnal habitat treatments at Sherburne Wildlife Management Area, Pointe Coupee Parish, Louisiana, USA. *Post-hoc* analysis was performed using the Tukey HSD test with $\alpha = 0.05$, and variables with the same letter (Post-hoc) are not statistically significantly different from one another.

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# Migration Timing, Routes, and Connectivity of Eurasian Woodcock Wintering in Britain and Ireland

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**ABSTRACT** Migration represents a critical time in the annual cycle of Eurasian woodcock (*Scolopax rusticola*), with potential consequences for individual fitness and survival. In October–December, Eurasian woodcock migrate from breeding grounds in northern Eurasia over thousands of kilometres to western Europe, returning in March–May. The species is widely hunted in Europe, with 2.3–3.5 million individuals shot per year; hence, an understanding of the timing of migration and routes taken is an essential part of developing sustainable flyway management. Our aims were to determine the timing and migration routes of Eurasian woodcock wintering in Britain and Ireland, and to assess the degree of connectivity between breeding and wintering sites. We present data from 52 Eurasian woodcock fitted with satellite tags in late winter 2012–2016, which indicate that the timing of spring departure varied annually and was positively correlated with temperature, with a mean departure date of 26 March (± 1.4 days SE). Spring migration distances averaged 2,851 ± 165 km (SE), with individuals typically making 5 stopovers. The majority of our sample of tagged Eurasian woodcock migrated to breeding sites in northwestern Russia (54%), with smaller proportions breeding in Denmark, Scandinavia, and Finland (29%); Poland, Latvia, and Belarus (9.5%); and central Russia (7.5%). The accumulated migration routes of tagged individuals suggest a main flyway for Eurasian woodcock wintering in Britain and Ireland through Belgium, the Netherlands, and Germany, and then dividing to pass through the countries immediately north and south of the Baltic Sea. We found a weak positive relationship between breeding site longitude and wintering site latitude, suggesting broadly parallel migration routes from distinct breeding areas but some mixing of individuals from different breeding areas at the same wintering site.

***Proceedings of the American Woodcock Symposium 11: 136–145***

**KEY WORDS:** Argos PTT, banding, Europe, flyway, hunting, population management, satellite telemetry, site fidelity, spring temperature, stopover

An understanding of annual migrations is important for the conservation of many birds, especially for species that are hunted. There is increasing evidence that habitat quality and environmental conditions at wintering and breeding sites used by migratory species may profoundly influence the fitness and survival of individuals (Marra et al. 1998, Webster et al. 2002, Møller and Hobson 2003, Norris et al. 2003). For migratory birds that overwinter thousands of kilometers from their summer breeding grounds, any deterioration in quality or loss of suitable stopover sites and wintering areas is of conservation concern. For hunted species, such as the Eurasian woodcock (*Scolopax rusticola*), the cumulative level of harvest along the migratory route also affects survival rate and population viability. Evaluating the importance of pressures at stopover sites or wintering areas at the population scale requires detailed knowledge of migratory routes and linkages between breeding and wintering sites.

The European population of the Eurasian woodcock is estimated at 13.8–17.4 million birds, approximately 96% of which breed in Scandinavia, Finland, the Baltic states, and Russia (Birdlife International 2015). In winter (December–mid-March), the population is concentrated principally in Britain, Ireland, France, the Iberian Peninsula,

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Italy, and Greece, with migrants starting to arrive from late September to mid-October (Gonçalves and Rodrigues 2017). The Eurasian woodcock is a prized quarry species in all of these countries in winter. It is also hunted in most central European countries during fall migration, and in Russia, Belarus, Romania, and Austria when males are roding (performing their courtship flights; Ferrand and Gossmann 2009a). Because of this widespread hunting, an understanding of migration routes, stopover sites, and timing is of conservation relevance for the species. Such knowledge is also important in evaluating the effects of changes in habitat and climate at stopover sites and wintering areas. To better inform management and hunting policies across Europe, reliable information is currently needed on the status of Eurasian woodcock in different countries and details of their migrations. Based on available information, which is of variable quality among countries, the European population of the Eurasian woodcock appears to be stable (Ferrand and Gossmann 2009a, Fokin and Blokhin 2013, Lindström et al. 2015), but the numbers breeding in Britain and Switzerland are believed to be declining (Estoppey 2001, Mulhauser 2001, Heward et al. 2015). There is some evidence from France and Spain that high shooting pressure is depressing adult survival in certain wintering regions (Tavecchia et al. 2002, Péron et al. 2011, Péron et al. 2012, Guzmán et al. 2017).

Until the last decade, knowledge of the movements of Eurasian woodcock has been based solely on recoveries of banded individuals. Band recoveries have been used to estimate the main breeding areas of Eurasian woodcock wintering in Britain, France, and Spain (Hoodless and Coulson 1994, Wernham et al. 2002, Bauthian et al. 2007, Guzmán et al. 2011). However, because the majority of recoveries are through hunting (e.g., 94% of all recoveries of known cause of Eurasian woodcock banded or recovered in Britain [Wernham et al. 2002]), analyses are subject to regional biases in recovery probability. With the exception of France, analyses have also been based on small numbers of recoveries (<400) accumulated over approximately 100 years. They are subject to temporal biases in banding effort and in recovery probability, resulting from changes in hunting seasons. Recent studies employing stable hydrogen isotope analysis of feathers have provided a contemporary insight into the breeding origins of Eurasian woodcock wintering in Britain, France, and Spain at a meta-population scale, but they have still relied on band recoveries as priors in Bayesian assignment of isotope-ratio values (Van Wilgenburg and Hobson 2011; Hobson et al. 2013a,b; Hoodless et al. 2013).

Details of connections between particular breeding, stopover, and wintering sites and accurate timing of movements are still lacking for Eurasian woodcock and have proved extremely difficult to establish for most migratory birds on the basis of band recoveries. However, recent advances in tracking technologies and, in particular, the miniaturization of devices have enabled a rapid expansion in understanding of various aspects of bird migration. Geolocators, which log time-stamped daylight levels at regular intervals and enable crude determination of latitude and longitude at midday and midnight from sunrise and sunset times (Hill 1994), have been used to document complete migratory tracks for many bird species over long distances, including waders (e.g., Stutchbury et al. 2009, Egevang et al. 2010, Niles et al. 2010, Klaassen et al. 2011). For Eurasian woodcock, geolocators provide valuable data on the timing of migratory movements but are not sufficiently accurate for determining stopover locations (Hoodless et al. 2013). GPS tags have been increasingly deployed on larger birds in the last 5 years, yielding very accurate movement data (Guilford et al. 2008, Bouten et al. 2013), but until very recently have been too large and costly for deployment on Eurasian woodcock.

Satellite telemetry provides reasonably accurate locations and permits the tracking of animals in near real-time. A solar-powered 9.5-g PTT, suitable for use on birds ≥317 g based on the 3% of body mass rule, has been available since 2006, and 5.0-g and 3.0-g PTTs are now available. These have yielded crucial information on the

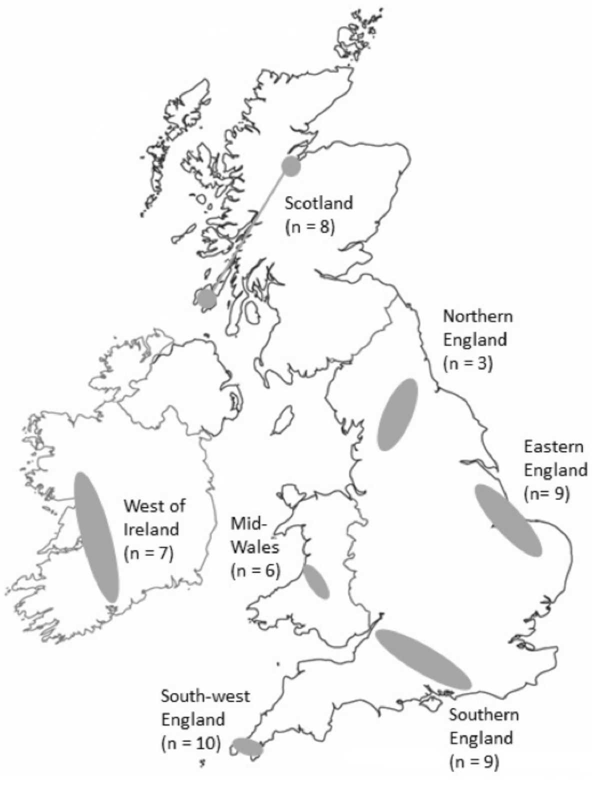

**Figure 1.** Regions where Eurasian woodcock were fitted with satellite tags, with sample sizes during 2012–2016.

relationship between migration route and survival rate for declining species (e.g., Hewson et al. 2016). Tracking studies of Eurasian woodcock using satellite telemetry are currently underway in Britain, France, Spain, and Italy. Results from individuals tagged in late winter in northern Spain indicate a mean spring departure date of 20 March and breeding locations mainly in European Russia, along with the unexpected discovery of a breeding site in central Russia (Arizaga et al. 2014).

Our objectives were to determine migration timing, principal migration routes, and degree of connectivity between breeding and wintering grounds of Eurasian woodcock using wintering sites in Britain and Ireland. We discuss our findings in the context of working towards better flyway-level management of Eurasian woodcock in Europe.

## Study Area

We worked in 7 geographically distinct regions in England (*n* = 4), Wales (*n* = 1), Scotland (*n* = 1), and Ireland (*n* = 1) to improve the likelihood of obtaining data representative of the range of migration routes used by Eurasian woodcock visiting Britain and Ireland (Fig. 1). We captured individuals at upland (>300 m asl, northern England, Mid-Wales, Scotland) and lowland sites. Most of our study sites comprised grazed pastures and deciduous woodland, but in southern England there was a mixture of crop fields and pastures, and in eastern England mainly crop fields.

## Methods

### SATELLITE TRACKING

During late February – early March 2012–2016, we fitted 60 Eurasian woodcock with Argos satellite tags (9.5-g solar PTT, Microwave Telemetry, Inc., Columbia, MD). We captured individuals mainly on fields at night with a spot-lamp (30 W) and a landing net with a 3-m handle or during the day by walking through suitable patches of habitat to flush individuals into mist-nets across woodland rides. We aged Eurasian woodcock as first-year birds (<1 year old) or adults (>1 year old) on the basis of plumage (Ferrand and Gossmann 2009b). We mounted tags on the lower back using a Rappole-Tipton (1991) style leg-loop harness made from 1.6-mm diameter, UV-resistant, marine-grade rubber cord (EPDM cord, Polymax Ltd, UK) passed through biomedical silicone tubing (Silastic tubing, Cole Parmer, UK). The mean mass of individuals at tagging was 338 ± 3 g, such that the tag and harness (combined mass 11.1 g) represented 3.29 ± 0.03% of body mass. The fitting of satellite tags was licensed by the British Trust for Ornithology's Special Methods Technical Panel and approved by the Game and Wildlife Conservation Trust's Animal Welfare and Ethical Review Body.

The tag schedule alternated between a 10-hour 'on' period, during which the tag transmitted messages to Argos satellites, and a 48-hour 'off' period devoted to recharging the battery via the solar panel. We obtained PTT locations via the Argos system (Argos 2016), and all data were Kalman filtered before downloading (Lopez and Malardé 2011). The accuracy of position fixes delivered by satellite tags varied according to the number of satellite passes on which a tag was detected. Three or 4 passes resulted in accuracy of 150 m–1.5 km (location classes 0–3), but fewer passes provided position estimates of unknown accuracy (location classes A and B). Our evaluation of datasets containing fixes of variable accuracy indicated that class A locations were often of comparable accuracy to class 1 locations (Hays et al. 2001). For Eurasian woodcock, class A and B locations have been estimated to be accurate to within 6 km and 10 km, respectively (www.euskonews.com/0484zbk/gaia48404en.html). To make best use of our data, we initially included location classes 0–3, A, and B and plotted all locations on Google Earth (Google LLC, Mountain View, CA) to help identify and remove spurious locations. These were typically the first transmissions after the PTT had not transmitted for a period of more than a month, and mirror locations sometimes occurred after an individual had moved a long distance from its previous location.

### MIGRATION PARAMETERS

We determined migration timing and stopover attributes using all transmissions for each individual until transmissions stopped. We classified all data rows according to the distance moved between consecutive locations, conservatively assuming no migration if the distance moved was ≤50 km but a migration flight if locations were >50 km apart (Britten et al. 1999, Hewson et al. 2016). We defined stopovers as periods when locations from ≥2 consecutive transmission periods fell within 50 km of each other. The minimum duration of stopovers we considered was 2 days. We estimated time of departure from the wintering site as the mid-point between the last location at the wintering site and the first location ≥50 km away. Similarly, we assumed time of arrival at the breeding site to be the mid-point between the last transmission at the final stopover location and the first transmission at the breeding site (always the maximum longitude and/or latitude reached before 1 June). Because locations were not received for every transmission cycle, we restricted departure and arrival time estimates to cases where the relevant consecutive transmissions occurred within 10 days. We defined duration of migration as the time between the estimated dates of spring departure from the wintering site and arrival at the breeding site. We processed data in the same way for fall migrations, with the exception that we calculated estimates of arrival time in Britain where relevant consecutive transmissions occurred within a 14-day period.

We calculated stopover locations as the median latitude and longitude of all locations within each period when individuals were considered not to be migrating. We calculated flight stage distances as the great-circle distance between stopover locations and migration distance as the sum of all stage distances. Migration speed was the total migration distance divided by the duration. We calculated flight speed according to the time and distance between consecutive locations where the distance moved exceeded 50 km and the time elapsed was at least 30 minutes. We used the mean values per stage flight per individual.

Calculation of the number of stopovers was complicated by the fact that sometimes, particularly in the second or subsequent springs when tag batteries had been depleted in winter, we received the first location for a month or more when an individual had commenced spring migration and had possibly already made >1 stage flight. In these cases, we estimated the number of stopovers as the number of known stopover locations plus 1, or occasionally 2, inferred stopovers based on information about the timing and speed of flights. Examination of data received during Argos transmission windows that spanned dawn and dusk indicated that migration flights were typically made at night, which in western Europe in late March — early April lasts 10–11 hours. Flight speed rarely exceeded 100 km/h; where a stage distance exceeded 1,000 km, we thus added a stopover to the count and excluded the stage distance from the calculation of the mean. In fall, we used 1,200 km as the cutoff for the maximum stage flight distance.

## Data Analysis

We based analyses of migration timing on Julian date and included data for all individuals in all years, including identity of each individual as a random factor to control for individual effects. We based other analyses and summary statistics on mean values per individual for those tracked in >1 year. We calculated statistics in Genstat v18.1. We present all mean values with standard deviations except where otherwise indicated.

We analysed variation in onset of spring migration using a generalized linear mixed model (GLMM) with departure date as the dependent variable, individual age and year as factors, latitude and longitude of the winter and breeding sites as covariates, and identity of an individual as a random factor. We specified a normal error term and an identity link function, and included the interactions age × year, winter site latitude × longitude, and breeding site latitude × longitude. We then examined the influence of temperature on departure date with a GLMM, with departure date as the dependent variable, individual age as a factor, and mean March temperature as a covariate, including the interaction temperature × individual age. We specified the random effect as region/individual identity/year because each region had >1 tagged individual, and years were repeated measures for some individuals. We obtained annual mean March temperature values for all regions where we tagged Eurasian woodcock from the Met Office (www.metoffice.gov.uk/climate/uk/summaries/2013/march/regional-values) and MET éireann (http://archive.met.ie/climate-request/).

We examined duration of spring migration with a GLMM using normal errors and an identity link function. We specified individual age and year as factors, and included departure date and migration distance as covariates, and identity of individuals as a random factor. Owing to smaller sample sizes in fall, we restricted comparisons of total migration distance, number of stopovers, and flight stage distance between spring and fall to individuals tracked in both seasons within the same year and conducted paired *t*-tests.

We examined connectivity between breeding and wintering sites with linear regression of latitudes and longitudes, using the coordinates for each individual once, in the first year that they were tracked. We crudely compared similarity of fall to spring migration routes by measuring the perpendicular distance, in Google Earth, from fall stopover locations to the spring track ≤3 points for each individual where complete or partial fall tracks were obtained. We averaged values per individual before calculating an overall mean.

## Results

Seven tags did not deliver useful data because 4 individuals were resident breeders in Britain and 3 individuals were presumed predated prior to migration. We lost contact with 1 individual during its first spring migration, leaving 52 individuals that completed ≥1 spring migration and 18 individuals for which we tracked multiple migrations.

### TIMING OF MIGRATION

Peak spring departure of Eurasian woodcock from Britain and Ireland was during the third week of March, but departure times spanned a 5-week window from 3 March to 13 April (Table 1). Spring departure date varied among years and differed between age classes (GLMM year $F_{4,34.0} = 17.36$, $P < 0.001$, bird age $F_{1,43.9} = 4.24$, $P = 0.046$), with winter and breeding site latitude and longitude, and model interactions, having no significant effects. The onset of migration was appreciably later in spring 2013, when mean temperature in Britain in March was 3.3°C below the 1981–2010 average (mean departure dates 21 March 2012, 9 April 2013, 22 March 2014, 24 March 2015, 26 March 2016). Adult Eurasian woodcock departed, on average, 4.5 ± 2.2 days (± SE) before first-year individuals. Departure date was correlated with mean March temperature, explaining the variation among years (GLMM March temperature $F_{1,45.2} = 56.79$, $P < 0.001$, individual age $F_{1,48.8} = 6.12$, $P = 0.017$, March temperature × individual age $F_{1,43.4} = 0.57$, $P = 0.456$). Eurasian woodcock commenced migration 3.9 ± 0.5 days (± SE) earlier for every 1°C increase in March temperature.

Eurasian woodcock migration in spring consisted of a series of flights averaging 413 ± 248 km, with individuals typically making 5 stopovers before reaching their breeding sites. Spring migration was completed in an average of 6 nocturnal flights, with mean flight speed estimated at 70 ± 39 km/h. Peak arrival at breeding sites was in mid-April, with individuals taking an average of 23 days to complete migration (Table 1). Duration of spring migration was negatively related to departure date and positively related to total migration distance, such that migrations were reduced by 0.60 ± 0.13 day (± SE) for every day that departure was delayed and increased by 0.69 ± 0.13 day (± SE) for every extra 100 km travelled (GLMM departure date $F_{1,37.4} = 21.70$, $P < 0.001$, migration distance $F_{1,39.6} = 30.25$, $P < 0.001$, individual age and year effects not significant).

Our data on fall migrations were relatively sparse, but indicated that Eurasian woodcock typically left their breeding sites around 10 October and arrived in Britain or Ireland on 10 November (Table 1). Total migration distance was 182 ± 328 km shorter in fall than in spring (paired *t*-test $t_{20} = -2.55$, $P = 0.019$). On average, Eurasian woodcock made 2 fewer stopovers on fall migration than in spring (paired *t*-test $t_{13} = -4.09$, $P = 0.001$), and mean flight stage distance was 114 ± 317 km greater in fall than in spring, although the difference was not statistically significant (paired *t*-test $t_{26} = 1.87$, $P = 0.073$). Sample sizes in fall were too small for comparison of the duration of spring and fall migrations.

### BREEDING LOCATIONS AND MIGRATORY CONNECTIVITY

Eurasian woodcock tagged in Britain and Ireland migrated to breeding sites in 8 countries: Denmark (*n* = 1, 1.9%), Norway (*n* = 4, 7.7%), Sweden (*n* = 7, 13.5%), Finland (*n* = 3, 5.8%), Poland (*n* = 1, 1.9%), Latvia (*n* = 3, 5.8%), Belarus (*n* = 1, 1.9%), and Russia (*n* = 32, 61.6%). Of those breeding in Russia, 28 settled in northwestern Russia, 1 in Sverdlovsk province, just east of the Ural Mountains (57°26'N, 59°51'E), and 3 used sites in Krasnoyarsk province, central Russia (mean 59°28'N, 91°52'E). Three of the individuals breeding in Norway were tagged in Scotland, with the fourth tagged in Ireland. The 3 that migrated to central Russia were tagged in southwestern England (*n* = 2) and eastern England (*n* = 1). Mean migration distance was 2,851 ± 1,168 km, but the 3 individuals breeding in central Russia undertook migrations of 6,274 ± 288 km and arrived on 10 May ± 12.1 days.

We found a weak relationship between breeding site longitude and winter latitude ($r_{52} = -0.314$, $P = 0.023$), which remained significant with the exclusion of the 3 individuals that bred in central Russia ($r_{49} = -0.284$, $P = 0.048$). We found no relationships between breeding site longitude and winter longitude ($r_{52} = 0.060$, $P = 0.673$) nor between breeding site latitude and winter latitude ($r_{52} = 0.004$, $P = 0.975$) or winter longitude ($r_{52} = 0.135$, $P = 0.341$) for individuals wintering in Britain and Ireland. However, individuals tracked in multiple years were largely faithful to the same breeding and wintering sites. Of 43 winter locations, relating to 30 individuals, in winters following the season of tagging, 39 (91%) were the same as the original tagging location. Three individuals changed winter site (1 of them twice). Two individuals were tagged in the relatively cold spring of 2013, and all 3 subsequently used winter sites to the east of where they were tagged. Of 28 breeding locations relating to 18 individuals, 27 (96%) were the same as those used in the first summer. The individual that changed breeding sites flew to northwestern Russia in 2015 and southwestern Sweden in 2016.

### MIGRATION ROUTES

With the exception of individuals breeding in Norway, most minimized the distance flown across the North Sea on spring migration by passing through France, Belgium, or the Netherlands, and then Germany, before crossing

**Table 1.** Timing, duration, and distance of spring and fall migrations of Eurasian woodcock tracked by satellite telemetry in western Europe during 2012—2016.

| | Spring migration | | | Fall migration | | |
|---|---|---|---|---|---|---|
| **Parameter** | ***n*** | **Mean ± SD** | **Range** | ***n*** | **Mean ± SD** | **Range** |
| Onset of migration | 52 | 26 Mar ± 10.3 d | 3 Mar–13 Apr | 13 | 10 Oct ± 32.3 d | 13 Jul–18 Nov |
| Arrival at breeding/winter site | 65 | 19 Apr ± 13.7 d | 21 Mar–25 May | 4 | 10 Nov ± 10.6 d | 3–23 Nov |
| Duration of migration (days) | 46 | 23.3 ± 13.2 | 3–50 | 4 | 19.5 ± 7.4 | 10–27 |
| Total migration distance (km) | 50 | 2,851 ± 1,168 | 988-6,605 | 18 | 3,018 ± 1360 | 1,287–6,365 |
| Number of stopovers | 73 | 4.7 ± 2.7 | 0–14 | 14 | 3.4 ± 2.1 | 1–9 |
| Flight stage distance (km) | 337 | 413 ± 248 | 53–992 | 55 | 515 ± 306 | 84–1,109 |

Denmark and north of the Baltic Sea to reach Sweden or Finland or heading south of the Baltic Sea to reach Finland, Belarus, or northwestern Russia (Fig. 2). Consequently, Germany, Poland, Lithuania, Latvia, and Belarus constitute an important spring migration corridor supporting a large proportion of the stopovers by migrant Eurasian woodcock wintering in Britain and Ireland (Fig. 3). Migration routes of individuals tracked in fall were largely similar to those taken in spring, with a mean divergence between routes of 124 ± 59 km.

## Discussion

Timing of migration in many species of birds has been shown to be dependent on weather, especially temperature (Sokolov 2001, Marra et al. 2005). It is not surprising that the timing of spring migration in Eurasian woodcock varied annually and was related to March temperature, given the species' dependence on soil invertebrates, particularly earthworms, and the influence of temperature on the accessibility of this food. Birds that undertake migration as a series of long flights, and typically most waders, need to store sufficient energy as fat before departure. Rates of food intake and energy storage in Eurasian woodcock are poorly understood, but when conditions are relatively cool in spring, it is likely to take individuals longer to attain their minimum departure mass, owing to increased thermoregulatory demand and reduced accessibility of food. By departing too soon, Eurasian woodcock also risk encountering frozen ground, or at least difficult feeding conditions, on the migration route when they have already exhausted a large proportion of their energy reserves, the consequences of which have been documented in other species (Whitmore et al. 1977, Marcström and Mascher 1979, Tryjanowski et al. 2004).

The fact that adult Eurasian woodcock set off on spring migration earlier than first-year individuals might be related to adults being better able to judge the appropriate time, based on experience. The earlier departure gives adults the advantage of reaching the breeding grounds first and potentially occupying the best habitat or, in the case of males, mating with a female before first-year males arrive. There is good evidence within migratory passerines that the males that arrive earliest on the breeding grounds typically occupy the best territories and have the highest reproductive success (Aebischer et al. 1996, Lozano et al. 1996, Kokko 1999, Currie et al. 2000). Competition for early arrival tends to be most intense in species with polygynous mating systems (Hasselquist 1998). Our data indicate that Eurasian woodcock have the capacity to partially compensate for a late spring departure by reducing the overall duration of their migrations, suggesting that in typical years they do not fully exhaust their energy reserves before each stopover.

The Argos PTTs yielded relatively poor data on fall migration, owing to reduced efficiency of solar charging between August and March. The complete datasets obtained for fall migrations suggest that migration is completed more quickly in fall than in spring, which is plausible if individuals wait on the breeding grounds until the onset of freezing weather and then need to keep moving ahead of it. However, a larger dataset is required to confirm that this is the case. Archival GPS loggers could provide more reliable data on fall migration, as current small models are capable of collecting accurate data for up to a year without the need for solar charging. GPS-GSM tags are also likely to be small enough for deployment on Eurasian woodcock within the next 1–2 years.

Our sample of tracked Eurasian woodcock indicates that northwestern Russia is a key breeding area for individuals wintering in the British Isles, with a major flyway for these individuals running through the countries immediately south of the Baltic Sea to Finland and northwestern Russia, along with a route through Denmark and southern Sweden up into Sweden and across to Finland. More accurately quantifying the relative contributions of these breeding areas to the British and Irish wintering Eurasian woodcock population, and the relative importance of the different flyways, will require further information. Specifically, data are needed on mid-winter densities of Eurasian woodcock in the regions where individuals were tagged, the number of individuals tagged at each location needs to be taken into account, and, ideally, a larger sample of individuals should be tracked to confirm the findings to date

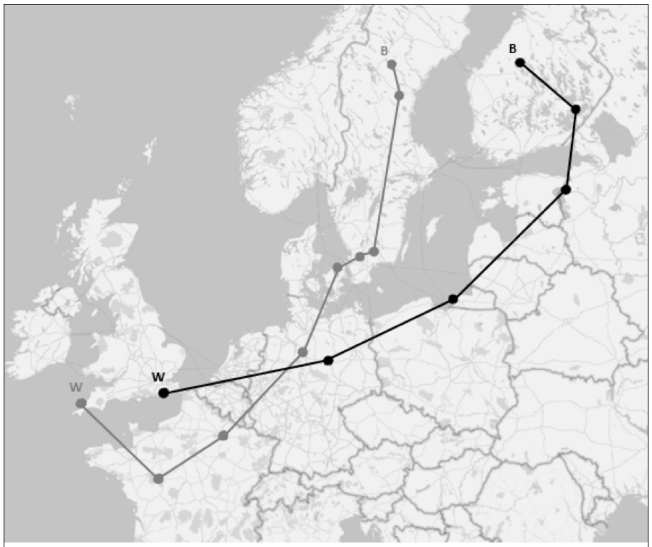

**Figure 2.** Examples of spring migration journeys by Eurasian woodcock from winter sites (W) in southern England to breeding sites (B) in central Sweden and southern Finland, illustrating the avoidance of long sea crossings. Dots indicate stopover locations.

and fill gaps for migration routes that we may not have detected with our small sample of tagged individuals.

Eurasian woodcock breeding in Norway flew directly across the North Sea. This is the shortest route, but it can be more perilous than migrating over land. Fishermen have reported hundreds of Eurasian woodcock drowned in the North Sea following storms, and they have been recorded settling on oil rigs (McKelvie 1990:94, m.facebook.com/story.php?story_fbid=2151841638159652&id=177523075591528). One of the individuals we tagged in Scotland and which spent the summer in Norway was caught in a storm on its fall migration in October 2012, turned back, and failed to make it to the Norwegian coast. Our data indicated that the majority of Eurasian woodcock breeding in other countries followed routes that largely avoided sea crossings.

The 3 individuals that travelled to breeding sites in central Russia flew approximately twice as far east as the furthest banded Eurasian woodcock recovered in Russia. One of 12 individuals fitted with satellite tags in Spain during 2006–2013 and completing journeys to their breeding sites travelled to a very similar area (Arizaga et al. 2014), as did one of 24 birds tagged in France in 2015–2016 (www.becassesmigration.fr/). This was previously unrecognized as a breeding area for Eurasian woodcock wintering in western Europe and, owing to the low density of human habitation, is unlikely to have ever been detected through band recoveries.

We found no evidence of high connectivity between particular breeding areas and wintering areas in Eurasian woodcock. The weak correlation between breeding longitude and winter latitude indicates broadly parallel directions of departure from the breeding grounds but considerable mixing of individuals from quite separate breeding sites at the same wintering site. This pattern could be better confirmed by pooling data from Eurasian woodcock tagged at winter sites in several countries and re-examining the relationship. Eurasian woodcock tagged in Spain typically bred further east than the individuals tagged in our study: of 12 that reached breeding sites, 1 settled in Finland, 3 in northwestern Russia, 6 were between Moscow and the Ural Mountains, 1 was near the Ukraine-Russia border, and 1 was in central Russia (Arizaga et al. 2014). It seems likely that first-winter Eurasian woodcock leave the breeding grounds in a roughly southwesterly direction in their first fall, and that the site at which they end up spending the winter is to some extent determined by the weather encountered during their first migration. In subsequent years, having found a suitable site at which they were able to survive the winter, they then appear faithful to the same wintering site, unless displaced by spells of cold weather, as suggested by Wilson (1983). High winter-site fidelity has been documented in most of the species within the family Scolopacidae in which it has been examined (Smith et al. 1992, Burton and Evans 1997, Burton 2000, Lourenço et al. 2016).

Satellite tags have now been deployed in 4 distinct wintering areas for Eurasian woodcock in Europe, and have significantly advanced our understanding of the species' spring migration strategy, migration routes, and breeding areas. The smaller models, however, as deployed on Eurasian woodcock, rely on solar charging of the battery and

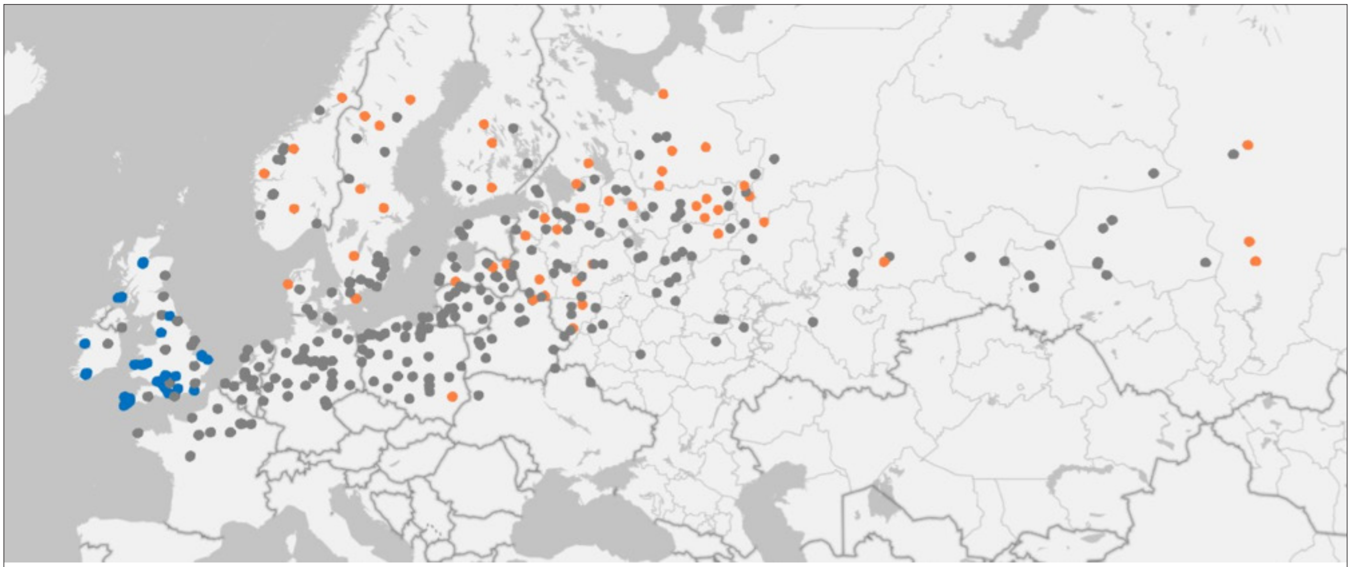

**Figure 3.** Map showing winter (blue), stopover (gray), and breeding (orange) sites of all tracked European woodcock that completed a spring migration. For individuals tracked in >1 year, only the locations during the first spring in which that individual was tracked are shown.

only transmit for 10 hours in every 58 hours to conserve power. This inevitably means that some information concerning an individual's trajectory and timing of movements is missed. This is compounded by the fact that the tags do not always charge sufficiently to transmit during every duty cycle, especially in fall and winter, which means that satellite tags provide incomplete data. Further work using GPS tags, delivering more accurate and frequent locations, seems to be the way forward to complete our understanding of Eurasian woodcock flyways and fall migrations. Ideally, this should involve collaboration between researchers in different parts of the European wintering range, along with the tagging of individuals on breeding grounds.

## Management Implications

Our study provides some of the first data for informing hunting policies on Eurasian woodcock and identifies potential issues for which further data collection would be valuable. Accurate arrival dates in Britain were obtained only for a very small number of individuals, but all were in November. This has implications for hunting management, as the European woodcock shooting season in Scotland opens on 1 September and in England, Wales, and Ireland on 1 October. The majority of Eurasian woodcock shot before November are, therefore, highly likely to be resident breeders. There is currently concern about a long-term decline in the British breeding Eurasian woodcock population (Heward et al. 2015), the reasons for which are currently unclear. Hence, hunters could reduce shooting mortality on this population by refraining from shooting Eurasian woodcock before November. The high fidelity of migrant Eurasian woodcock to particular wintering sites is also important: high shooting pressure in localized areas will likely impact adult Eurasian woodcock and break the migratory links with these sites.

Eurasian woodcock hunting is permitted in most European countries with the exception of Slovenia, parts of Switzerland, the Netherlands, and the Flanders region of Belgium (Ferrand and Gossmann 2009a). Along with harvesting in Britain and Ireland, Eurasian woodcock following most migration routes will also be susceptible to shooting at stopover sites during fall. A better understanding of this cumulative pressure along different migration routes is clearly an important step towards ensuring sustainable flyway management. Relative to the annual bag in the UK, estimated at 160,000 (PACEC 2014), bags taken mainly during periods of passage through the Baltic States, Finland, Scandinavia, and Germany between October and December are small (1,300–6,000 per country, Lutz and Jensen 2005). However, our study highlights the importance of northern Germany, Denmark, and southern Sweden as a passage area for Eurasian woodcock travelling between Finland, Sweden, and the British Isles. The Eurasian woodcock season in Denmark runs from 1 October to 31 December, and the annual bag estimate (25,000) is relatively high compared to that of neighbouring countries (Lutz and Jensen 2005). Little information is available concerning European woodcock bags in Poland and Belarus, and more accurate determinations for these countries are desirable. An attempt to quantify the relative impact of hunting on Eurasian woodcock originating from different breeding zones would be valuable, but the fundamental issue is whether the bags, in aggregate, are affecting the number of breeding Eurasian woodcock in Europe. Monitoring data from Scandinavia and Russia suggest that numbers there are currently stable (Fokin and Blokhin 2013, Lindström et al. 2015).

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# Survival Rates and Stopover Persistence of American Woodcock Using Cape May, New Jersey, during Fall Migration

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**ABSTRACT** Cape May, New Jersey is an important stopover area for American woodcock (*Scolopax minor*,; hereafter woodcock) during fall migration along the Atlantic Coast of the United States. Previous research has indicated that many woodcock stop at Cape May prior to crossing Delaware Bay; however, little is known about survival of woodcock while using Cape May. To better understand woodcock survival on Cape May during fall migration and to estimate emigration rates for woodcock migrating through Cape May, we captured and marked a total of 271 woodcock with VHF transmitters and radio-tracked them weekly from November through early January 2010-–2013. Of the 271 marked woodcock, our radio-tracking efforts indicated that 131 migrated from Cape May, 57 remained on Cape May, 72 died, and 11 were censored. We used a multi-state model within Program MARK to estimate weekly survival and emigration probabilities for marked woodcock. Our best-supported model indicated that survival rate varied by year, but was constant by week within years. Weekly survival rate estimates ranged from 0.894 (95% CI = 0.834 – 0.934) in 2010 to 0.962 (95% CI = 0.928 – 0.981) in 2011, which equates to a 9-week period survival rate ranging from 0.365 (95% CI = 0.185 – 0.545) to 0.706 (95% CI = 0.541 – 0.870), respectively. The 2010–-2011 field season was marked by several large snowstorms during which a large percentage of marked woodcock died, whereas the other 3 years had more mild conditions and higher woodcock survival rates. Our best-supported model indicated that weekly emigration rates varied by year and week, with each year showing a different pattern of emigration from Cape May. Survival and emigration information will be useful in the development of future demographic-based population models for woodcock migrating along the Atlantic Coast.

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**KEY WORDS:** American woodcock, Cape May, emigration, migration, stopover, survival

The Cape May Peninsula in southern New Jersey has long been recognized as important to migrating American woodcock (*Scolopax minor*, ; hereafter woodcock). Cape May forms a natural funnel where woodcock migrating along the East Coast of the U.S. concentrate prior to crossing Delaware Bay during fall migration. During a 5-year study from 1968 to 1972, Krohn et al. (1974) banded over 2,200 woodcock on Cape May in the fall. Band recoveries from their work indicated that woodcock migrating through Cape May wintered on the coastal plain of Virginia and North Carolina and originated from New England and eastern Canada. All recoveries, both direct and indirect, were from within the area defined as the Eastern Woodcock Management Region (Cooper and

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Kelley 2010). Although the work by Krohn et al. (1974) provided information on the importance of Cape May to woodcock, information on how long woodcock stayed in Cape May or their survival there is unknown.

To date, most published estimates of period-specific woodcock survival rates, using radio telemetry techniques, have focused on estimating survival rates during the breeding season (e.g., Longcore et al. 1996, 2000; McAuley et al. 2010; Derleth and Sepik 1990) or during the winter (Krementz and Berdeen 1997, Krementz et al. 1994, Pace 2000). Data are lacking for woodcock survival rates during migration (Longcore et al. 1996, D.J. Case and Associates 2010);, a period when woodcock may have higher mortality risks because they are transient, and at least for first-time migrants, are using new, unfamiliar areas as they migrate. Information about survival rates during migration comes primarily from banding data and telemetry studies (Longcore et al. 1996, 2000), with additional information coming from assessments of the effect of hunting on survival rates coinciding with the start of fall migration in the Northeast (McAuley et al. 2005) and Midwest U.S (Bruggink et al. 2013). Although these studies of hunting effects on survival rates extended partially into the fall migration period, both ended in November and there are no assessments of survival rates later in the fall at important mid-latitude locations such as on the Cape May Peninsula.

Because woodcock populations have experienced long-term declines (Seamans and Rau 2016), managers need to better understand what portion of the woodcock's annual cycle may be limiting populations (D.J. Case and Associates 2010). Determining period survival rates using radio telemetry may help to better understand factors limiting woodcock populations and be useful for deriving population models that include the entirety of the annual cycle for woodcock. As such, the primary objectives of our study were to estimate survival rates for woodcock using Cape May during late fall/early winter and to better understand emigration patterns for woodcock migrating through Cape May, New Jersey.

## Study Area

We conducted our study in Cape May County, New Jersey USA (39.1521°N, -74.8065°W). Cape May County is a peninsula at the southern end of New Jersey separating Delaware Bay from the Atlantic Ocean (Fig. 1). The landscape is a composite of active and abandoned farm fields, woodlands, and suburban and commercial development (Allen 2017). Topography is relatively flat, (average elevation of 14 m above sea level, SD = 11.1 m, max = 60.0 m), with oak (*Quercus* spp.)-pine (*Pinus* spp.) forest on well-drained sites, whereas and poorly drained sites are dominated by maple (*Acer* spp.) and sweetgum (*Liquidamber stryaciflua*) forests. We captured woodcock on properties

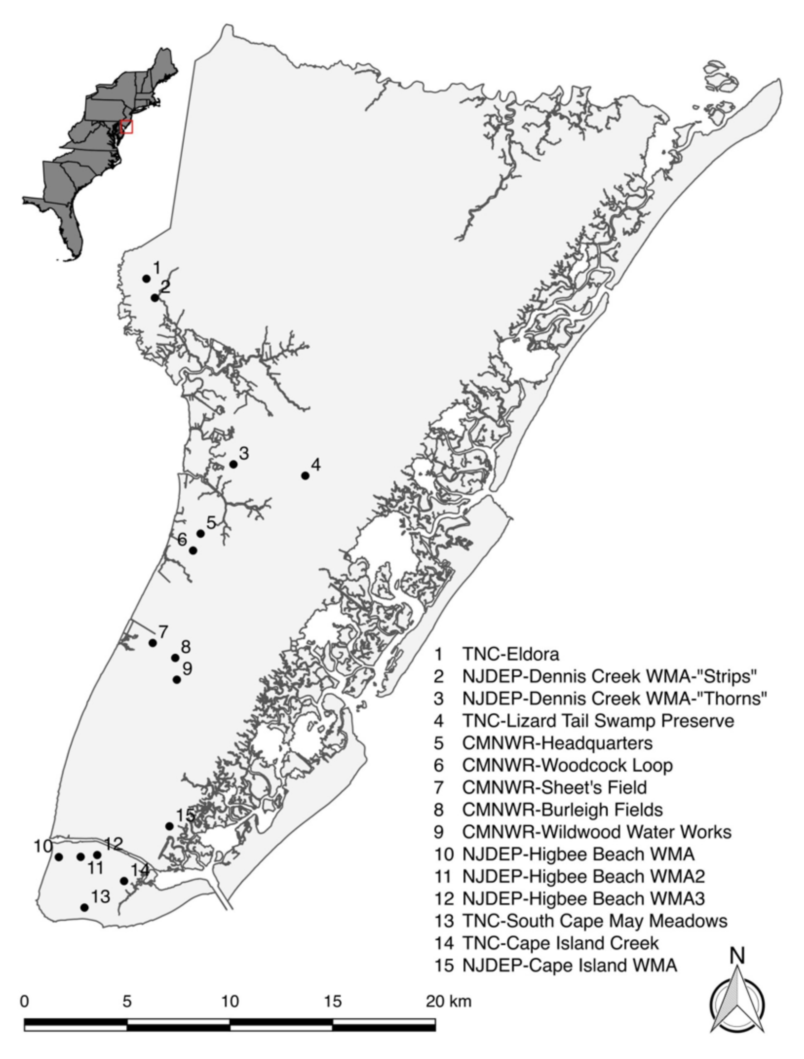

**Figure 1.** Study area and trapping locations (numbered sites) where American woodcock were radio-marked and monitored during migration at Cape May, New Jersey, 2010–2013. TNC = The Nature Conservancy, NJDE*P* = New Jersey Department of Environmental Protection, and CMNWR = Cape May National Wildlife Refuge.

owned and managed by the Cape May National Wildlife Refuge (CMNWR), New Jersey Division of Fish and Wildlife (NJDFW), and the New Jersey Chapter of The Nature Conservancy (TNC) (Fig. 1). State, federal, and municipality lands accounted for most of the land ownership on Cape May (Cape May County records),; but because woodcock also used lands in private ownership, we extended our work onto these lands when radio-tagged woodcock left state, federal, or municipality land holdings.

## Methods

### FIELD METHODS

We captured and radio-marked woodcock at Cape May during the fall and early winter period from 2010 through 2013. We began fieldwork during the last week of October and ended radio tracking marked woodcock from mid-January to early February each year depending on funding and field technician availability. As such, we only used data from a 9-week period (1 November until early January) each year to estimate survival and emigration rates because we had consistent data for this period during all 4 years of our study.

We captured woodcock on fields at night using night-lighting techniques (Rieffenberger and Kletzly 1967) and fitted individuals with a uniquely numbered U. S. Geological Survey leg band and an approximately 4.0-g VHF radio transmitter (Advanced Telemetry Systems, Inc., Isanti, MN) using methods described by McAuley et al. (1993). We aged woodcock as hatch-year (HY) and after hatch-year (AHY), determined sex using wing characteristics (Martin 1964, Mendall and Aldous 1943), and measured mass (± 1 g) and bill length (± 1 mm) for each individual. We used bill length to aid in sex determination (Mendall and Aldous 1943). We radio-marked between 50 and 80 individuals each year, and staggered radio-tag deployment to about 10 woodcock per week to maximize temporal coverage throughout the migration period. We deployed transmitters in this manner to maintain adequate sample sizes and account for the constant turnover of woodcock migrating through our study area. Cape May is best known as a migratory stopover site for woodcock and other birds, but woodcock breed and remain on the peninsula year- round (https:// www.timberdoodle.org). As such, we searched the study area in early March each year to determine if any woodcock in our marked sampled remained on Cape May going into the breeding season. The transmitters we used lasted ≥6 months, so we should have detected radio-marked woodcock if they remained on Cape May in early March.

We used a vehicle with a 6-element Yagi antenna mounted on the roof to search for radio-tagged woodcock daily. We attempted to locate each marked woodcock every 2 days on foot by homing to it without flushing using a three-element Yagi (Advanced Telemetry Systems, Isanti, MN) or H-style antenna (Telonics Inc., Mesa AZ) and handheld receiver. We established a woodcock's status (i.e., alive, dead, or not encountered) during these observations. For woodcock found dead, we determined the cause of death based on a post-mortem examination and classified the cause of death as avian predation (carcass in tree, bill marks on harness, feathers plucked around the carcass), mammalian predation (teeth marks on the harness, most of the carcass eaten), or unknown mortality. We recorded presence/absence of a woodcock in the study area on days that we did not home in on an individual. When we did not detect radio-tagged woodcock, we systematically searched the study area using a vehicle with a mounted antenna and receiver, and we continued monitoring for the presence of those individuals for the duration of the field season. If we did not relocate a marked individual during consecutive 2-day survey periods, we assumed the bird migrated from Cape May. To test this assumption, we conducted 2 aerial reconnaissance flights over Delaware, the Eastern Shore of Maryland, and northern Virginia on 22 December 2011 and 4 January 2012 to search for marked woodcock.

All procedures involving woodcock were approved by the U.S. Geological Survey Patuxent Wildlife Research Center Animal Care and Use Committee.

### STATISTICAL METHODS

We used multi-state live-recapture models in Program MARK (White and Burnham 1999, White et al. 2006) to estimate survival and emigration rates for woodcock using Cape May as a stopover site during fall migration. Multistate models allow estimation of survival (S), live-recapture (p), and transition probabilities ($\psi$) between states. For our analysis, we considered 2 states: within the study area (C for Cape May) and outside the study area (O for outside the study area). Our primary interest was estimating survival rates of woodcock spending time in Cape May (SC) and trends in emigration rates from Cape May ($\psi^{CO}$). Because all woodcock in our study were equipped with radio transmitters, we assumed that detection rates were 1 within the Cape May study area ($p^C = 1$) and that we knew with certainty when birds left the study area (i.e., if a radio signal was not detected, we assumed the individual emigrated from the study area and migrated south; $p^O = 1$ for the first interval a woodcock was not detected). We also assumed that once woodcock emigrated from the study area, they could not return ($\psi^{OC} = 0$), and censored them from the analysis for the remainder of that season. .

Our primary goal for this analysis was to explore annual patterns in survival rates and within- and among-year patterns in emigration rates. Therefore, we considered 2 alternative patterns in survival rates: constant among years ($S.^C$) and categorical year effects ($S_y^C$). Because we only had 4 years of data and resulting small numbers of woodcock in any given week, we did not evaluate trends in weekly survival rates among years. As described above, we tracked marked woodcock weekly and organized the capture histories into 9 within-season, week-long periods. We considered 4 alternative temporal models for transition probabilities: constant among periods ($\psi.^{CO}$);, categorical effects of period ($\psi_{t}^{CO}$),; linear trend over the 9 periods ($\psi_{T}^{CO}$);, and quadratic trend over the 9 periods ($\psi_{T^2}^{CO}$). We included each of these 4 alternatives with and without interactive effects of year: $\psi_{y}^{CO}$, $\psi_{y*t}^{CO}$, $\psi_{y*T}^{CO}$, and $\psi_{y*T^2}^{CO}$. We included these 8 transition models with the 2 alternative models of survival rates for a total of 16 models. We ranked the 16 models using a sample-size adjustment of Akaike's Information Criteria (AIC$_c$; Burnham and Anderson 2002) and used model weights to estimate model-averaged estimates of weekly survival and emigration probabilities. We determined the 9-week period survival rate (PSR) for each year by taking the weekly survival rate and raising it to the 9th power, with the SE of PSR determined using the delta method (Powell 2007).

A secondary objective of this analysis was to explore potential effects of age and sex on survival rates of woodcock stopping on Cape May. We used the top-ranked model describing trends in survival rates to estimate survival rates based on sex and age (hatch year versus after hatch-year). We compared additive versus interactive effects of sex on survival rates, but only considered additive effects of age because the sample size of after hatch-year woodcock was too small to estimate effects among years. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service and the U. S. Geological Survey.

**Table 1.** Cohort summary for 271 woodcock VHF-tracked on the Cape May Peninsula of New Jersey, 2010–2013 (HY = Hatch Year, AHY = After Hatch-Year).

| | Male | | Female | | |
|---|---|---|---|---|---|
| **Year** | **HY** | **AHY** | **HY** | **AHY** | **Total** |
| 2010 | 25 | 5 | 22 | 6 | 58 |
| 2011 | 23 | 7 | 19 | 4 | 53 |
| 2012 | 50 | 2 | 22 | 6 | 80 |
| 2013 | 44 | 13 | 19 | 4 | 80 |
| Total | 142 | 27 | 82 | 20 | 271 |

## Results

During our 4 field seasons (2010–2013), we radio-marked and tracked 271 woodcock during the 9-week periods from 1 November through early January. The sample included 142 hatch-year males, 27 after hatch-year males, 82 hatch-year females, and 20 after hatch-year females (Table 1). The fates of marked woodcock in our sample included 72 that died, 57 that remained on Cape May and were still alive at the end of our tracking period, 131 that migrated, and 11 that were censored (Table 2). The censored woodcock included 9 that slipped their transmitter harness and 2 that died due to their bill getting stuck in the transmitter harness. We could not determine the cause of mortality for 32 woodcock, whereas predation was the likely cause of death for 40 individuals (Table 2).

We did not find any live birds remaining from our marked sample when we searched the study area in the beginning of March each year. During the 2 reconnaissance flights south of our study area, we located 6 birds;: 3 on the Eastern Shore of Maryland, 1 on the Eastern Shore of the Virginia National Wildlife Refuge, and 2 in northern Virginia. Although we located only 6 woodcock during these flights, locations of these 6 woodcock provided support for our assumption that woodcock not relocated on Cape May had migrated south of our study area.

Our AIC best-supported model (Table 3) indicated that survival rates were constant by week but varied by year and that weekly emigration rates followed different quadratic trends among years. Weekly survival rates ranged from 0.894 (95% CI = 0.834 – 0.934) in 2010 to 0.962 (95% CI = 0.928 – 0.981) in 2011 (Fig. 2), which equates to a 9-week period survival rate (PSR) ranging from 0.365 (95% CI = 0.185 – 0.545) to 0.706 (95% CI = 0.541 – 0.870), respectively (Table 4).

**Table 2.** Fates of 271 American woodcock VHF-tracked on the Cape May Peninsula of New Jersey, 2010–2013 Table 1. Cohort summary for 271 woodcock VHF-tracked on the Cape May Peninsula of New Jersey, 2010–2013 (HY = Hatch Year, AHY = After Hatch-Year).

| | Mortality | | | | | | |
|---|---|---|---|---|---|---|---|
| **Year** | **Unknown** | **Avian** | **Mammalian** | **Censored** | **Migrated** | **Stayed**[a] | **Total** |
| 2010 | 22 | 0 | 0 | 2 | 30 | 5 | 59 |
| 2011 | 1 | 5 | 3 | 1 | 19 | 24 | 53 |
| 2012 | 7 | 16 | 4 | 4 | 33 | 15 | 79 |
| 2013 | 2 | 8 | 4 | 4 | 49 | 13 | 80 |
| Total | 32 | 29 | 11 | 11 | 131 | 57 | 271 |

[a] Were alive and still on Cape May at the conclusion of the tracking period in early January each year.

Our best-supported model indicated that weekly emigration rates varied by year and week with each year exhibiting a different pattern of emigration from Cape May (Fig. 3). This model indicated that emigration rates were low and relatively constant throughout most of the study, with a rapid increase during the last few weekly periods in 2010. In 2011, emigration rates were close to zero the first few weekly periods, followed by a peak during period 6 and then a decline towards the end of the season. The temporal trend in emigration rates during 2012 was similar to the pattern observed in 2010, whereas the peak emigration rate appeared to be during the first few weekly periods in 2013. Overall, emigration rates ranged from none up to a one-third of woodcock leaving in a given week.

Because the survival rate model that included an interaction between sex and year on survival rates did not converge, we considered age and sex as additive effects to year to assess whether those variables improved model fit and to estimate any potential effects of those variables. Including sex (Δ AICC = 1.51) and age (Δ AICC = 1.70) did not improve the fit of the best-supported model. Parameter estimate for the effect of sex indicated that males had slightly higher survival rates than females and the estimate for age indicated that after hatch-year woodcock had slightly higher survival probabilities than hatch-year woodcock. However, confidence intervals for both parameter estimates broadly overlapped zero, indicating that the effects of these variables were weak ($\beta_{sex}$= 0.28, 95% CI = -0.45, 1.0; $\beta_{age}$= 0.32, 95% CI = -1.40, 0.76).

## Discussion

Our period survival rate estimates (PSR) for November through early January ranged from 0.365 (95% CI = 0.185 – 0.545) to 0.706 (95% CI = 0.541 – 0.870). These estimates represent the first empirical survival rate estimates for woodcock during the late fall/early winter portion of the annual cycle. Previous estimates (e.g., Longcore et al. 1996, 2000) for this period were derived using annual survival estimates from banding data combined with PSRs estimated with telemetry data for other periods of the year (e.g., breeding season, post-breeding, wintering). Longcore et al. (1996) derived a PSR of 0.853 for after hatch-year male woodcock during mid-October to mid-December, whereas Longcore et al. (2000) derived a PSR of 1.045 for after hatch-year females during the same period. Both these estimates were higher than our estimates and are likely biased high, especially the PSR for after hatch-year females (1.045), which is unrealistic,

**Table 3.** Relative rankings of 16 a priori models of weekly survival (S) and emigration (ψ) probabilities for radio-marked American woodcock using the Cape May Peninsula of New Jersey during late fall, 2010–2013. Data include differences in Akaike information criteria ($\Delta AIC_c$), $AIC_c$ weights (wi), number of model parameters (K), and model deviance.

| Model[a] | $AIC_c$ | $\Delta AIC_c$ | $AIC_c\ w_i$ | K | Deviance |
|---|---|---|---|---|---|
| $S_{y,}^{C}\psi_{y*T^2}^{CO}$ | 1135.65 | 0 | 0.72 | 16 | 1103.14 |
| $S_{y,}^{C}\psi_{y*t}^{CO}$ | 1138.15 | 2.50 | 0.21 | 36 | 1063.62 |
| $S_{.,}^{C}\psi_{y*T^2}^{CO}$ | 1140.93 | 5.28 | 0.05 | 13 | 1114.59 |
| $S_{.,}^{C}\psi_{y*t}^{CO}$ | 1143.20 | 7.55 | 0.02 | 33 | 1075.07 |
| $S_{y,}^{C}\psi_{y*T}^{CO}$ | 1148.13 | 12.48 | 0 | 12 | 1123.84 |
| $S_{.,}^{C}\psi_{y*T}^{CO}$ | 1153.45 | 17.81 | 0 | 9 | 1135.29 |
| $S_{y,}^{C}\psi_{y}^{CO}$ | 1173.50 | 37.85 | 0 | 8 | 1157.36 |
| $S_{y,}^{C}\psi_{T^2}^{CO}$ | 1174.25 | 38.60 | 0 | 7 | 1160.14 |
| $S_{y,}^{C}\psi_{T}^{CO}$ | 1177.65 | 42.00 | 0 | 6 | 1165.57 |
| $S_{.,}^{C}\psi_{y}^{CO}$ | 1178.87 | 43.22 | 0 | 5 | 1168.82 |
| $S_{.,}^{C}\psi_{T^2}^{CO}$ | 1179.63 | 43.99 | 0 | 4 | 1171.60 |
| $S_{.,}^{C}\psi_{t}^{CO}$ | 1181.27 | 45.62 | 0 | 12 | 1156.98 |
| $S_{.,}^{C}\psi_{T}^{CO}$ | 1183.05 | 47.40 | 0 | 3 | 1177.03 |
| $S_{y,}^{C}\psi_{.}^{CO}$ | 1184.13 | 48.48 | 0 | 5 | 1174.08 |
| $S_{.,}^{C}\psi_{t}^{CO}$ | 1186.60 | 50.95 | 0 | 9 | 1168.43 |
| $S_{.,}^{C}\psi_{.}^{CO}$ | 1189.54 | 53.89 | 0 | 2 | 1185.53 |

[a] S = survival, ψ = emigration, *y* = year effects, *t* = categorical period effect, *T* = linear trend among periods, $T^2$ = quadratic trend among periods, C = Cape May, CO = emigration from Cape May to outside of Cape May study area, and * = interactive effect between parameters.

**Table 4.** Weekly survival rate estimates, standard errors (SE), 95% confidence interval (CI), and 9-week period survival rate estimates (PSR), standard errors (SE), and 95% confidence interval (CI) for American woodcock using the Cape May Peninsula of New Jersey, 2010–2013.

| Year | Weekly Survival | SE | 95% CI | PSR[a] | SE(PSR) | 95% CI PSR |
|---|---|---|---|---|---|---|
| 2010 | 0.894 | 0.0250 | 0.834–0.934 | 0.365 | 0.092 | 0.185–0.545 |
| 2011 | 0.962 | 0.0127 | 0.928–0.981 | 0.706 | 0.084 | 0.541–0.870 |
| 2012 | 0.948 | 0.0117 | 0.919–0.967 | 0.618 | 0.069 | 0.484–0.753 |
| 2013 | 0.954 | 0.0124 | 0.922–0.973 | 0.655 | 0.077 | 0.504–0.805 |

[a] PSR = November through early January; calculated by taking weekly survival to the 9th power. SE of PSR was calculated using the delta method (Powell 2007), where var(PSR) = $9^2 WSR^{(9-1)*2} \times var(WSR)$.

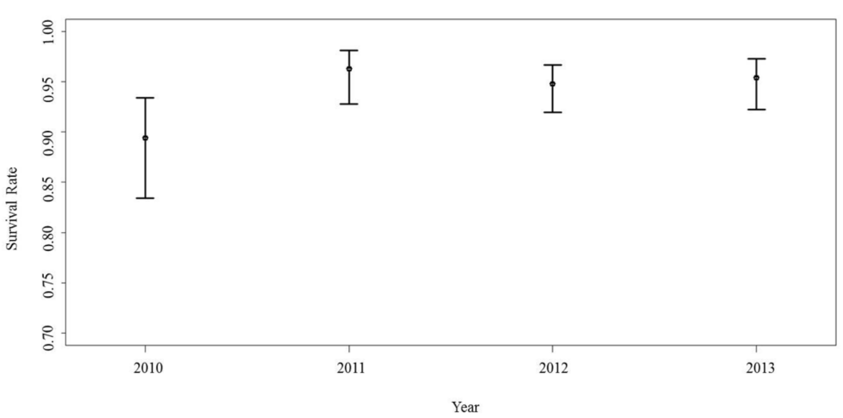

**Figure 2.** Mean weekly survival rate estimates for American woodcock using the Cape May Peninsula of New Jersey, 2010–2013.

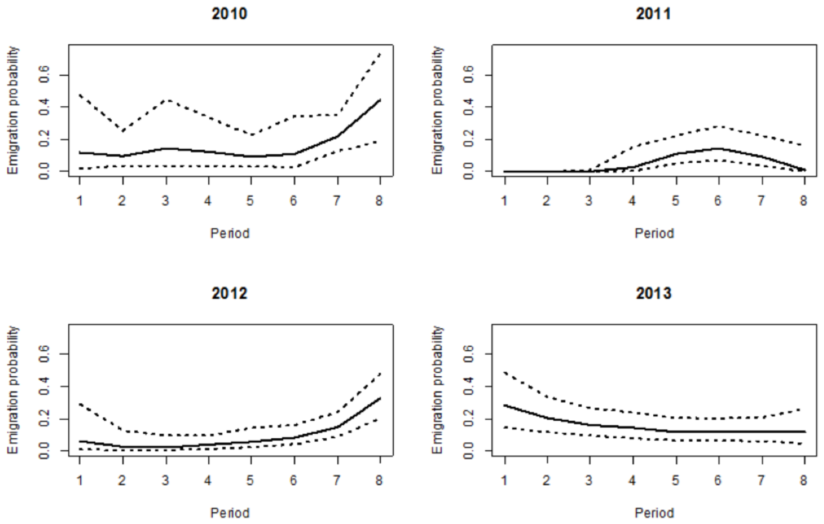

**Figure 3.** Period (weekly) emigration rates and associated 95% confidence intervals for American woodcock using the Cape May Peninsula of New Jersey during November through early January 2010–2013.

as Longcore et al. (2000) noted. Survival estimates based on band recoveries may not be reliable because so few woodcock are banded and recovery rates are low (Dwyer and Nichols 1982).

Other telemetry studies (e.g., Krementz et al. 1994, McAuley et al. 2005) have estimated PSRs during the fall and winter; however, their study locations and periods differed from those in our study. Nonetheless, survival rate estimates calculated from these studies were useful for deriving cumulative estimates to compare with our PSRs. McAuley et al. (2005) estimated survival rate from September to the end of November within the northern part of the Eastern Management Region and found no difference between hunted (0.636) and non-hunted sites (0.661). They also estimated a weekly survival rate of 0.981 for the month of November after the hunting season ended, which equates to a November PSR of 0.925. Krementz et al. (1994) estimated winter survival (0.647) during the period from December through February/March within the southern portion of the Eastern Management Region. Combining the non-hunted site estimate (0.661) from McAuley et al. (2005) with the winter survival estimate (0.647) from Krementz et al. (1994) provides a cumulative survival rate estimate of 0.428 from the beginning of September through February/March. Combining the November survival estimate (0.925) calculated from McAuley et al. (2005) with the Krementz et al. (1994) estimate (0.647) provides a cumulative survival rate estimate of 0.598 from November through February, a period more closely matching our study period. Both to of these cumulative estimates, —0.428 and 0.598, respectively, —fall within the range we estimated (0.365 to 0.706) for woodcock using Cape May during November through early January.

Predation and exposure were the primary causes of mortality based on our examination of recovered woodcock. Although we could not always identify the species of predator that killed radio-marked woodcock, our post-mortem examinations indicated that avian predators were probably responsible for most deaths from predation. Avian predators were extremely numerous on Cape May;, with raptors likely being the most frequent cause of mortality based on evidence we observed at recovery sites (e.g., woodcock remains found below perches, talon marks in skin, piles of feathers, and stripped carcasses). Extreme weather events also contributed to mortality, particularly a severe snowstorm that occurred in late December 2010. We attributed 13 of the 22 unknown mortalities that occurred in 2010 to the late December storm. We documented no hunting mortalities during our study even though woodcock hunting season was open during part of the period we tracked woodcock on Cape May.

We determined that weekly emigration rates from Cape May varied by year and week within each year. There were several weeks where no marked woodcock left the peninsula, versus other weeks when as many as one-third of the marked woodcock migrated. Nearly 20% of marked woodcock (57) remained in Cape May at the end of the tracking period into January, indicating that Cape May is potentially an important over wintering area for woodcock within the Eastern Management Region; however, woodcock wintering on Cape May, however, are vulnerable to extreme storm events as occurred like that occurring in during late December 2010. Krohn and Clark (1977) reported some band recoveries from southern New Jersey during the winter, but the extent to which woodcock winter at mid-latitudes in the Eastern Woodcock Management Region is unknown.

A majority of the woodcock we tracked were hatch-year birds (Table 1). Past studies indicated a disparate age ratio of woodcock using Cape May. Haramis and McAuley (2010) used a series of towers to record the passage of VHF-marked woodcock through Cape May captured as part of the study of McAuley et al. (2005). In 1998, they detected 4 woodcock, in 1999 they detected 19 woodcock, and in 2002 they detected 20 woodcock. Only 2 woodcock landed on Cape May--; most passed over Cape May in flight. The woodcock that stopped on Cape May stayed a couple of days before emigrating.

Our study provides some of the first information about woodcock survival rates at mid-latitude stopover sites, but we were unable to assess the relation(s) between survival rates and covariates likely to influence survival rates. Potential fruitful lines of inquiry would be to evaluate relation(s) between survival rates and covariates such as body condition, habitat selection, and environmental conditions (e.g., accumulated thermal units and precipitation). Incorporating the results from the Allen et al. (2017) resource selection function (RSF) model as an individual's habitat suitability index may provide insight into the quality of habitat an individual is using. That is, if individuals using areas with greater RSF values have higher survival rates, then landscapes could be managed to increase RSF values in areas where they are currently low. For example, Allen et al. (2017) found that potential roost fields in close proximity to migratory stopover diurnal covers, in particular deciduous wetland forest, was an important factor in a woodcock's decision to select a particular diurnal cover. It would be prudent, however, to evaluate the effects of habitat selection on vital rates prior to prescribing a management action.

## Acknowledgments

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# Using Pointing Dogs and Hierarchical Models to Evaluate American Woodcock Winter Occupancy and Densities

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**ABSTRACT:** Use of dogs has increased for multiple wildlife research purposes ranging from carnivore scat detection to estimation of reptile abundance. Use of dogs is not particularly novel for upland gamebird biologists, and pointing dogs have been long considered an important research tool. However, recent advances in Global Positioning System (GPS) technology and the development of hierarchical modeling approaches that account for imperfect detection may improve estimates of occupancy and density of cryptic species such as the American woodcock (*Scolopax minor*; hereafter, woodcock). We conducted surveys for woodcock using a trained pointing dog wearing a GPS collar during the winters of 2010–2011 and 2011–2012 in East Texas, USA. We surveyed 0.5-km-radius circular plots *(n* = 24; survey sites) randomly placed along secondary roads in Davy Crockett National Forest and on private timber property. Surveys lasted 1.5 hrs and were repeated 3–5 times each winter. We estimated woodcock occupancy and density using multiple modeling approaches at the survey site and forest stand scales within survey sites. Woodcock occupied 88% (21/24) of survey sites and 48% (39/82) of forest stands (i.e., unique cover types) within sites. Using a modified distance sampling technique, we estimated an average density of 0.16 birds/ha (SE = 0.13) throughout both study areas. We describe the first attempt to blend use of pointing dogs with hierarchical modeling approaches to derive estimates of regional diurnal woodcock occupancy and density, and describe relationships between these estimates of abundance and habitat covariates. Although forest stand occupancy estimates had the lowest coefficients of variation, our estimates of density provided the most useful inference of habitat use. Surveys using pointing dogs paired with hierarchical models of occupancy and density may provide a cost-efficient and effective approach to estimate habitat abundance at broad spatial scales.

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**KEY WORDS:** American woodcock, detection, distance sampling, dogs, hierarchical models, occupancy, habitat, *Scolopax minor*

The use of pointing and flushing dogs in upland gamebird research in North America has an extensive history as an aid in collecting field specimens, documenting life history events, and banding (Audubon 1839, Bendire 1889, Reeves 1966). More recently, use of very high frequency (VHF) transmitters and Global Positioning System (GPS) telemetry to evaluate wildlife habitat use has become prominent (Millspaugh et al. 2012, Daw et al. 1998, Powell et al. 2005,

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Peterson et al. 2015). The same technological advancements that have made it possible to monitor marked individuals in fine detail have also allowed for expanded use of dogs into nontraditional realms of wildlife research (Dahlgren 2012). For example, the development of GPS tracking collars for dogs can improve the utility of dogs in wildlife research (Dahlgren 2012). Dogs have been used to detect wildlife mortalities related to wind turbines, among many other uses (Arnett 2006, Dahlgren et al. 2012), and advances in technology provide an opportunity to revisit the use of pointing dogs for estimating habitat use for cryptic webless migratory gamebird species such as the American woodcock (*Scolopax minor*; hereafter, woodcock).

In addition to technological advances, recently developed analytical methods allow for accounting of nuisance variables that can increase the error of occupancy and density estimates. Hierarchical models integrate detection and related covariates to estimate "true" occupancy or density of wildlife (Royle et al. 2004, Mackenzie et al. 2006). Hierarchical models account for imperfect detection using multiple repeat surveys, as in occupancy modeling, or by quantifying the relationship of detection with distance from the observer, as in distance sampling (Mackenzie et al. 2006, Buckland et al. 1993). The replicate surveys that some hierarchical models require introduce logistical constraints that limit the spatial extent of survey efforts and, therefore, the scale of inference. However, it may be more feasible to survey a broad geographic area multiple times than to capture, mark with transmitters, and monitor individuals over the same geographic extent.

Hierarchical models that account for detection probability can provide biologically relevant estimates of wildlife occupancy or density, allowing a clearer understanding of relationships between unmarked animals and habitat-related covariates, especially when detection probability covaries with habitat variables (Gu and Swihart 2004). The true values of occupancy and/or density adjusted for detection probability may be of less interest to land managers and conservationists than the relationships among habitat variables. Both occupancy and density estimates are products of the underlying point process pattern, and both can provide inference on habitat use (Kery and Royle 2016). Using occupancy or density to assess habitat use through evaluating models including habitat-related covariates may aid in guiding management decisions. A carefully designed study is needed to estimate occupancy and density of woodcock, which can occupy 9.2-ha diurnal winter home ranges (Horton and Causey 1979), make within-season movements ≥500 m in response to changes in precipitation and daily temperature (Doherty et al. 2010), and exhibit varied use of cover types both within and among winters (Krementz et al. 1994). Guidelines for designing such studies are needed to ensure that inference on woodcock ecology can be gleaned in the most cost-effective manner when using pointing dogs and hierarchical models.

Other tools that can improve estimates of occupancy and density include the advancement of Geographic Information Systems (GIS). Dog collars with GPS tracking capabilities make it straightforward to record, save, and analyze the track of a searching dog using GIS. Location errors for currently available dog-tracking devices are typically <20 m (Sepulveda et al. 2015). Information from GPS collars can provide spatially explicit information on survey efforts, including estimates of distances covered and time spent during surveying specific cover types when combined with GIS. Advances in GIS can make traditional pointing-dog surveys highly informative when dog tracks are georeferenced and overlaid on remotely sensed land-cover data. Linking woodcock habitat use to GIS layers would be beneficial for estimating the distribution of diurnal habitat for woodcock, which has been identified as a priority information need (Case and Case 2010).

We assessed the utility of conducting surveys for woodcock with pointing dogs in combination with hierarchical modeling and GIS tools to estimate diurnal occupancy and density on a portion of their wintering distribution in East Texas, USA. Specifically, we present methods using pointing dogs and hierarchical models to evaluate woodcock habitat use (occupancy and density) among land-cover types and in relation to habitat characteristics as a case study for use in future monitoring and research efforts.

## Study Area

We conducted surveys for woodcock at 2 study areas representative of typical land-cover types in East Texas, USA. Campbell Unit #106 (hereafter, the Campbell Unit) was a 2,400-ha private timber site in San Augustine County and was managed for loblolly pine (*Pinus taeda*) timber-production. Our other study area was the 65,529-ha Davy Crockett National Forest (hereafter, DCNF) in Houston and Trinity counties (Fig. 1). The DCNF was managed on longer rotations for multiple uses including wildlife and timber production. However, timber harvest was greatly restricted at this study area (Van Kley 2006). The study areas were within the West Gulf Coastal Plain Bird Conservation Region (WGCP BCR), which was comprised mostly of loblolly pine (38%) and mixed-pine/hardwood forests (Krementz et al. 2008). The East Texas portion of the WGCP BCR was heavily forested and even-aged loblolly pine plantations were common. Our study areas were comprised of various soil types, with excessively drained sandy upland soils and poorly drained floodplain soils interspersed across the landscape (Van Kley 2006). Ultisol and Alfisol soil orders dominated uplands, although some Vertisols and Entisols were also present. Upland topsoils were typically a light-brown to reddish sandy loam, loam, or clay loam, medium to strongly acidic, and nutrient poor, whereas alluvial Entisol and Inceptisol soils dominated river floodplains (Van Kley 2006).

## Methods

### FIELD COLLECTED DATA

*Survey site selection* Within our study areas, we selected 24 0.5-km-radius sites to conduct woodcock surveys using a stratified random sampling design: 18 in DCNF and 6 in the Campbell Unit. We selected the centers of woodcock survey sites by placing evenly spaced points 1 km apart on secondary roads throughout each study area. We then created 0.5-km buffers in ArcMap 10 (ESRI 2010) around each point to create adjacent circles along all secondary roads in both study areas. We stratified sampling on soil type, as soil type has been used to characterize winter habitat suitability for woodcock (Cade 1985; see supplemental material).

*Forest stand delineation* Within the 2 study areas (Campbell Unit and DCNF), we evaluated woodcock habitat use at the 1) survey site and 2) stand scales. The survey site scale included the total area (78.5 ha) within each 0.5 km-radius survey site (see supplemental material for a summary of survey site habitat use via occupancy modeling). The stand scale was based upon the extent of land-cover types (stands) within each survey site, which varied among survey sites. We classified stands based on land-cover classifications from Diamond and Elliott (2009) and measured the area (in ha) of each stand within survey sites. We used land-cover types as both individual and aggregated categories in occupancy and density models. We classified stands into 8 land-cover types including grassland, streamside management zones (SMZ), upland deciduous forest, mature pine forest, mesic mixed pine/hardwood forest, pine forest 1–3 m tall, pine plantation >3 m tall, and riparian forest (see Diamond and Elliott 2009; more details in supplemental material).

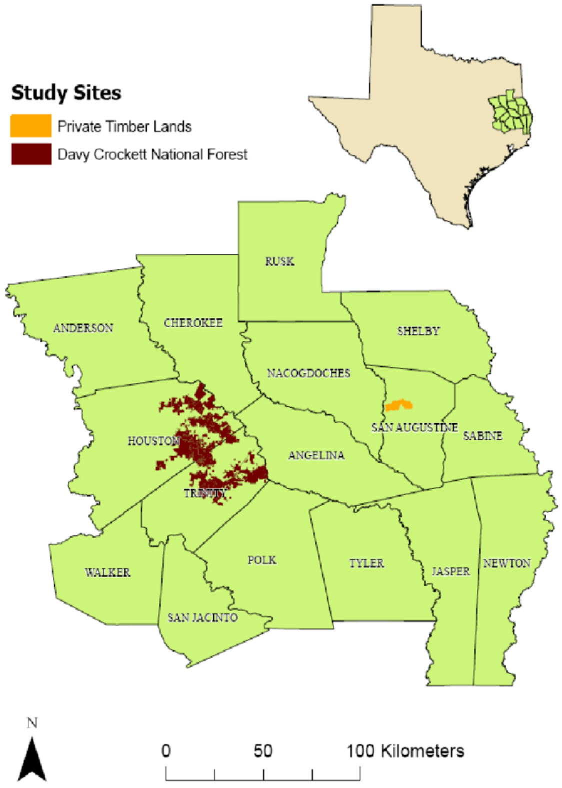

**Figure 1.** Counties and location of Davy Crockett National Forest and private industrial timberlands (Campbell timber Unit #106) surveyed for American woodcock during the winters of 2010–2011 and 2011–2012 in East Texas, USA.

*Vegetation covariates within stands* We measured structural vegetation characteristics at 416 random points after completing woodcock surveys. We randomly distributed points throughout all survey sites (Sullins 2013) using Hawth's Analysis (Beyer 2004) tools in ArcGIS 9.2 (ESRI, Redlands, CA). All random points were ≥200 m apart to ensure adequate coverage of each survey site. At each random point we measured percent vegetation cover (%) at 2 strata—<30 cm tall, and >0.5 m and <5 m tall—using the line-intercept method in each cardinal direction beginning at each random point (Hays et al. 1981). We measured vegetation cover <0.3 m tall along 2-m transects, and measured vegetation 0.5–5 m tall along 5-m transects (Hays et al. 1981). We measured stem density of trees >5.0 m tall within a 5-m radius of each random point following Hays et al. (1981).

*Woodcock surveys* We conducted multiple woodcock surveys at each site using the same trained pointing dog during the winters of 2010–2011 (31 December 2010–12 February 2011) and 2011–2012 (8 November 2011–3 March 2012). The trained pointing dog was a Llewellin Setter that was 1 year old when surveys began in 2010 (Fig. 2A). We began each survey at the center of each 0.5 km-radius survey site and proceeded in a manner that ensured complete coverage of potential diurnal woodcock habitat within each survey site. We remained within survey site boundaries by setting a handheld GPS to navigate to the center of the survey site throughout each survey, even though we were not navigating to the center, which allowed us to monitor if we were within 500 m of center of the site throughout the survey. Each survey lasted 1.5 hr, and we surveyed each site 3–4 times in 2010–2011 and 4–5 times in 2011–2012. No individual site was surveyed twice in the same day. Typically, and at most, we conducted 3 individual surveys (on different sites) on a given day, between 0700 and 1400 CST. We separated repeat visits on the same survey site by ≥2 days to ensure independence among visits. We randomized the order in which we surveyed sites so that each site would be surveyed first, second, and third during morning surveys, respectively.

We outfitted the pointing dog with a Garmin DC 40 GPS collar (Garmin International, Inc., Olathe, KS, USA) to record its movements through the survey site. We downloaded and saved the tracked movements of the pointing dog at the end of every day that we conducted surveys (Fig. 2A–B). Upon flushing a woodcock during a survey, we marked the location where the woodcock flushed using a handheld Garmin Astro 320 GPS. We recorded the flight direction of each flushed woodcock to minimize chances of recording the same woodcock multiple times. We followed procedures outlined in Gutzwiller (1990) and Dahlgren et al. (2012) in that we used the same dog for all surveys, surveyed each site at least once during all time intervals, and standardized search efforts by having only 1 dog handler (DSS) during all surveys. We attempted to minimize the influence of temperature, wind, precipitation, and barometric pressure on the probability of detecting woodcock by conducting all surveys during similar conditions (Gutzwiller 1990, Dahlgren et al. 2012). We also included weather-related covariates in initial candidate model sets to assess their effects (see below).

For use in estimating the effective area searched by the dog, we measured the point-to-flush distance (PFD) for each woodcock located by the pointing dog using a hip chain from where the dog first went on point to where the woodcock flushed (Guthery and Mecozzi 2008). We assumed the pointing behavior of the dog immediately occurred upon detection of a woodcock (Guthery and Mecozzi 2008). If the dog flushed a bird without pointing, we recorded the PFD as 0 m. We recorded locations of woodcock incidentally flushed by the dog handler, for future measurements of habitat variables, but we did not use these encounters to estimate occupancy and density.

*Survey weather* We obtained weather data from Weather Underground (weatherunderground.com) using data from stations that were closest to each survey site. We downloaded temperature (°C), humidity (%), and precipitation (cm) data for each day we conducted surveys. We used total rainfall in the 7 days prior to each date we conducted a survey as a precipitation covariate in occupancy and density models. We expected that weather-related variables may influence the detection of woodcock.

### HIERARCHICAL MODELING AND MODEL SELECTION

We conducted occupancy modeling and distance sampling using the woodcock detections and PFDs acquired from surveys using pointing dogs during the winters of 2010–2011 and 2011–2012 in East Texas. We modeled occupancy at 2 spatial scales (survey site and stand scale) whereas we used distance sampling models to estimate density at only the stand scale. Survey site occupancy methods and results are included in the supplemental material. For models of woodcock occupancy and density, we only used count data from 3 repeat surveys occurring between 31 December 2010 – 6 February 2011, during the first season, and from 14 December 2011– 6 February 2012, during the second season. We did not use counts from surveys occurring in November and later in February when woodcock have not yet completed migration or have already started northward migration (Tappe et al. 1989, Olinde and Prickett 1991, Roberts 1993, Krementz et al. 1994, Moore and Krementz 2017).

### STAND-SCALE OCCUPANCY MODELING

We estimated occupancy based on detection histories (present, $Y_{ij} = 1$; absent, $Y_{ij}= 0$) of survey sites ($_{i}$,) among multiple visits ($_{j}$; Mackenzie et al. 2006, Royle and Dora-

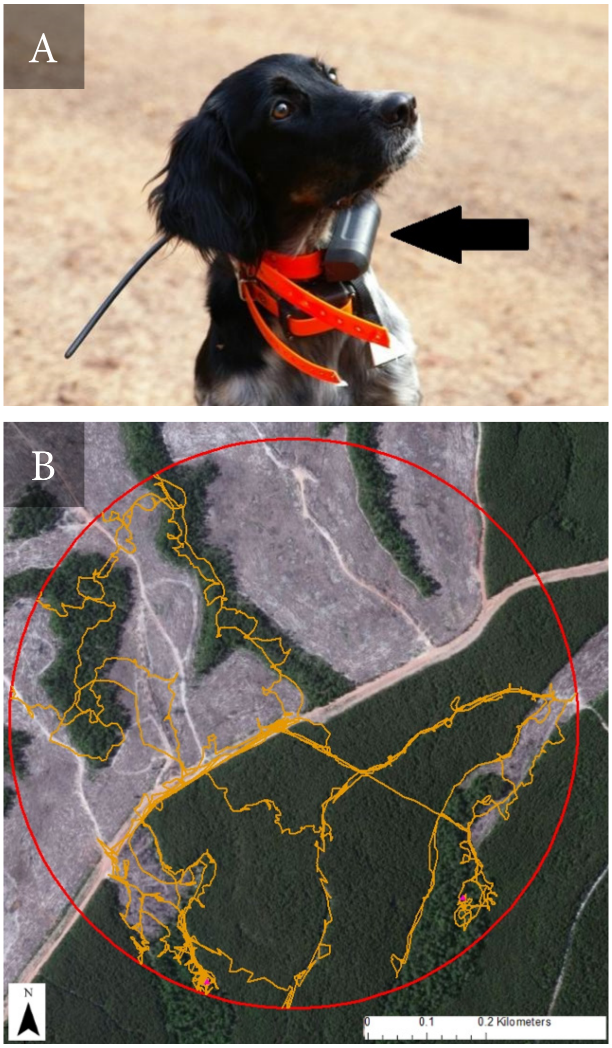

**Figure 2.** Trained pointing dog wearing a Garmin DC 40 GPS collar during American woodcock surveys in East Texas, USA during winters of 2010–2011 and 2011–2012. The black arrow points to the GPS collar (A). An example of a 0.5-km-radius survey site, outlined in red, on the Campbell timber unit in East Texas, USA and the dog track recorded by the GPS collar is displayed in gold (B).

zio 2008). Occupancy modeling estimates the probability of a site being occupied [$\psi = \Pr(Z_i = 1)$] while accounting for imperfect detection using a hierarchical model (Mackenzie et al. 2006). The hierarchical model is based on the Bernoulli joint distribution of the observation conditional on the latent occupancy state and incorporates an estimated probability of detection (ρ) where

$$Z_i \sim Bernouli(\psi)$$
$$(Z_{i\rho}) \sim Bernouli(\psi)$$

We estimated the probability of a site (ψ), or stand, being occupied and the detection probability (ρ) using hierarchical models with maximum likelihood estimators (Mackenzie et al. 2006). We used a logit link to generalize the model and likelihood to assess occupancy and detection probability as a function of covariates.

*Observation Process* We developed *a priori* candidate models to 1) explain latent woodcock occupancy and 2) identify factors related to detection as part of the observation process based on previously published information (Cade 1985). First, we identified top-ranked univariate detection models for each season by holding occupancy constant. We estimated stand-scale occupancy (ψ) and detection probabilities (ρ) using the function occu() in the package unmarked in R (Mackenzie et al. 2006, Fiske and Chandler 2011, R Development Core Development Team 2016).

We held occupancy constant while fitting models with covariates to explore relationships between detection probability and area searched within a stand (ha), average daily temperature (degrees C), survey specific detection, and percent canopy cover <0.3 m tall. We estimated the area searched within each stand by buffering each dog track in ArcGIS10 with the estimated ESW that we modeled using distsamp within the R package unmarked (Fiske and Chandler 2011, see distance sampling modeling methods below). We then intersected the polygon of area searched by the dog with the polygons of individual stands to quantify the area searched within each stand. We identified the best-supported univariate candidate model to predict detection probability using Akaike's Information Criterion adjusted for sample size ($AIC_c$; Burnham and Anderson 2002).

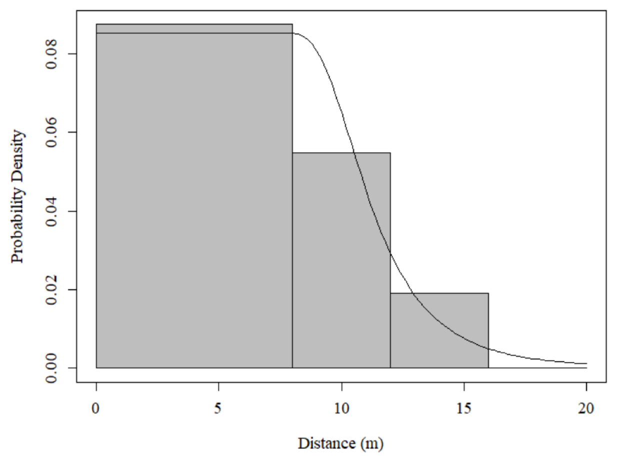

**Figure 3.** Estimated probability density function derived from the frequency of point-to-flush distances of American woodcock during winter in East Texas, USA at 0–7.9 m, 8–11.9 m, 12–14.9 m, 15–17.9 m, and 18–21 m away from the transect. Black line depicts the hazard rate function fit to the detection curve.

*Occupancy covariate modeling* We then used the covariate in the top-ranked detection model to control for nuisance variation in the observation process when fitting all occupancy models. We assessed latent occupancy using 2 groups of models. The first group included categorical descriptors of each stand, or *land-cover type*. The second group included covariates related to *vegetation structure* within stands that are described above and are hypothesized to influence diurnal habitat abundance during winter (Cade 1985): percent canopy cover 0.5–5.0 m tall and stem density of trees >5 m tall (trees/ha). For the land-cover type model group, we derived land-cover-type covariates, which were all categorical except for patch size (ha; patchsize), from Diamond and Elliott (2009). We directly assessed occupancy in the 8 cover types we delineated (see Forest Stand Delineation, above). We also evaluated occupancy in young pine forests 1–3 m tall (Ypine), mature pine forests (Mpine), and forested wetland/streamside riparian cover types (Wet), which were aggregates of multiple cover types (see Forest Stand Delineation and supplemental material). We defined patch size as the area (ha) of each surveyed forest stand.

We developed candidate models within the *land-cover type* and *vegetation structure* groups using single covariates and all possible combinations of covariates as interactive and additive models. We evaluated the best-supported candidate model, within and among groups, to predict woodcock occupancy using $AIC_c$ (Burnham and Anderson 2002), model weights (*w*), and precision of coefficient estimates (SE). We reported coefficients (β) ± SE in the results section of the manuscript for candidate models of interest. We considered models informative if 85% confidence intervals of the untransformed coefficients did not contain zero (Arnold 2010). We assessed goodness-of-fit of global occupancy models in each year using 500 bootstrap simulations. We refit data sets from the model to "perfect" data and estimated a fit statistic using $\chi^2$ (Fiske and Chandler 2011). We also estimated $\hat{c}$ using the AICcmodavg package following Mackenzie and Bailey (2004).

### STAND-SCALE DENSITY ESTIMATES

We used a hierarchical distance sampling approach from Royle et al. (2004) that was modified for use in surveys conducted by a pointing dog (Guthery and Mecozzi 2008). Similar to occupancy modeling, distance sampling incorporates the observation process to estimate a latent state variable; however, distance sampling results in estimates of density instead of occupancy. Hierarchical distance sampling uses a multinomial Poisson mixture model where $N_t$ is the latent abundance on transect $_t$ and $\pi$ is the vector of cell probabilities among distance intervals that correspond to the vector of counts $Y_t$. In distance sampling, the vector of cell probabilities is the product of the probability of detection and the probability of occurrence based on the distance of the organism from the observer (Royle et al. 2004, Fiske and Chandler 2011) where

$$N_t \sim Poisson(\lambda)$$
$$(N_t) \sim Multinomial(N_t, \pi)$$

The hierarchical distance sampling method allows for covariate modeling using a log link (Royle et al. 2004).

We modified the distance sampling approach to quantify the area searched by the pointing dog and estimate densities of woodcock following Guthery and Mecozzi (2008). To estimate total area searched within each survey site, we established a line transect from each GPS track and a corresponding effective strip width (ESW) that we estimated using PFDs (Guthery and Mecozzi 2008). To estimate the ESW, we truncated the greatest 5% of all PFDs and fit remaining PFDs to a hazard rate key function, to model the detection rate as a function of distance from the pointing dog transect for this study (Buckland et al. 1993). In addition, we buffered each line transect by its estimated ESW using ArcGIS 10, and used the resulting estimated area as the total area (ha) searched as a detection covariate in multi-visit hierarchical models of occupancy (see above). We visually assessed detection-curve shape within stands, survey sites, and study areas using PFD histograms. We then pooled PFDs across surveys because there was not a consistent difference in detection-curve shape among stands, survey sites, or study areas (i.e., the pointing dog detected birds similarly at all sites).

We binned all PFDs within the first 8 m from the transect together and used a hazard rate key function to model detection probability as a function of distance. By creating a large first bin for the multinomial Poisson mixture model from Royle et al. (2004), we were able to model detection in a domain where it decreased as distance increased. The hazard rate key function also provided a good description of the detection function and can be used when the detection function has a wide shoulder of equal detection probability (Marques et al. 2011).

Distance sampling operates under the assumptions that detection is perfect at the center of the transect line [g(0) = 1] and that animals are detected at their initial location (Buckland et al. 1993). Further assumptions of the methods outlined in Guthery and Mecozzi (2008) include: that PFD measurements are accurate, woodcock are only counted once, each flushing observation is an independent event, the probability of detection is independent of clustering, the creation of transect lines does not influence the spatial distribution of woodcock, PFDs are an adequate surrogate to perpendicular distances from the line transect, and the random selection of survey sites outweighed any bias resulting from having nonrandom transects within survey sites and stands.

*Observation Process* We estimated woodcock density using the distsamp() function in the R package unmarked (Royle et al. 2004, Fiske and Chandler 2011, R Development Core Team 2016). We binned multiple survey transects and distance data (PFD) with breakpoints at 0, 8, 12, 16, and 20 m to estimate detection probability as a function of distance (Royle et al. 2004). To remove redundantly searched portions of dog tracks, where the dog circled back onto its original track, we buffered all surveys by an ESW estimated from the hazard rate detection model in ArcGIS 10. We estimated transect lengths from buffered GPS dog tracks by subtracting πESW2, dividing by 2ESW, and finally adding 2ESW. We then converted the area searched estimates back to t`ransect length estimates. The resulting transect length estimates did not contain redundantly searched areas and were therefore appropriate for use in the Royle et al. (2004) model.

We fit multinomial-Poisson mixture models to detections and distances (Royle et al. 2004). We first modeled the observation process and examined the influence of average daily temperature (degrees C), percent canopy cover <0.3 m tall, and effect of a first survey on the distance at which we detected woodcock using hazard rate, half-normal, and uniform functions (Buckland et al. 1993). Similar to the multi model approach we used for occupancy models, we included each covariate and functions as separate candidate models and assessed the rank of each model based on $AIC_c$ (Burnham and Anderson 2002). We included a first-survey effect to assess whether there was a difference in detection between first and repeat surveys. Hazard rate key function models were best-supported based on $AIC_c$ and we used the hazard rate key function to examine habitat covariate influence on abundance (λ) estimates.

*Density covariate modeling* To allow for comparison to occupancy estimates, we used the same covariates, candidate models, and modeling approach described above for occupancy models. We grouped covariates in land-cover type and vegetation structure hierarchical model sets to assess habitat use differences among both stand types and the available cover within stands. We estimated densities in the 8 land-cover types and aggregated cover types delineated previously for occupancy models (see Forest Stand Delineation above). We evaluated the best-supported candidate model, within and among groups, to predict woodcock densities using AIC$_c$, *w* (Burnham and Anderson 2002), and precision of coefficient estimates (SE). We reported coefficients (β) ± SE in the results section of the manuscript for candidate models of interest. We considered models informative if 85% confidence intervals of the untransformed coefficients did not contain zero (Arnold 2010). We used parametric bootstrapping to assess goodness-of-fit of distance sampling data pooled among years using 500 bootstrap simulations. We refit data sets from the model to "perfect" data and estimated a fit statistic using $\chi^2$ (Fiske and Chandler 2011). Similar to occupancy models, we considered a model to fit these data if the observed value was >0.05% of the reference distribution (Sillett et al. 2012). Finally, we used the best-supported detection model with constant density to estimate density pooled among all survey sites and winters.

### COMPARISON OF OCCUPANCY AND DENSITY ESTIMATES

We estimated occupancy and density for each cover type to evaluate the use of each approach for comparing habitat use among stands. We reported coefficients of variation (CV) to provide a relative estimate of error among all models and model approaches.

## Results

During 185 surveys, the pointing dog traversed 1,596 km, we flushed woodcock 283 times, and we detected 300 individual woodcock. Woodcock were sparsely distributed throughout the survey sites ($\underline{x}$ = 1.65 flushes per survey) and occupied 83% and 71% of the 78.5-ha survey sites during the winters of 2010–2011 and 2011–2012, respectively. In 2010–2011, we flushed an average of 1.70 (SD = 2.06) woodcock per survey on both study areas combined, and in 2011–2012, we flushed an average of 1.60 (SD = 2.21) woodcock on both study areas combined. The mean area of all stands that woodcock occupied was 23.14 ha (SD = 21.50) and we estimated the highest woodcock density in stands classified as pine forests 1–3 m tall (Fig. 5).

### STAND-SCALE OCCUPANCY

We identified 82 unique stands within survey sites that were on average 22.9 (SD = 21.50) ha in size. We detected woodcock at least once in 32% of stands (naïve ψ = 0.34; site-by-land-cover-type polygons) in 2010–2011, and in 35% of stands (naïve ψ = 0.35) in 2011–2012. The constant single-season occupancy model produced estimates of ρ = 0.53 (SE = 0.07) and ψ = 0.39 (SE 0.06) in 2010–2011 and ρ = 0.58 (SE = 0.05) and ψ = 0.38 (SE 0.06) in 2011–2012. The estimated probability of not detecting a woodcock when woodcock were present was 0.10 and 0.03 in 2010–2011 and 2011–2012, respectively. Both single-season models exhibited adequate goodness-of-fit (2010–2011 $\hat{c}$ = 0.36, *P* = 0.80, 2011–2012 $\hat{c}$ = 0.79, *P* = 0.51).

*Observation process* We held state variables (occupancy and density) constant using intercept-only stand-scale models to estimate detection probabilities based on stand and survey site covariates (Table 1). For occupancy models, the proportion of area searched (areasearched) within each stand was related to detection in 2010–2011 but not in 2011–2012 (Table 1). The best-supported detection probability model for 2010–2011 included the proportion of stand surveyed as a covariate (Table 1) and was the only candidate model with more support (based on AIC$_c$, *w* = 0.67) than the intercept-only model (*w* = 0.11). All relationships that follow are reported as the coefficient (β) ± SE. The proportion of stand surveyed was positively related

**Table 1.** Candidate hierarchical models of American woodcock detection and single-season occupancy in East Texas during the winters of 2010–2011 and 2011–2012. Single-season occupancy models were constructed using the R package unmarked (Mackenzie et al. 2006, Fiske and Chandler 2011).

| **Winter 2010–2011** | | | | | **Winter 2011–2012** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model$^{1,2}$** | **k** | **AICc** | **ΔAICc** | ***w*** | **Model$^{1,2}$** | **k** | **AICc** | **ΔAICc** | ***w*** |
| ψ(.),ρ(areasearched) | 3 | 213.23 | 0.00 | 0.67 | ψ(.),ρ(.) | 2 | 211.54 | 0.00 | 0.34 |
| ψ (.),ρ(.) | 2 | 216.83 | 3.60 | 0.11 | ψ(.),ρ(areasearched) | 3 | 213.02 | 1.48 | 0.16 |
| ψ (.),ρ(firstsurvey) | 3 | 217.59 | 4.36 | 0.08 | ψ(.),ρ(firstsurvey) | 3 | 213.38 | 1.84 | 0.14 |
| ψ (.),ρ(30cm) | 3 | 218.10 | 4.87 | 0.06 | ψ(.),ρ(julian) | 3 | 213.54 | 2.00 | 0.13 |
| ψ (.),ρ(julian) | 3 | 218.50 | 5.27 | 0.05 | ψ(.),ρ(30cm) | 3 | 213.61 | 2.07 | 0.12 |
| ψ (.),ρ(temp) | 3 | 218.85 | 5.62 | 0.04 | ψ(.),ρ(temρ) | 3 | 213.69 | 2.15 | 0.12 |

[1] k = no. of parameters, AIC$_c$ =Akaike's Information Criterion adjusted for sample size, ΔAIC$_c$ = difference in AIC$_c$ relative to smallest value. Model symbols included ψ = occupancy probability, and ρ = detection probability for multiple-visit models.

[2] Covariates represent estimated proportion of survey site searched each survey by the dog (areasearched), estimation of a second detection probability for the first survey (first survey), canopy cover <30 cm tall (<30cm), days since the first survey (julian), and temperature (temp).

with detection probability in 2010–2011 (β = 0.81 ± 0.37), and its 85% confidence interval did not contain zero. In 2011–2012, proportion of stand surveyed was not related to detection (β = 0.41 ± 0.47, *w* = 0.16) and was not competitive with the intercept-only model (*w* = 0.34).

*Occupancy covariate modeling* After accounting for detection, we modeled relationships of occupancy with habitat covariates within the land-cover type and vegetation structure model groups. Within the land-cover type model group, occupancy in 2010–2011 was better predicted by quadratic patch size of the timber stands than by land-cover-type category, and the quadratic effect of patch size ($\beta_1$ = 1.24 ± 0.44, $\beta_2$ = -0.47 ± 0.40; w = 0.19) was the best predictor of occupancy (Table 2). In 2011–2012, occupancy was best predicted by the model including categorical land-cover types (*w* = 0.25).

Within the vegetation structure model group, canopy cover 0.5–5 m tall was the best predictor of occupancy in both 2010–2011 (β = 0.97 ± 0.39, *w* = 0.62) and 2011–2012 (β = 0.80 ± 0.31, *w* = 0.60; Table 2) and did not contain zero in the 85% confidence interval. The highest occupancy rates were associated with percent canopy cover 0.5–5 m tall >60% (Fig. 4), and we estimated a canopy cover threshold of 50% (i.e., stands with <50% canopy cover 0.5–5 m tall were likely to be occupied by woodcock). At least 50% of the stands with >50% canopy cover 0.5–5 m tall were occupied by woodcock.

### STAND-SCALE DENSITY ESTIMATES

We estimated an ESW of 10.03 m based on a hazard rate detection function (Buckland et al. 1993). Our estimate of density for both winters pooled was 0.16 woodcock/ha (SE = 0.13) and the goodness-of-fit was adequate ($\chi^2$=1,999, *P* = 0.331). Woodcock density was higher in 2010–2011 ($\underline{x}$ = 0.27 woodcock/ha [SE = 0.12]) than in 2011–2012 ($\underline{x}$ = 0.13 woodcock/ha [SE = 0.02]) when estimated using the intercept-only density model.

*Observation process* Detection-related covariates did not improve the parsimony of models of woodcock density. However, we did assess the shape of the detection curve (e.g., half-normal, uniform, or hazard rate function) separately for PFDs from each year of the study. We measured PFD at 221 locations where we flushed woodcock during both winters of the study. The best-supported detection model included a hazard rate key function and carried 91% of the model weight (*w* = 0.91) when compared to half-normal and uniform models.

Within the land-cover-type model group, the model including land cover was the best-supported model in 2010–2011 and 2011–2012 (*w* = 1.0 in 2010–2011 and 2011–2012). Overall, pine forests 1–3 m tall supported the greatest woodcock density (Fig. 5).

Within the vegetation structure model group, densities were best predicted by canopy cover 0.5–5 m tall (Table 2). In both years of the study, models of density that included canopy cover 0.5–5 m tall were the best-supported (*w*= 0.62 in 2010–2011 and *w* = 0.60 2011–2012) and had *β*-coefficients (2010–2011= 0.28 ± 0.10, 2011–2012 = 0.57 ± 0.09) with 85% confidence intervals that did not contain zero (Fig. 4).

### COMPARISON OF OCCUPANCY AND DENSITY ESTIMATES

In 2010–2011, density of woodcock in pine forest 1–3 m tall was greater than in pine plantations >3 m tall, mature pine forests, and disturbed/tame grassland based on 85% confidence intervals (Table 3; Fig. 5). In 2011–2012, densities in pine forest 1–3 m and SMZ areas were greater than at all other cover types except pine plantation >3 m based on 85% confidence intervals. Occupancy models had an average CV of 3.8%, and density models based on distance sampling had an average CV of 37% (Table 3, Fig. 5).

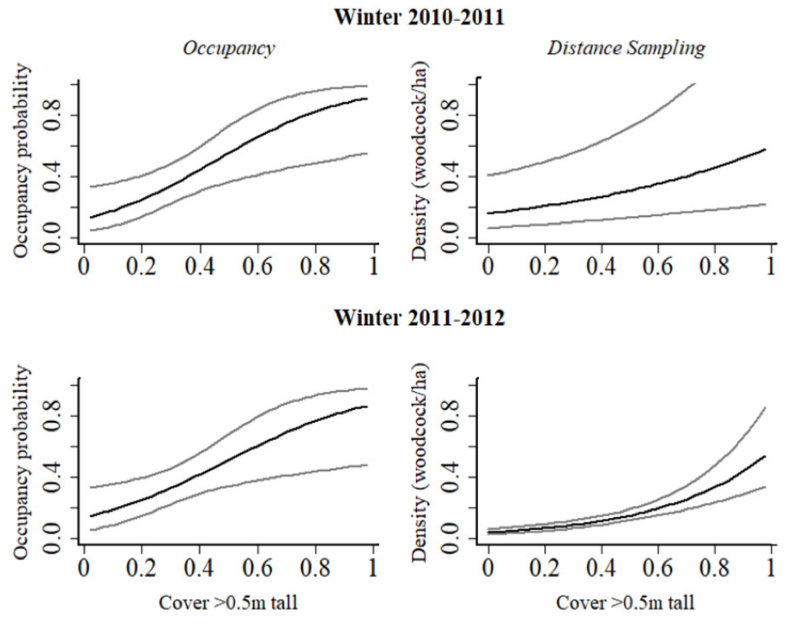

**Figure 4.** Relationships from best-supported models predicting American woodcock occupancy and density during winter in East Texas, USA as a function of the percent canopy cover of vegetation 0.5–5.0 m tall. Plots are from single-season occupancy models (left) and models of density based on distance sampling (right).

## Discussion

Understanding woodcock population response to global and local change necessitates the use of cost-effective monitoring that can identify differences in habitat use among land-cover types and variably distributed resources at broad geographic scales (Morrison 2001, Grimm et al. 2008, Keith et al. 2008, Ellwood et al. 2013). We evaluated the combined use of pointing dogs, hierarchical models, and GIS analysis to characterize woodcock winter habitat use at the survey-site and stand scales (Guthery and Mecozzi 2008, Fiske and Chandler 2011, Diamond and Elliott 2009). Woodcock in East Texas occupied diurnal sites in forest stands having >50% canopy cover 0.5–5 m tall. Additionally, we found that relationships between occupancy and specific land-cover types (stands) differed between years but density of woodcock was consistently higher in pine forest 1–3 m tall. We implemented a modified distance sampling approach to estimate density and compare habitat use among stands with different forest cover types (site-by-land-cover polygons). Effect sizes of factors related to density estimated using distance sampling were greater compared to occupancy modeling and an N-mixture modeling approach described by Sullins (2013), whereas occupancy estimates had lower CVs. Although lower CVs indicated that occupancy estimates were more precise, the greater differences in estimated density among stands may make our distance sampling approach more useful when comparing habitat use among forested cover types or management practices.

Within occupied survey sites, mean stand area was 23.14 ha (SD = 21.50), which is >2X the average diurnal home-range size estimate for wintering woodcock in Alabama ($\underline{x}$ = 9.2 ha, SD = 2.3; Horton and Causey 1979). Although most forested stands had similar occupancy estimates, our occupancy modeling approach that used surveys conducted with trained pointing dogs highlights a potential tool that may aid future surveys for woodcock. In particular, occupancy surveys using pointing dogs could assist in monitoring populations during the winter when they are more difficult to detect than displaying males in spring, and for which limited information exists regarding habitat use and land-cover associations. The simplicity of occupancy estimates limits bias while also maintaining high precision; it is more likely to correctly predict presence or absence as opposed to density (Table 3, Walther and Moore 2005). We observed no use of disturbed or tame grassland and deciduous forest cover types by woodcock during the day on wintering areas in East Texas. The absence of woodcock in deciduous forest stands was likely a result of all forest cover types dominated by hardwoods occurring in drier upland areas on our study areas. The xeric nature of upland deciduous forest combined with drought during our study period likely made this land-cover type unsuitable. We did observe woodcock using more traditional bottomland hardwood forest, but most of these areas included some component of coniferous (*Pinus* spp.) forest cover and were therefore classified as mixed pine/hardwood forest. Disturbed and tame grasslands in our classification system included grasslands and recent clear-cuts. Although the limited use of grasslands by woodcock during the daytime has been previously reported, woodcock in East Texas

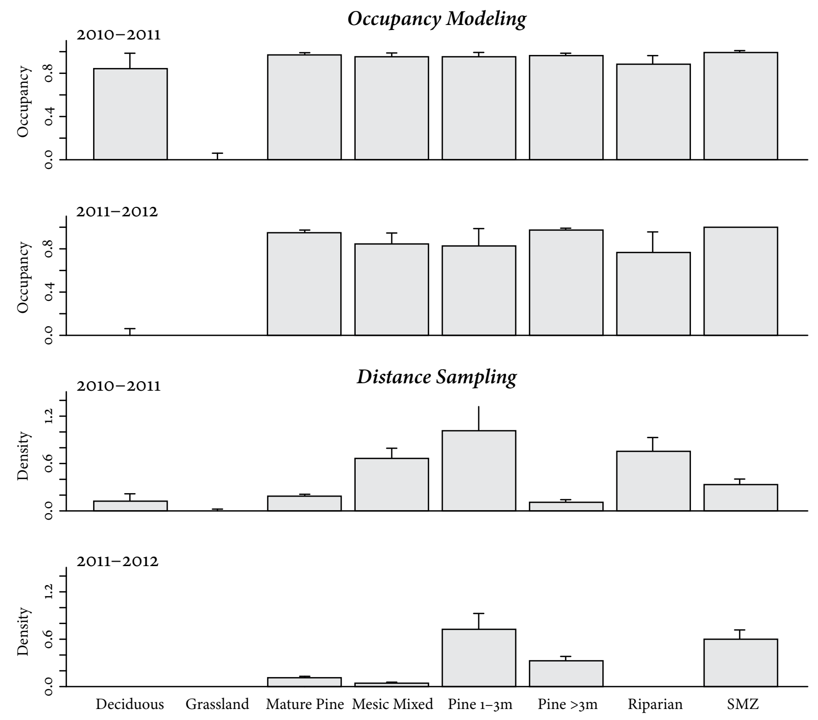

**Figure 5.** Predicted occupancy and density of American woodcock in 8 land-cover types (stands) in East Texas, USA during winter of 2010–2011 and 2011–2012. The 8 land-cover types were deciduous forest (Deciduous), disturbance/tame grassland (Grassland), mature pine forest (Mature Pine), mesic mixed pine/hardwood forest (Mesic Mixed), pine forest 1–3 m tall (Pine 1–3m), pine plantation >3 m tall (Pine >3m), forest wetland/riparian area (Riparian), and streamside management zones (SMZ). See Methods for description of forest stand delineation and details on classification.

were historically known to use recent clear-cuts when forest management incorporated piling debris in windrows (Whiting 2001), suggesting the availability or suitability of this cover type may have changed with changing forest management practices.

Best-supported models of both occupancy and density included canopy cover 0.5–5 m tall, indicating the importance of dense thicket habitat for woodcock in the winter. The probability of occupancy of stands by woodcock increased with percent canopy cover of vegetation 0.5–5 m tall. This relationship with occupancy exhibited a threshold where at ~50% canopy cover of vegetation 0.5–5 m tall the probability of occupancy of woodcock was ~0.5. We also found a more exponential relationship between percent canopy cover of vegetation 0.5–5 m tall with woodcock density (Fig. 4). The information provided from occupancy modeling related to canopy cover covariates may be of greater use to land managers who need to make discrete, yes-or-no decisions when setting specific habitat-related goals (Mavrommati et al. 2016). For questions related to habitat abundance and habitat connectivity, the coarse but precise estimates from the occupancy modeling may be especially useful.

**Table 2.** Hierarchical models (3 highest ranking and intercept-only) used to estimate American woodcock occupancy and density at survey sites in East Texas in winter during 2010–2012. We constructed single-season occupancy models and models of density based on distance sampling in the R package unmarked (Mackenzie et al. 2006, Royle et al. 2004, Fiske and Chandler 2011).

| **Winter 2010–2011** | | | | | **Winter 2011–2012** | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Model**[1,2] | **k** | **AICc** | **ΔAICc** | ***w*** | **Model**[1,2] | **k** | **AICc** | **ΔAICc** | ***w*** |
| **OCCUPANCY** | | | | | | | | | |
| *Vegetation structure* | | | | | | | | | |
| ψ(>0.5m),ρ(.) | 4 | 204.97 | 0.00 | 0.62 | ψ(>0.5m),ρ(.) | 3 | 204.86 | 0.00 | 0.60 |
| ψ(>0.5m+Sdense),ρ(.) | 5 | 206.02 | 1.05 | 0.37 | ψ(>0.5m+Sdense),ρ(.) | 4 | 205.78 | 0.92 | 0.38 |
| ψ (.),ρ(.) | 3 | 213.23 | 8.26 | 0.01 | ψ(.),ρ(.) | 3 | 213.02 | 8.16 | 0.01 |
| *Landcover* | | | | | | | | | |
| ψ($PS^2$),ρ(.) | 4 | 208.22 | 0.00 | 0.19 | ψ(Ltype)ρ(.) | 9 | 200.90 | 0.00 | 0.25 |
| ψ(Ypine+$PS^2$),ρ(.) | 5 | 209.23 | 1.01 | 0.11 | ψ(Wet+Mpine+Ypine+PS) | 8 | 201.81 | 0.91 | 0.16 |
| ψ(Ltype),ρ(.) | 10 | 212.80 | 4.58 | 0.02 | ψ(Mpine+Wet*PS)ρ(.) | 8 | 202.49 | 1.59 | 0.11 |
| ψ(.),ρ(.) | 3 | 213.23 | 5.01 | 0.02 | ψ(.)ρ(.) | 4 | 212.92 | 12.02 | 0.00 |
| **DENSITY** | | | | | | | | | |
| *Vegetation structure* | | | | | | | | | |
| haz(.)λ(>0.5m) | 4 | 442.16 | 0.00 | 0.70 | haz(.)λ(>0.5m) | 4 | 480.27 | 0.00 | 0.68 |
| haz(.) λ(>0.5m+Sdense) | 5 | 444.28 | 2.12 | 0.24 | haz(.)λ(>0.5m+Sdense) | 5 | 481.80 | 1.53 | 0.32 |
| haz(.)λ(.) | 3 | 447.12 | 4.96 | 0.06 | haz(.)λ(.) | 3 | 515.35 | 35.08 | 0.00 |
| *Landcover* | | | | | | | | | |
| haz(.)λ(Ltype) | 10 | 391.85 | 0.00 | 1.00 | haz(.)λ(Ltype) | 10 | 421.14 | 0.00 | 1.00 |
| haz(.) λ(Mpine+Ypine+Wet) | 6 | 405.66 | 13.81 | 0.00 | haz(.)λ(Mpine*PS) | 8 | 457.38 | 36.24 | 0.00 |
| haz(.)λ(Ypine+Wet) | 5 | 406.72 | 14.87 | 0.00 | haz(.)λ(Wet*PS) | 8 | 477.85 | 56.71 | 0.00 |
| haz(.)λ(.) | 3 | 447.12 | 55.27 | 0.00 | haz(.)λ(.) | 3 | 515.35 | 94.21 | 0.00 |

[1] k = no. of parameters, $AIC_c$ =Akaike's Information Criterion adjusted for sample size, $\Delta AIC_c$ = difference in $AIC_c$ relative to smallest $AIC_c$ value. Model symbols included ψ = occupancy probability, ρ = detection probability for multiple-visit models, haz = hazard rate key function used to model detection distance, and λ = abundance parameter.

[2] Covariates represent canopy cover 0.5–5 m tall (>0.5m), stem density of trees >5 m tall (Sdense;trees/ha), area of land-cover stands within survey sites (PS), pine plantation >3 m tall and mature pine forest (Mpine), forest wetland and riparian land-cover types (Wet), young pine forest 1–3 m tall (Ypine), and 8 categorical land-cover types created from Diamond and Elliott (2009; Ltype). The estimated area searched based on distance sampling was used as a probability of detection covariate for all occupancy models.

Our detection curves derived through distance sampling were similar to those reported by Guthery and Mecozzi (2008) for flushes of >7 northern bobwhites (*Colinus virginianus*). Both northern bobwhites and woodcock showed a peak in frequency of detections away from the center of the survey transect, likely due to using PFDs instead of perpendicular distances from a transect that was a straight line. Namely, PFD was not always equivalent to the perpendicular distance because, upon detection, the pointing dog typically stopped ~5 m from the woodcock even when the woodcock would have been directly on the transect (i.e., a perpendicular distance of 0 m). The estimation of detection curves in distance sampling is contingent on probability of detection decreasing as distance from the transect line increases. To meet the assumption of detection decreasing with distance it is important to consider how distance intervals are binned (Buckland et al. 1993). The first bin will likely need to encompass a larger area when surveying wildlife with pointing dogs compared to traditional distance sampling with a human visual observer.

One potential drawback of the distance sampling method we used is that, although the starting points were randomly generated, the paths followed were not completely random. A potential solution to this issue is to generate random, straight-line transects that the dog handler walks while the pointing dog roams freely (Warren and Baines 2011). In this approach, the detection distance is the perpendicular distance from the straight-line transect (i.e., where the handler walks) to where birds flush (Warren and Baines 2011). The Warren and Baines (2011) method was developed in treeless areas where observing flushes is possible at great distances. In contrast, visually monitoring a pointing dog at distances >50 m is not feasible in densely stocked 5-m-tall pine plantations. Although our transects were not completely randomly located we did survey all cover types within survey sites during each visit and the handler stayed <50 m away from the pointing dog to ensure detection of woodcock that flushed unexpectedly.

**Table 3.** Estimates, standard errors (SE), and coefficients of variation (CV) of occupancy and density of American woodcock in 8 land-cover types derived from Diamond and Elliot (2009) in East Texas. We constructed single-season occupancy models and models of density using distance sampling using the R package unmarked (Mackenzie et al. 2006, Royle et al. 2004, Fiske and Chandler 2011).

| | Occupancy | | | Density | | |
|---|---|---|---|---|---|---|
| **Land-cover type** | **Estimate** | **SE** | **CV** | **Estimate** | **SE** | **CV** |
| **2010–2011** | | | | | | |
| Deciduous | 0.84 | 0.15 | 18 | 0.11 | 0.11 | 100 |
| Grassland | 0.00 | 0.06 | N/A | 0.00 | 0.00 | N/A |
| Mature Pine | 0.96 | 0.02 | 2.2 | 0.18 | 0.03 | 16 |
| Mesic Mixed | 0.95 | 0.04 | 3.8 | 0.65 | 0.15 | 23 |
| Pine 1–3m | 0.94 | 0.05 | 5.6 | 1.01 | 0.33 | 32 |
| Pine >3m | 0.96 | 0.03 | 2.8 | 0.10 | 0.04 | 36 |
| Riparian | 0.87 | 0.09 | 10 | 0.74 | 0.18 | 25 |
| SMZ | 0.99 | 0.01 | 1.4 | 0.32 | 0.09 | 28 |
| **2011–2012** | | | | | | |
| Deciduous | 0.00 | 0.06 | N/A | 0.00 | 0.00 | N/A |
| Grassland | 0.00 | 0.00 | N/A | 0.00 | 0.00 | N/A |
| Mature Pine | 0.95 | 0.02 | 0.02 | 0.10 | 0.02 | 16 |
| Mesic Mixed | 0.85 | 0.10 | 0.12 | 0.02 | 0.02 | 100 |
| Pine 1–3m | 0.83 | 0.16 | 0.19 | 0.71 | 0.21 | 30 |
| Pine >3m | 0.97 | 0.02 | 0.02 | 0.33 | 0.05 | 16 |
| Riparian | 0.76 | 0.20 | 0.26 | 0.00 | 0.00 | N/A |
| SMZ | 1.00 | 0.00 | <0.001 | 0.59 | 0.12 | 20 |

[1] Land-cover type abbreviations are for deciduous forest (Deciduous), disturbance/tame grassland (Grassland), mature pine forest (Mature Pine), mesic mixed pine/hardwood forest (Mesic Mixed), pine forest 1–3 m tall (Pine 1–3m), pine plantation >3 m tall (Pine >3m), forest wetland/riparian area (Riparian), and streamside management zones (SMZ).

### COMPARISON OF OCCUPANCY AND DENSITY ESTIMATES

Density and occupancy are inherently related (Kery and Royle 2016, Miller et al. 2016). Occupancy and density are linearly related when species are rare and local abundance is low. In contrast, when a species is common, density can provide more inference on relationships between abundance and habitat-related variables (Kery and Royle 2016). In East Texas during winter, woodcock were common throughout almost all forest cover types, and density estimates improved inference of habitat use among forest cover types (Table 3) compared with occupancy estimates. Occupancy estimates within forest cover types, excluding deciduous forests in 2011–2012, ranged from 0.76–1.00, whereas density estimates ranged from 0.02–1.00 woodcock/ha. If the goal of future research or monitoring is to evaluate differences in habitat use among categorically defined patches—whether land-cover type, as in this example, soil type, or management practice—the distance-sampling approach has the greatest potential value. Quantifying differences in habitat use among sites using occupancy may be most effective when the proportion of occupied sites approaches 0.5 (Kery and Royle 2016).

## Management Implications

Effective monitoring is a necessary step for the adaptive management of landscapes for woodcock. Using pointing dogs to monitor woodcock populations provides an option for estimating abundance of woodcock outside of breeding season when Singing Ground Surveys are conducted, and may provide an effective means of evaluating management on the wintering grounds and at migratory stopover sites. Our monitoring of woodcock occupancy and densities indicated that current forest management practices in East Texas provided habitat for woodcock at broad scales, and that use of cover types varies among years with greatest densities in pine forests 1–3 m tall. Therefore, forest management that maintains a heterogeneity of forested cover types on the landscape may be ideal. We advise future winter monitoring efforts to survey between 15 December – 31 January if possible, based on known arrival and departure dates on wintering grounds. Finally, a stratified random sampling design to distribute starting points among categorical land-cover covariates is appropriate when differences in occupancy or densities among cover types is the question of interest. Our survey protocol was not extravagant and, therefore, field work could be replicated with limited funding when matched with the proper personnel ($300–700 for a GPS collar and handheld unit).

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## Supplemental Material

### METHODS

*Stratified random sampling of survey sites based on soil suitability* We derived digital soil suitability following Cade (1985) using SSURGO (Soil Survey Geographic Database) soil maps to stratify sampling and identify survey sites (Sullins 2013, Soil Survey Staff 2017). Soil suitability scores were based on the texture and drainage characteristics of soil types, and we used them to evaluate the Cade (1985) woodcock wintering habitat suitability index model in a concurrent research project (Sullins 2013). Soil suitability scores ranged from 0–1, where a soil suitability score of 0 indicated unsuitable soils for woodcock and a score of 1 indicated optimal soils (Cade 1985). In DCNF, we randomly selected 6 survey sites within 3 different classes of soil suitability scores: 0–0.39, 0.4–0.85, and 0.86–1.0. At the Campbell Unit, we randomly selected survey sites within 2 classes of soil suitability scores (0–0.85, and 0.86–1.0), because there were fewer soil types present and they were less variable than those at DCNF. We selected survey sites only if the assigned soil suitability class comprised ≥40% of its area.

*Landcover classification and aggregation* Pine forest 1–3 m tall included both pine plantations and naturally regenerating pine forest. We delineated the SMZ classification and land-cover classification corrections for timber stands harvested after publication of Diamond and Elliott (2009) using satellite imagery provided as a basemap in ArcGIS 10 (imagery provided by ESRI, i-cubed, USDA FSA, USGS, AEX, GeoEye, Getmapping, Aerogrid, and IGP). Streamside management zones were typically mixed pine/hardwood or hardwood forest, and included areas within 30–80 m of ephemeral streams. We combined stands of pine plantation >3 m tall and mature pine forest land-cover classifications from Diamond and Elliott (2009) to estimate proportion of mature pine forest (Mpine). We grouped all wetland, SMZ, and stream/riparian cover types together to estimate proportion of wet cover (Wet) because woodcock are thought to select young forest cover types with moist soil (Straw et al. 1994, Berry et al. 2006).

*Survey site occupancy* We estimated woodcock occupancy ($\psi$) and detection probabilities ($\rho$) at the survey site scale using the package unmarked (Fiske and Chandler 2011) in R (R Development Core Team 2016) and following Mackenzie et al. (2006). We estimated naïve occupancy for each winter (i.e., 2010–2011 and 2011–2012) as the ratio of sites having ≥1 detection to those with zero woodcock detections. We modeled detection at the survey site scale and included covariates for study area, percent mature pine forest (Diamond and Elliott 2009), percent vegetation cover <0.3 m tall, percent vegetation cover 0.5–5 m tall, average daily temperature (degrees C), ordinal date (0 + median survey date each winter), and precipitation (mm accumulated in 7 d leading up to survey). After obtaining the top-ranking detection model based on $AIC_c$, we kept the detection portion of the model constant, using the covariate from the top-ranked detection model, and fit models with the same covariates list immediately above to predict the latent occupancy process.

We tested goodness-of-fit of the global model using 1,234 bootstrap samples and considered models overdispersed if $\hat{c} > 1.0$ (Burnham and Anderson 2002, Mackenzie and Bailey 2004). When models were overdispersed (i.e., $\hat{c} > 1.0$), we used $QAIC_c$ for model selection and inflated parameter standard error estimates by $\sqrt{\hat{c}}$ (Burnham and Anderson 2002, Mackenzie et al. 2006). We estimated the probability of not detecting a woodcock at a site where it was actually present using:

$$(1- \rho)^n,$$

where $n$ was the number of surveys per survey site (Mackenzie et al. 2006).

## RESULTS

*Survey Site Occupancy* In winter 2010–2011, most (77%; 14/18) 0.5-km radius survey sites at DCNF and all (6/6) survey sites at the Campbell Unit were occupied by ≥1 woodcock. The total proportion of survey sites occupied (naïve $\psi$) in 2010–2011, not adjusted for detection probability, was 0.83. In 2011–2012, 3 survey sites occupied the prior winter were not occupied, and 1 previously unoccupied survey site was occupied at DCNF. There was no change in occupancy at survey sites at the Campbell Unit, as we detected woodcock during ≥1 survey at all survey sites during both winters. For both study areas combined, in 2011–2012, the naïve occupancy estimate was 0.71 (17/24 survey sites). In the winter of 2011–2012, we detected ≥1 woodcock at all Campbell Unit survey sites and 61% of DCNF survey sites. For both winters combined, we detected woodcock at least once on 87% of survey sites, detected 1–3 woodcock at 50% of occupied survey sites, and detected a maximum of 8 woodcock during a single survey.

The best-supported detection probability model for both years did not include any covariates and we used the intercept-only model to estimate detection as $\rho = 0.61$ (SE = 0.07) in 2010–2011 and $\rho = 0.75$ (SE = 0.05) in 2011–2012. Overall $\psi$ was 0.89 (SE = 0.09) and 0.71 (SE = 0.09) in 2010–2011 and 2011–2012, respectively. The estimated proportion of survey sites where woodcock were present but not detected during our surveys (i.e., false negative) was 0.06 (2010–2011) and <0.01 (2011–2012). Model goodness-of-fit estimated from 1,234 bootstrap simulations provided evidence of slight overdispersion in 2010–2011($\hat{c}$ = 1.39, p = 0.23) and no overdispersion in 2011–2012 ($\hat{c}$ = 0.62, p = 0.88).

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# Habitat Selection of American Woodcock and its Implications for Habitat Management Where Young Forests are Rare

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**ABSTRACT** American woodcock (*Scolopax minor*; hereafter woodcock) habitat use or selection has been studied extensively since the mid-1960s; most such studies, however, have taken place when and where young forest habitat selected by woodcock was relatively common. Woodcock population declines have been mostly attributed to loss of young forest vegetation types throughout the species' range. Thus, understanding woodcock habitat selection and the benefits of habitat management in areas where young forests are rare is important in conserving woodcock and other wildlife that uses young forest. We conducted studies of male radio-tagged woodcock in Rhode Island, USA, when and where the extent of upland young forests in non-coastal areas comprised only 1.4% of the land area and was decreasing by ≥1.5% per year. We determined habitat selection of woodcock, then used the derived resource selection function to assess potential benefits of certain forest management scenarios for male woodcock and non-target birds. Landscapes comprising deciduous wetland forests, wetland young forests with nearby agricultural openings, or patches of upland young forest received relatively high use by woodcock. After integrating habitat management scenarios into GIS, our derived resource selection function suggested that creating fewer, larger patches of upland young forest and herbaceous forest openings may be less beneficial than creating more smaller patches. Openings with early-successional forest were an important component of woodcock habitat because they provided safe nighttime roost sites where mammalian predators were less active. These openings also provided habitat for a more diverse bird assemblage than unmanaged forests. Active habitat management is required to conserve woodcock populations in many landscapes, and managers should highlight the benefits of woodcock habitat management for non-target wildlife.

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**KEY WORDS:** American woodcock, habitat selection, habitat management, resource selection function, predation risk, young forest, songbirds, umbrella species

The American woodcock (*Scolopax minor*; hereafter woodcock) is a popular game bird in eastern and central regions of the United States and eastern Canada. Hunters spent ~399,700 days afield and killed ~200,200 woodcock during

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the 2015–2016 season (Seamans and Rau 2016). Woodcock populations throughout the species range have declined since the late 1960s, and this does not appear to be related to hunting mortality (McAuley et al. 2005, Seamans and Rau 2016). Given that woodcock hunting mortality under current regulations is likely compensatory in nature, population declines are likely caused by habitat loss and reduced habitat quality (Sauer and Bortner 1991, Dessecker and McAuley 2001, McAuley et al. 2005).

Woodcock habitat use and selection has been studied extensively since the mid 1960s. On breeding grounds, and depending on activity and time of day, woodcock generally use a variety of early successional cover types, including herb-dominated forest openings, abandoned hayfields, recent clearcuts, and regenerating stands of young forest (Sheldon 1967, Wishart and Bider 1976, Gutzwiller et al. 1983, McAuley et al. 1996, Dessecker and McAuley 2001). Forest openings provide breeding sites (i.e., singing grounds) during springtime crepuscular periods and roosting sites during summer nights, whereas dense stands of young forest, generally <30 years old, provide nesting sites for females and daytime feeding sites for all age-sex classes (Kelley et al. 2008). Woodcock routinely commute on a given day between dense stands of young forest and more sparsely vegetated forest openings at dusk and dawn (Sheldon 1961, Owen and Morgan 1975, Masse et al. 2013). As a result, they spend most of their time during the breeding season in daytime feeding coverts, and these dense vegetation types are important for providing access to food and protection from diurnal predators (Keppie and Whiting 1994, Dessecker and McAuley 2001).

Most studies of woodcock habitat use during the breeding season occurred in earlier times (e.g., 1960s–1990s) or in areas (e.g., Maine, central Massachusetts, and Pennsylvania, USA; Quebec, Canada) when and where young forests were relatively common (e.g., Sheldon 1967, Wishart and Bider 1976, Hudgins et al. 1985, McAuley et al. 1996). During the 1950s–1990s, the extent of young forest declined across the northeastern and most of the north-central United States, but seedling-sapling timberland still comprised roughly 15–30% of forest cover towards the end of this period (Trani et al. 2001). However, the extent of young forest has continued to decline in most areas, and this vegetation type is rare in some regions of the woodcock breeding range. In Rhode Island, USA, shrubland or young forest vegetation types comprised only 3.3% of the land area during 2008 (Buffum et al. 2011). Importantly, these vegetation types covered only 1.4% of non-coastal uplands, sites where woodcock habitat management is most feasible, and their extent was decreasing by ≥1.5% per year (Buffum et al. 2011).

Because young forests have become less common on many landscapes, it is important to understand woodcock habitat use and the benefits of woodcock habitat management under current conditions. This is true for managers in areas where young forest initiatives are planned or occurring; increasing the extent of these young forest vegetation types can help conserve woodcock and other wildlife. Herein we describe key findings from recent woodcock studies that we conducted in Rhode Island, and discuss their implications for habitat management. Our specific objectives were to: 1) illustrate the use of a resource selection function we developed for demonstrating responses of woodcock to different habitat management scenarios in areas where young forest is rare, and 2) highlight specific benefits of woodcock habitat management practices for woodcock and non-target birds.

## Study Area

We conducted our studies at Arcadia, Big River, and Great Swamp Wildlife Management Areas (WMAs) in Kent and Washington counties, Rhode Island. Arcadia WMA was the largest (ca. 6,200 ha) followed by Big River (ca. 3,300 ha) and Great Swamp WMAs (ca. 1,500 ha). All 3 WMAs were forest-dominated, but relative amounts of dominant forest cover types differed among sites. Upland forest (coniferous, deciduous, and mixed) was co-dominant at Arcadia WMA, whereas coniferous upland forest was dominant at Big River WMA and wetland forest was dominant at Great Swamp WMA. Eastern white pine (*Pinus strobus*) comprised the majority of coniferous upland forests; various oaks (*Quercus* spp.), hickories (*Carya* spp.), and red maple (*Acer rubrum*) dominated deciduous upland forests; and red maple swamps were the most abundant wetland forest type (Enser and Lundgren 2006).

From 1995–2006, the Rhode Island Department of Environmental Management began creating scattered patches (2–5 ha each) of young forest at each WMA to help conserve woodcock and other young forest wildlife. Sections of older, secondary forest were generally clearcut, resulting in young forest patches typically dominated by coppice growth. More consistent and concentrated young forest management began at Great Swamp WMA during 2007, and that site was designated a Woodcock Habitat Demonstration Area in 2008 (Buffum et al., this volume). Young forest was rare at Arcadia and Big River WMAs (1–2% of total area), but more common at Great Swamp WMA (15%) given more frequent clearcutting at that site. Abandoned meadows and agricultural fields were also rare and widely scattered at each site.

## Methods

### WOODCOCK RESOURCE SELECTION

During April–May, 2011–2012, we captured 92 male woodcock on singing grounds using mist-nets and attached a Model A5400 transmitter (Advanced Telemetry Systems, Isanti, MN) to each bird following McAuley et al. (1993).

We released all woodcock immediately after marking. Approximately 1 week after release, we tracked tagged woodcock via homing up to 4 times per week between 23 May–25 August and marked locations of tagged woodcock once per day (0600–1900 EST) using a Garmin eTrex GPS unit (Garmin Ltd., Canton of Schaffhausen, Switzerland). We included in our analyses 52 individuals with >25 locations throughout the summer monitoring period: 27 males during 2011 and 25 males during 2012.

We used kernel density methods (Worton 1989) to determine the summer home range (95% contour) and core-use area (50% contour) of each bird. We estimated available and used habitat (design I study, sampling protocol A; Manly et al. 2002) at each management area by creating a single composite home range for all tagged woodcock and placing a minimum convex polygon (Mohr 1947) around this, and creating a single composite core-use area for all tagged woodcock, respectively (Masse et al. 2014). We used ArcGIS 10.1 (Environmental Systems Research Institute 2012) to clip areas of available and used habitat by forest boundaries and converted these areas into raster grids (10 $m^2$ pixels). As described in Masse et al. (2014), we generated raster grids for elevation (m), slope (%), forest cover type, and distance (m) to nearest stream, agricultural opening, upland young forest, and moist soil. We randomly selected 10% of available *(n* = 40,090) and used *(n* = 3,047) pixels and extracted raster grid values from these.

We used logistic regression to estimate coefficients for the exponential resource selection function (RSF; $[w(x) = exp(\beta_{1x1} + \ldots + \beta_{pxp})]$; Manly et al. 2002) based on available and used habitat (Johnson et al. 2006). We ranked 15 candidate models using Akaike's Information Criterion (Anderson et al. 2000) and used the best-supported model to map (Raster Calculator; ArcGIS 10.1) relative probability of use by male woodcock across a 400-ha case study area at Arcadia WMA (see Masse et al. 2014). We defined categories of relative probability of use (low ≤ 0.2446; low-moderate = 0.2447–0.3355; moderate = 0.3356–0.5802; moderate-high = 0.5803–1.2381; and high ≥ 1.2382) using geometrical interval classification (ArcGIS 10.1) and assessed the proportionality of our RSF to true probability of use following Johnson et al. (2006). We retained coefficients for upland and wetland forest cover types in our best-supported RSF model regardless of statistical significance because these forest types have been shown in previous studies to be used differentially for daytime coverts (Sheldon 1967, Keppie and Whiting 1994), and because retaining these cover types during modeling of hypothetical management scenarios facilitated illustrating relative differences in probability of use by woodcock across all forest cover types in the case study area. We then simulated 3 hypothetical forest management scenarios on the study area and observed how relative probability of use by woodcock changed. Scenario 1 involved creating 7 patches of young forest (2–10 ha each) and 3 herb-dominated forest openings (2–6 ha each) on 10% (i.e., 40 ha) of the case study area (Masse et al. 2014). We compared this Scenario 1 to 2 other scenarios not previously considered in Masse et al. (2014). For Scenario 2, we simulated the same level of management, but in fewer, larger patches: 2 patches of young forest (ca. 15 ha each) and 1 10-ha herbaceous forest opening. Scenario 3 involved simulating a higher level of management on the case study area (i.e., 60 ha or 15%) by creating 10 patches of young forest (2–10 ha each) and 5 herbaceous forest openings (2–6 ha each).

### WHY WOODCOCK COMMUTE

From 1 July – 20 August 2011 – 2012, we simultaneously monitored nighttime (2030 – 0240 EST) locations for a subset of our marked woodcock. Because we were interested in determining factors that influenced woodcock commuting behavior between diurnal coverts and nocturnal roosts, we only included individuals that we detected moving between these sites. We acknowledge that some individuals may not move between diurnal coverts and nocturnal roosts, and that areas these individuals select may be particularly important. However, we did not know if individuals never moved between sites or simply did not move between sites during nights we monitored. Thus, including only the woodcock we were certain had moved provided the strongest test of the commuting hypotheses. We flushed each woodcock once from its nocturnal roost, and once from its diurnal covert on the following day, to mark exact sites where woodcock were located. After flushing, we immediately dug 5 $900\text{-cm}^3$ soil pits to 10-cm deep around each flush site (Masse et al. 2013). We sealed soil pit contents from nocturnal roosts in plastic bags overnight and collected soil macroinvertebrates via hand sorting the following day, whereas we immediately collected soil macroinvertebrates from soil pits dug at diurnal coverts. We also monitored mammalian predator activity at nocturnal roosts and diurnal coverts during 2011 and 2012 using baited track stations (Linhart and Knowlton 1975) and camera traps (Gompper et al. 2006), respectively (Masse et al. 2013). For each tagged woodcock's locations, we simultaneously monitored sites for evidence of mammalian predator activity for a 10-day (2011) or 14-day period (2012).

We quantified food availability at nocturnal roosts and diurnal coverts for 38 woodcock (2011: *n* = 17; 2012: *n* = 21). We calculated earthworm (Haplotaxida) mass (g), density (no./$m^2$) of potential prey, and species richness and diversity (Jost 2006) of potential prey at nocturnal roosts and diurnal coverts, and compared these using paired *t*-tests or Wilcoxon signed-rank tests (Ott and Longnecker 2010). To maintain our paired design and promote independence of observations, we quantified predator activity at nocturnal roosts and diurnal coverts for 11 woodcock during

2011 and 12 woodcock during 2012 (see Masse et al. 2013). During 2011, we counted the number of nights (out of 10) that a mammalian predator visited a woodcock's nocturnal roost or diurnal covert and compared these counts using log-linear regression (Agresti 2007, Pedan 2011) with woodcock frequency as a random effect. During 2012, we used paired *t*-tests to compare the number of days until any predator (mammalian or avian) visited a woodcock's nocturnal roost or diurnal covert.

### BENEFITS OF WOODCOCK HABITAT MANAGEMENT FOR NON-TARGET BIRDS

Each spring, we marked locations of singing grounds using a Garmin eTrex GPS unit and quantified the relative abundance and diversity of non-target birds associated with these sites using standard (i.e., 10-min, 50-m radius) point count surveys (Ralph et al. 1993) from 27 May – 2 July. We limited point counts to woodcock singing grounds—as opposed to randomly selected patches of young forest—because singing grounds are critical components of woodcock habitat (Dessecker and McAuley 2001) and we were certain woodcock were using these exact sites. Thus, this provided a sound study design for assessing the potential of woodcock to serve as an umbrella species. During 2011, we surveyed a random subset of 9 singing grounds at Arcadia and Great Swamp WMAs that were ≥200 m from other singing grounds, and during 2012–2013 we surveyed a random subset of 10 singing grounds at each of the 3 WMAs (Masse et al. 2015). We also generated a random sample of 10 locations in unmanaged forest (i.e., 60–100 year-old second-growth) at each WMA and conducted identical point counts at these sites each year. We counted the total number of birds and calculated bird diversity (Jost 2006) at each singing ground and random forest site, and compared these using a linear mixed model (see Masse et al. 2015). We also calculated relative abundances for the 3 most common species at each type of site to highlight differences in the composition of bird assemblages.

## Results

Our highest-ranked RSF indicated that probability of use by male woodcock increased in deciduous wetland forest ($\beta$ = 0.68390, SE = 0.06688, $z$ = 10.225, $P$ < 0.01), wetland young forest ($\beta$ = 0.39340, SE = 0.09719, $z$ = 4.048, $P$ < 0.01), and mixed wetland forest ($\beta$ = 0.19930, SE = 0.09273, $z$ = 2.149, $P$ = 0.03), and marginally so in deciduous upland forest ($\beta$ = 0.09060, SE = 0.05612, $z$ = 1.614, $P$ = 0.11), compared to mixed upland forest [(reference cover type; see Masse et al. (2014) for a more complete description of the RSF]. Increased elevation ($\beta$ = 0.00210, SE = 0.00076, $z$ = 2.781, $P$ < 0.01) led to increased probability of use by woodcock. Probability of use by woodcock decreased in coniferous upland forest ($\beta$ = -0.31110, SE = 0.06277, $z$ = -4.956, $P$ < 0.01) and upland young forest ($\beta$ = -0.22690, SE = 0.13770, $z$ = -1.648, $P$ = 0.10), and was not influenced by coniferous wetland forest ($\beta$ = -0.02730, SE = 0.16460, $z$ = -0.166, $P$ = 0.87) compared to mixed upland forest. In addition, probability of use by woodcock decreased on higher slopes ($\beta$ = -0.01870, SE = 0.00354, $z$ = -5.295, $P$ < 0.01) and at greater distances to the nearest agricultural opening ($\beta$ = -0.00162, SE = 0.00008, $z$ = -20.718, $P$ < 0.01), moist soil ($\beta$ = -0.00117, SE = 0.00024, $z$ = -4.954, $P$ < 0.01), stream ($\beta$ = -0.00080, SE = 0.00011, $z$ = -7.508, $P$ < 0.01), and upland young forest ($\beta$ = -0.00025, SE = 0.00006, $z$ = -4.460, $P$ < 0.01). Management Scenario 1 reduced the extent of low probability of use by 92 ha, whereas we observed simultaneous increases in the extents of low-moderate (+26 ha), moderate (+38 ha), and moderate-high (+16 ha) probabil-

**Table 1.** Forest area (ha) in each category of relative probability of use [P(use)] by male American woodcock before and after implementation of 3 possible habitat management scenarios simulated using a Resource Selection Function developed for woodcock (Masse et al. 2014) in Rhode Island, USA. Change in forest area (Δ) illustrates how probability of use changed in response to each forest management scenario (i.e., Δ = after - before). Management Scenario 1 involved managing 40 ha (10% of study area in southwestern Rhode Island) by creating 7 patches of young forest (2–10 ha each) and 3 herbaceous forest openings (2–6 ha each). Scenario 2 involved the same amount of management (i.e., 40 ha), but in fewer, larger patches of young forest *(n* = 2; 15 ha each) and 1 herbaceous forest opening (10 ha). Scenario 3 involved managing 60 ha (15% of case study area) by creating 10 patches of young forest (2–10 ha each) and 5 herbaceous forest openings (2–6 ha each).

| | **Management Scenario 1** | | | **Management Scenario 2** | | | **Management Scenario 3** | | |
|---|---|---|---|---|---|---|---|---|---|
| **P(use)** | **Before** | **After** | **Δ** | **Before** | **After** | **Δ** | **Before** | **After** | **Δ** |
| Low | 210 | 118 | -92 | 210 | 196 | -14 | 210 | 120 | -90 |
| Low-moderate | 77 | 103 | 26 | 77 | 78 | 1 | 77 | 106 | 29 |
| Moderate | 77 | 115 | 38 | 77 | 81 | 4 | 77 | 111 | 34 |
| Moderate-high | 22 | 38 | 16 | 22 | 26 | 4 | 22 | 37 | 15 |
| High | 3 | 5 | 2 | 3 | 4 | 1 | 3 | 5 | 2 |

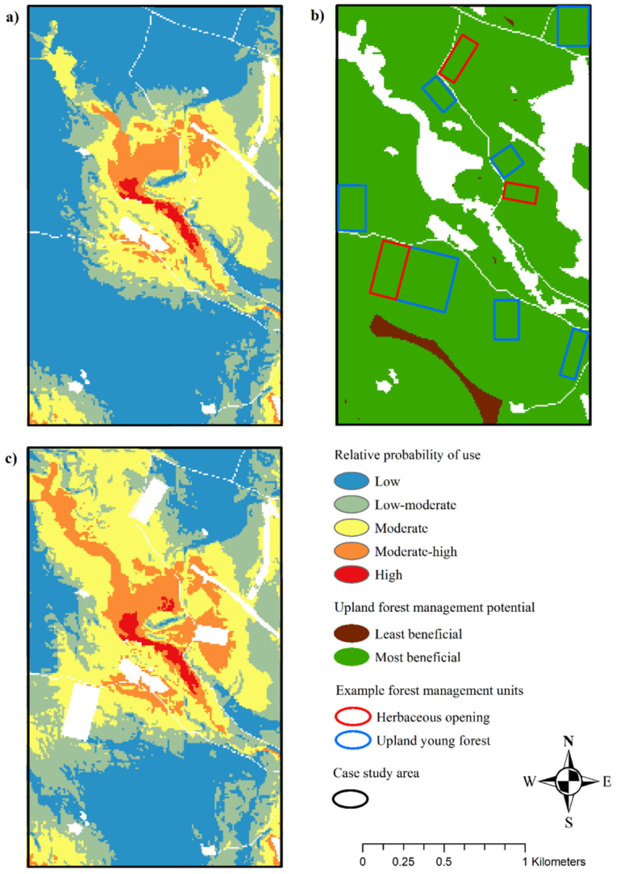

**Figure 1.** Probability of use by male woodcock of forested land in a 400-ha case study area in Arcadia Wildlife Management Area in southwestern Rhode Island, USA, that is considered for forest management (A). The hypothetical forest management scenario considered for this site (B) included creating 30 ha of upland young forest (7 patches; 2–10 ha each) and 10 ha of herbaceous forest openings (e.g., wildlife openings or old fields; 3 patches; 2–6 ha each) in areas of older second-growth upland forest (e.g., 60–100 years) deemed most beneficial for woodcock habitat management. Following management (C), the estimated extent of low relative use by woodcock of the managed forest decreased by 92 ha whereas the estimated extents of low-moderate, moderate, and moderate-high relative use increased by 26 ha, 38 ha, and 16 ha, respectively. White areas represent non-forested cover types in panels A and C, and represent these cover types along with cover types other than older second-growth upland forest in panel B. Reprinted from Masse et al. (2014) with permission from Elsevier.

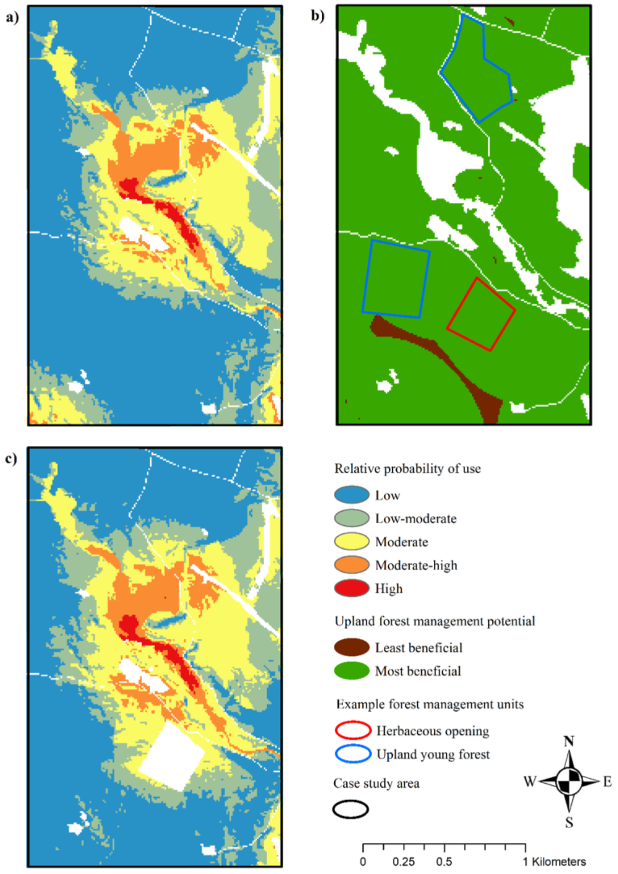

**Figure 2.** Probability of use by male woodcock of forested land in a 400-ha case study area in Arcadia Wildlife Management Area in southwestern Rhode Island, USA, that is considered for forest management (A). The hypothetical forest management scenario considered for this site (B) included creating 30 ha of upland young forest (2 patches; 15 ha each) and one 10-ha herbaceous forest opening (e.g., wildlife opening or old field) in areas of older second-growth upland forest (e.g., 60–100 years) deemed most beneficial for woodcock habitat management. Following management (C), the estimated extent of low relative use by woodcock of the managed forest decreased by 14 ha. The estimated extents of low-moderate, moderate, and moderate-high relative use increased by ≤4 ha. White areas represent non-forested cover types in panels A and C, and represent these cover types along with cover types other than older second-growth upland forest in panel B.

ities of use (Fig. 1). Scenario 2 reduced the extent of low probability of use from 210 ha to 196 ha. All other categories of use increased by ≤4 ha (Fig. 2; Table 1). In contrast, Scenario 3 reduced the area of low probability of use from 210 ha to 120 ha and increased the areas of low-moderate (+29 ha), moderate (+34 ha), and moderate-high (+15 ha) probabilities of use (Fig. 3).

Average earthworm density (no./m$^2$) was consistently greater at male woodcock diurnal coverts (2011 = 30.59; 2012 = 15.66) than nocturnal roosts (2011 = 9.93, $t_{16}$ = 2.14, $P$ = 0.02; 2012 = 4.23, $t_{20}$ = 2.52, $P$ = 0.01). Likewise, the average difference in earthworm fresh mass between diurnal coverts and nocturnal roosts was approximately 10 grams during 2011($t_{16}$ = 2.10, $P$ = 0.03) and 2012 ($t_{20}$ = 3.25, $P$ < 0.01). The average difference in earthworm dry mass between sites was approximately 3 g during 2011 ($t_{16}$ = 2.12, $P$ = 0.03) and 2 grams during 2012 ($t_{20}$ = 3.39, $P$ < 0.01). The combined density of potential woodcock prey was similar at diurnal covers and nocturnal roosts during 2011 ($t_{16}$ = 1.14, $P$ = 0.27) and 2012 (V = 102, $P$ = 0.66), whereas richness ($t_{16}$ = 2.85, $P$ = 0.01) and diversity ($t_{16}$ = 2.30, $P$ = 0.04) of woodcock prey tended to be higher at diurnal coverts during 2011. During 2012, richness ($t_{20}$ = 1.06, $P$ = 0.30) and diversity ($t_{20}$ = 0.54, $P$ = 0.59) of woodcock prey were similar between sites (see Fig. 1B–C in Masse et al. 2013). Mammalian predators visited track stations at nocturnal roosts less often than diurnal coverts for 8 of 11 marked woodcock during 2011 (F1, 10 = 8.11, $P$ = 0.02), and the number of days until initial predator visit was longer at nocturnal roosts than diurnal coverts for 9 of 12 woodcock during 2012 ($t_{11}$ = 2.02, $P$ = 0.03).

On average, the number and diversity of birds associated with singing grounds was ≥1.5 times greater than that of unmanaged forest sites at each of the WMAs (Fig. 4). At each WMA, young forest species such as cedar waxwing (*Bombycilla cedrorum*), gray catbird (*Dumetella carolinensis*), common yellowthroat (*Geothlypis trichas*), and prairie warbler (*Setophaga discolor*) were more common at singing grounds (Fig. 1 in Masse et al. 2015). In contrast, forest generalists (e.g., red-eyed vireo [*Vireo olivaceus*]) or more mature forest species (e.g., ovenbird [*Seiurus aurocapilla*]) were most common at unmanaged forest sites during our breeding season surveys, but such species readily utilize patches of young forest during the post-fledging period (Chandler et al. 2012).

## Discussion

We found that in areas where upland young forests are rare, male woodcock tend to use forest cover types other than upland young forests for daytime coverts. Specifically, deciduous wetland forests were favored, followed by wetland young forests and mixed wetland forests. Coniferous upland forests exerted the strongest negative effect on probability of use by woodcock, whereas we detected no significant effect of deciduous upland forest, upland young forest, and coniferous wetland forest on probability of use by woodcock. Although young upland forests typically are regarded as an important component of woodcock habitat (Keppie and Whiting 1994), these areas were uncommon at our study sites and tended to be less frequently used by male woodcock compared to some other forest types. We conclude that in areas where preferred young upland forests are rare, male woodcock select among the best remaining available vegetation types (Sepik et al. 1989),

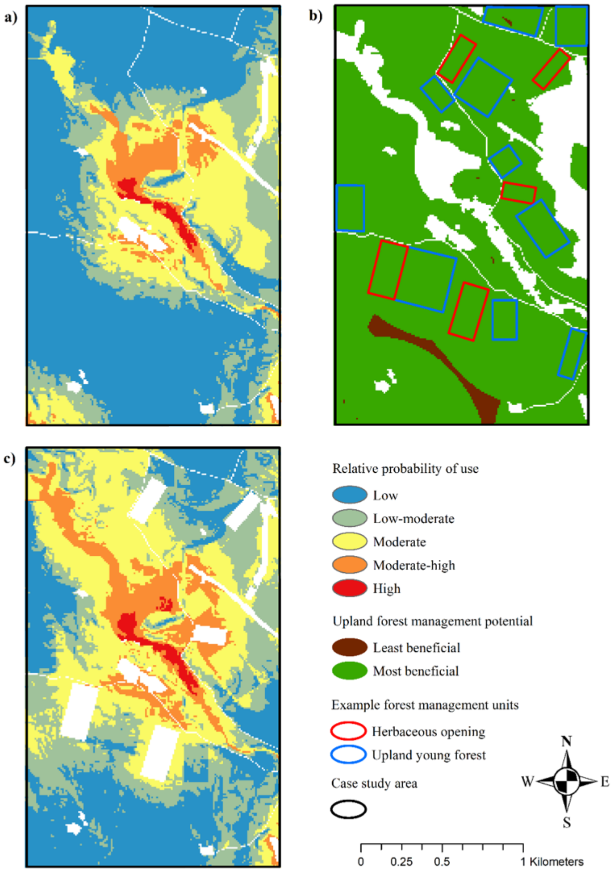

**Figure 3.** Probability of use by male woodcock of forested land in a 400-ha case study area in Arcadia Wildlife Management Area in southwestern Rhode Island, USA, that is considered for forest management (A). The hypothetical forest management scenario considered for this site (B) included creating about 40 ha of upland young forest (10 patches; 2–10 ha each) and 20 ha of herbaceous forest openings (e.g., wildlife openings or old fields; 5 patches; 2–6 ha each) in areas of older second-growth upland forest (e.g., 60–100 years) deemed most beneficial for woodcock habitat management. Following management (C), the estimated extent of low relative use by woodcock of the managed forest decreased by 90 ha whereas the estimated extents of low-moderate, moderate, and moderate-high relative use increased by 29 ha, 34 ha, and 15 ha, respectively. White areas represent non-forested cover types in panels A and C, and represent these cover types along with cover types other than older second-growth upland forest in panel B.

which in our study area was wetland forests with relatively dense understory vegetation (Masse et al. 2014). However, because we only investigated male woodcock, and we did not investigate demographic parameters such as survival or reproduction, we are unable to speculate on the consequences of this habitat use for woodcock populations in southern New England.

In Rhode Island, higher shrub and sapling density, and shorter and smaller-diameter trees, characterized deciduous wetland forests and wetland young forests favored by male woodcock (Masse et al. 2014). These patterns are similar to structural characteristics of woodcock diurnal coverts described in other parts of the breeding range (Rabe 1977, Hudgins et al. 1985, Straw et al. 1986, Keppie and Whiting 1994). Consequently, these wetland forest types may provide woodcock with similar protective cover from diurnal predators in areas where upland young forests are rare. Indeed, older forests (e.g., >30 years) may represent an important component of woodcock habitat if shrub and sapling densities are sufficiently high (Williamson 2010). Areas with moist soils also help to ensure more consistent access to earthworms (Dessecker and McAuley 2001), and so deciduous wetland forests and young wetland forests in Rhode Island were likely favored by woodcock because these areas provided adequate food and cover (Masse et al. 2014).

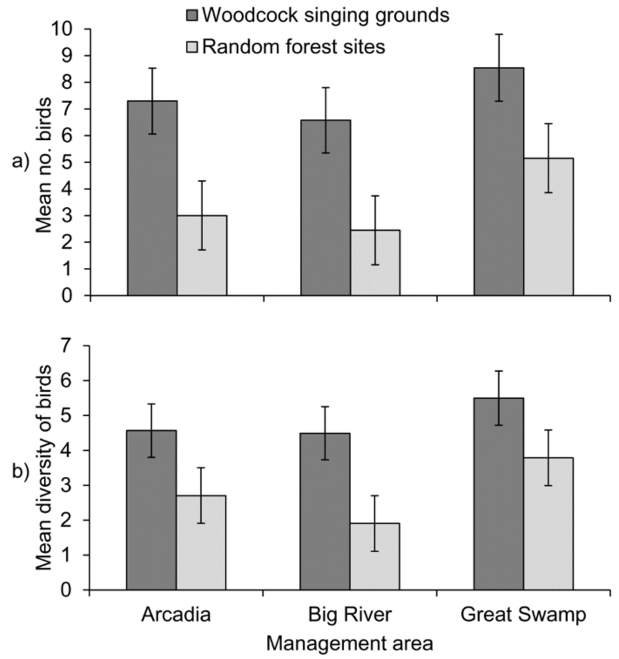

**Figure 4.** Mean number of birds (A) and diversity of birds (B) per 50-m-radius point count location at woodcock singing grounds and nearby random forest sites based on 10-minute point count surveys conducted from 27 May–2 July 2011–2013 at Arcadia and Great Swamp Wildlife Management Areas, and 2012–2013 at Big River Wildlife Management Area, in Kent and Washington counties, Rhode Island, USA. Whiskers represent 95% CIs. Reprinted from Masse et al. (2015) with permission from John Wiley and Sons.

In addition to quantifying how landscape covariates influenced probability of use by male woodcock, our RSF was useful in predicting how probability of use might change following forest management. This is a potentially important application of our RSF, and of others developed in the future, because extensive woodcock habitat management will be required to stabilize and ultimately increase woodcock populations (McAuley et al. 2005, Kelley et al. 2008). For example, Williamson (2008) suggested maintaining young forest on about 27% of Rhode Island's land area to increase young forest bird populations to levels observed during 1970. In contrast, Dettmers and Rosenberg (2000) suggested a more likely goal of managing young forest on 10% of the land in southern New England to conserve these species.

Across our 400-ha study area, managing 40 ha (10%) as a series of upland young forest patches *(n* = 7; 2–10 ha each) and herbaceous forest openings *(n* = 3; 2–6 ha each) caused the largest change in probability of use by male woodcock (Table 1; Fig. 1). Managing larger patches (e.g., ≥10 ha each) is suggested for conserving some young forest wildlife (e.g., New England cottontail [*Sylvilagus transitionalis*]; Arbuthnot 2008), but this strategy produced minimal change to probability of use by woodcock on our study area (Fig. 2). Young forest birds do not exhibit area-sensitivity with respect to survival and productivity (Rodewald and Vitz 2005, Lehnen and Rodewald 2009), these species are therefore adapted to exploit smaller, more localized patches of habitat. Interestingly, our more intensive management Scenario 3 (i.e., 60 ha or 15%) yielded nearly identical changes to probability of use as our less intensive management Scenario 1 (Table 1, Figs. 1 and 3). We acknowledge that altering the size, shape, and/or location of managed patches may have produced different results given the landscape and distance parameters incorporated into our RSF. In this regard, there are endless combinations of patch size, shape, and conFiguration that could have been simulated. The purpose of our RSF simulation was to illustrate that these models can be used to compare potential outcomes of competing management scenarios and work towards selecting a management option that is relatively more beneficial in terms of increasing the probability of use by a target species such as woodcock. When available, RSFs can help habitat managers visualize probability of use by target wildlife to certain management practices or scenarios. In doing so, managers can build support for implementing strategies that may produce the greatest probability of use.

Our RSF indicates that converting patches of older coniferous upland forest to young forest would benefit woodcock because coniferous upland forests negatively affected relative probability of use. However, coniferous uplands may be important for woodcock during drought years (Sepik et al. 1983), and therefore some of these areas should remain intact. Male woodcock were more likely to use areas closer to upland young forest patches, and closer to agricultural openings. This explains why creating more, smaller patches of young forest and herbaceous forest openings on our study area elicited a stronger positive change to relative probability of use than creating fewer, larger patches. We emphasize that our RSF is applicable in helping to predict the potential consequences of woodcock habitat management in southern New England or similar regions or landscapes where young forests are rare and forested wetlands are a component of the landscape.

Male woodcock prefer forests closer to herbaceous forest openings because these openings serve as safe nighttime roost sites during summer (Masse et al. 2013). Woodcock commuting behavior has long been known (Sheldon 1961), but specific benefits of moving between diurnal coverts and nocturnal roosts had remained undocumented. Dunford and Owen (1973) were the first to suggest that nocturnal roost sites offered safe refuge from predators, but there had been no attempts to support or refute this predation-risk hypothesis with field data. Our paired study design was unique in that we were able to assess both food availability and mammalian predation risk at the diurnal coverts and nocturnal roosts for individuals that chose to move between these different vegetation types. In Rhode Island, mammalian predators were either more abundant or more active at diurnal coverts compared to nocturnal roosts, so moving to roost fields at night provided periods of relative safety (Masse et al. 2013). We attempted to quantify avian predation risk by monitoring the fate of live rock pigeons (*Columba livia*) placed at diurnal coverts and nocturnal roosts, but raptors never visited these caged birds at either site (see Masse et al. 2013). This evidence suggests that avian predation risk at diurnal coverts and nocturnal roosts was similar. We simultaneously documented more preferred foods at diurnal coverts compared to nocturnal roosts, which supports earlier conclusions that woodcock generally do not move to nocturnal roost sites to exploit feeding opportunities (Krohn 1970, Wishart and Bider 1976).

Active forest management is required to conserve populations of woodcock and other young forest birds in many landscapes, but young forests and other early-successional vegetation types are often viewed unfavorably by the general public (Gobster 2001). As a result, managers of public lands may experience resistance when proposing young forest management plans aimed primarily at a single target species (e.g., Woodcock Habitat Demonstration Areas). In areas where young forests are rare, sites managed to provide components of woodcock habitat (i.e., singing grounds) simultaneously provided benefits to a greater number and diversity of non-target birds than unmanaged forest sites (Fig. 4). Young forest birds, several of which are identified as species of high continental or regional conservation priority (Dettmers and Rosenberg 2000) or species of greatest conservation need (RIDEM 2005), were more abundant at woodcock singing grounds and largely absent at unmanaged forest sites (Masse et al. 2015). Best management practices for woodcock generally call for creating mosaics of ≥2 ha clearcut patches or 30-m strips on target landscapes (McAuley et al. 1996, Williamson 2010). Our findings suggest that many non-target birds readily use small patches of young forest or herb-dominated forest openings managed to provide components of woodcock habitat. Use of small clearcuts (e.g., 1–4 ha) by young forest birds has been documented elsewhere (Schlossberg and King 2007), but our study was unique in that we conducted bird surveys in areas actively being managed for and used by woodcock. Woodcock may serve as an umbrella species for young forest bird assemblages (Masse et al. 2015), although additional studies are needed that document whether woodcock habitat management leads to increased reproduction and/or survival of non-target songbird species. This additional demographic information on songbirds could be used to increase public awareness about the many benefits of young forest management, and to convince private landowners that targeted and well-planned forest clearcutting is not necessarily at odds with broader conservation goals focused on songbirds and game species such as woodcock.

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## CHAPTER FIVE

# Singing-ground Survey Evaluation

# Assessment of the American Woodcock Singing-Ground Survey Zone Timing and Coverage

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**ABSTRACT** The American woodcock (*Scolopax minor*; hereafter, woodcock) Singing-Ground Survey (SGS) was developed to inform management decisions by monitoring changes in the relative abundance of woodcock. The timing of the designated survey windows was designed to count resident woodcock while minimizing counting of migrating woodcock. Since the implementation of the SGS in 1968, concerns over survey protocols that may bias data have been raised and investigated; however, the extent of survey coverage and the timing of the survey window zones have not been critically investigated. We used 3 years of data collected from male and female woodcock marked with satellite tags to assess the extent of survey coverage and the timing of the SGS survey windows relative to presence of woodcock. SGS coverage encompassed the majority of woodcock breeding-period sites (locations where marked woodcock returned to in spring) within the U.S. (*n* = 17, 92%) and approximately half of the breeding-period sites in Canada (*n* = 6, 43%). Thirteen of the 37 monitored woodcock with known breeding-period site arrival dates (35%) were migrating through a survey zone during an active survey window, all in the northernmost 4 of 5 SGS zones. Thirteen woodcock arrived at breeding-period sites after the start of surveys, and all but one of these was located in the northernmost 2 zones. The combination of migration through a SGS zone during the survey window and arrival at breeding-period sites after the beginning of the survey window in northern zones may result in the SGS weighing too heavily the contribution of routes in the southern portion of the primary breeding range, while weighing too lightly the routes in the northern portion of the primary breeding range. We suggest that additional information is necessary to evaluate whether current survey windows are sufficient, or whether they need to be changed.

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**KEY WORDS:** Population management, satellite transmitters, *Scolopax minor*, survey design

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The American woodcock (*Scolopax minor*; hereafter, woodcock) Singing-Ground Survey (SGS) was developed to monitor changes in relative abundance of woodcock by exploiting the conspicuous courtship display of the male woodcock (Cooper and Kelley 2010). Several studies suggest that counts of singing males can provide a reliable index to woodcock populations and can be used to monitor annual changes in abundance (Mendall and Aldous 1943, Kozicky et al. 1954, Goudy 1960, Duke 1966, Whitcomb 1974, Tautin et al. 1983). The SGS is composed of approximately 1,500 routes covering the central and northern portions of the woodcock breeding range (Fig. 1). Survey routes are located along lightly traveled secondary roads within randomly chosen 10-minute degree blocks for each state and province covered by the survey. Each route is 5.4 km long with 10 listening stops that are spaced at 0.6 km intervals. Observers survey the routes shortly after sunset and record the number of individual woodcock heard peenting (one vocalization of displaying male woodcock) over a period of 2 minutes at each stop.

Acceptable dates for conducting the survey align with latitudinal bands intended to coincide with peaks in courtship behavior of resident woodcock (Fig. 1). In most states, the peak of courtship activity (including resident

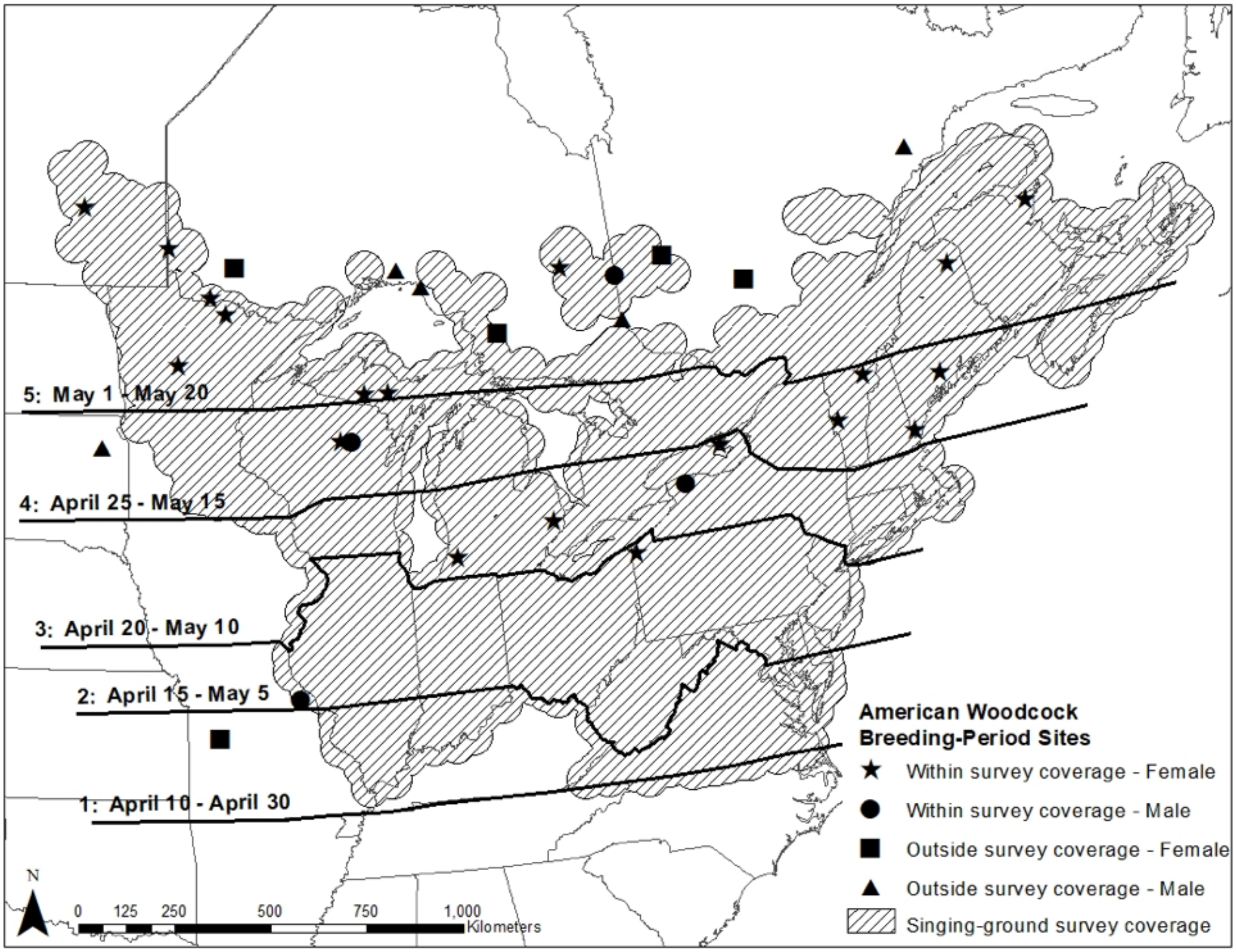

**Figure 1:** Spatial extent of the American woodcock Singing-Ground Survey (SGS) coverage, spatial extent and temporal windows of SGS zones, and breeding-period sites of 33 PTT-marked American woodcock. We estimated the extent of SGS survey coverage by buffering the center point of each 10-degree block containing an official SGS route by 50 km (except in Quebec, where the starting point of each SGS route was buffered). PTT-marked woodcock were captured during the winter period in Texas *(n* = 9) and Louisiana *(n* = 24). Twenty-three woodcock migrated to breeding-period sites within SGS coverage and 10 woodcock migrated to breeding period sites outside of SGS coverage. Breeding-period sites outside of SGS coverage are in Missouri *(n* = 1), Ontario *(n* = 5), Quebec *(n* = 3), and South Dakota *(n* = 1).

woodcock and transient woodcock still migrating) may occur earlier in the spring and local reproduction may already be underway during survey windows. However, the timing of the designated survey windows (20 days in length) was designed to count woodcock that have settled in an area while minimizing counting migrating woodcock to the best extent possible (Goudy 1960, Duke 1966, Tautin et al. 1983). The 20-day survey window also allows for flexibility to complete routes given unpredictable weather conditions and observer scheduling conflicts. Survey protocols provide guidance for acceptable environmental conditions (e.g., wind, precipitation, and temperature) to avoid adverse weather conditions that may affect courtship behavior or the ability of observers to hear woodcock.

Data from the SGS are used to inform hierarchical models to estimate woodcock population indices and the most recent 2-year, 10-year, and long-term (1968 – present) trends for both the Eastern and Central Management Regions (Seamans and Rau, this volume). Data from the SGS have been used to inform management for a number of purposes, including 1) harvest management decisions (Woodcock Harvest Strategy Working Group 2010), 2) development of harvest strategies (Woodcock Harvest Strategy Working Group 2010), 3) development of spatially-explicit population and habitat goals based on historical and contemporary SGS data (Kelley et al. 2008), and 4) spatially-explicit models relating woodcock abundance and landscape-level variables (Thogmartin et al. 2007, Loman et al. 2017). The indices and trends derived from SGS data continue to be relied on for both management decisions and research.

Since the implementation of the SGS in 1968, concerns over survey protocols that may bias data have been raised and investigated. We grouped these concerns into five general sets of variables (Table 1). Two aspects of the SGS that have not been critically investigated are the extent of survey coverage and the timing of the survey windows within survey zones. The timing of the SGS by zone is of particular concern because detecting migrating woodcock and counting those individuals as resident breeders could have consequences for trend estimation. Double counting individual woodcock within and among SGS zones, states, provinces, or management units is a by-product of improper timing. If the timing of migration varies among years, double counting at the state, provincial, or management-unit scales may not be constant and short-term trends would be biased. Tautin et al. (1983:380) summarized the current SGS zone timing as follows:

> "Routes should be run during a three-week period beginning April 10 in southern portions of survey regions and ending May 20 in the most northern portions. Sexual recrudescence occurs early in woodcock; males occasionally begin exhibiting courtship behavior on wintering areas and continue through migration. The recommended dates focus the survey period after most migrants have passed through an area, thus minimizing the possibility of counting transient males."

Previous investigation of survey windows in SGS zones was based on observations of unmarked displaying males

**Table 1.** Factors that may influence American woodcock singing-ground survey results as reported by various authors, 1955–2011.

| Factor Studied | | References |
|---|---|---|
| Scheduling | Daily survey starting time and ending time | Mendall and Aldous (1943), Goudy (1960), Tautin (1982) |
| Time-of-day effects | | Duke (1966) |
| Observer ability | Observer effects | Goudy (1960), Duke (1966), Tautin (1982) |
| | Survey participation pattern effects | Cooper and Kelley (2010) |
| | Noise effects | Goudy (1960) |
| Environmental conditions | Weather effects | Duke (1966) |
| | Moon phase effects | Mendall (1955), Goudy (1960), Duke (1966) |
| | Temperature effects | Goudy (1960), Dwyer et al. (1988 |
| | Wind velocity effects | Blankenship (1954), Goudy (1960), Bergh (2011) |
| Other variables | Effects of changing habitat along survey routes | Dwyer et al. (1988), Morrison et al. (2010), Nelson and Andersen (2013), Bergh (2011) |
| | Woodcock density effects | Duke (1960), Bergh (2011) |
| | Probability of detection along routes | Bergh (2011) |

and may have included both migrating and breeding woodcock. Goudy (1960), working in southern Michigan, suggested that surveys run from 20 April – 10 May, whereas Duke (1966), working in southern Michigan, suggested that surveys run from 15 April – 15 May. Dwyer et al. (1988) compared statistically derived estimates of local woodcock populations on their study area (Maine) against SGS results for the 2 counties that overlapped their study area and concluded that the timing of the SGS or observer quality resulted in different temporal patterns of woodcock abundance. Whiting (2010) reexamined the survey window assessments of both Goudy (1960) and Duke (1966) and concluded that, in both of their studies, migrating woodcock were counted. Based on his reexamination of these results, Whiting (2010:155) concluded that "The magnitude of including migrating males in continental-wide population estimates has not been quantified and warrants further evaluation."

We used 3 years of data collected from male and female woodcock marked with satellite transmitters to assess the extent of SGS coverage and timing of the SGS survey windows. We assessed 1) whether transmitter-marked woodcock chose breeding-period sites (locations where marked woodcock returned in the spring) outside SGS coverage; 2) if migration was ongoing during survey windows, suggesting there may be the potential to double count woodcock; and 3) if individuals arrived at breeding-period sites after the start of the survey window, suggesting that there may be potential to undercount woodcock. Information on timing of SGS windows relative to presence of resident woodcock will enable decision makers to assess if changes to the SGS survey windows are necessary.

## Study Area

Woodcock are resident during the breeding period throughout eastern North America and are managed on the basis of an Eastern and a Central Management Region, where management region boundaries are analogous to those of the Atlantic and Mississippi Flyways (Seamans and Rau, this volume, American woodcock population status). To represent woodcock across the breeding-period and wintering distribution within the Central Management Region, we captured woodcock across a large area in the northern and southern portion of the Central Management Region within the United States. We captured woodcock at sites during the breeding period in Minnesota, Michigan, and Wisconsin, during the wintering period in Louisiana and Texas, and 1 woodcock we presumed to be migrating during spring in northwestern Arkansas (Fig. 1). We chose specific study sites primarily to facilitate woodcock capture. In addition to study sites where we captured woodcock, our study area encompassed the locations to which transmitter-marked woodcock migrated, which included portions of the Eastern Management Region.

## Methods

We trapped 75 woodcock between September 2013 and February 2016 using spotlights and hand-held nets at night both while on foot and from all-terrain vehicles (Rieffenberger and Kletzly 1967). We also trapped woodcock using mistnets during the crepuscular period (McAuley et al. 1993), and captured 1 woodcock with a hand-held net and a trained pointing dog during daylight. We captured woodcock close to the initiation of migration (either fall or spring) to reduce the risk of mortality or transmitter failure before migration began. Before spring migration, we captured woodcock between 5 January and 16 February; before fall migration, we captured woodcock between 18 September and 3 November. We determined age, sex, and mass of captured woodcock (Martin 1964), and banded all woodcock with an aluminum band issued by the U.S. Geological Survey. We attached satellite transmitters, also knowns as Platform Transmitter Terminals (PTT), using a modified thigh harness, where the PTT rested on the woodcock's lower back and was secured by loops over each leg (Rappole and Tipton 1991, Streby et al. 2015). We constructed PTT harnesses with 2 strands of 0.7-mm Stretch Magic® elastic plastic cord (Pepperell Braiding Company, Pepperell, MA) threaded through Tygon tubing (Saint Gobain, Courbevoie, France; Hughes et al. 1994) crimped with metal rings. We performed this study under protocols approved by the Institutional Animal Care and Use Committee (IACUC) at the University of Arkansas, protocol # 15011, and by the IACUC at the University of Minnesota, protocol # 1408-31777A.

### SATELLITE TRANSMITTERS

We equipped woodcock with 3 types of PTTs: a 9.5-g PTT, a 5-g PTT, and a 4.9-g GPS PTT. The 9.5-g and 5-g PTTs (Microwave Telemetry, Columbia, MD) were solar-powered and transmitted messages on a 10-hour-on and 48-hour-off duty cycle. The Argos Data Collection and Location System (Service Argos Inc., Landover, MD) estimated woodcock locations using the Doppler shift of transmissions originating from the PTTs (Argos 2016). Associated with each location was a location class that provided estimated error. Reported location errors were between 250 and 1,500 m or had no error estimation (Argos 2016). These PTTs had auxiliary sensors that provided information on temperature, voltage, and activity (i.e., whether the PTT changed orientation). We censored location data from PTTs when auxiliary sensors indicated that the tag was no longer moving and the temperature had dropped to ambient, or when we stopped receiving messages. The battery powered 4.9-g GPS PTTs (Lotek Wireless, Newmarket, Ontario, Canada) had only enough charge to collect 30 GPS locations along 1 migration path. Before deployment, we programmed the times and dates these 30 GPS locations would be collected. After collecting the GPS locations, the PTT attempted to transmit all the location data to the Argos system on a 6-hour-on and 6-hour-off duty cycle. The Argos system used Doppler shift to collect additional locations while the GPS PTTs transmitted GPS locations. In spring 2016, we programmed GPS transmitters to record 1 location on 24 January, 1 location on 31 January, a location every 3 days from 7 February to 1 May, and a final location on 8 May. Transmitter mass did not exceed 5% of the individual's body mass, and we received an exception from the U.S. Geological Survey Bird Banding Laboratory to exceed the standard 3% body mass restriction for auxiliary markers. We deployed 9.5-g PTTs only on females with mass >200 g, whereas we deployed 5-g PTTs and 4.9-g GPS PTTs on males and females with mass >150 g.

### DATA ANALYSIS

Seven of the tagged woodcock were monitored over multiple spring migrations. Preliminary analysis of these tracked woodcock indicated that most individuals exhibited fidelity to breeding-period sites and used similar spring migration routes among years (Moore 2016). Therefore, we used only the first recorded spring migration from an individual transmitter-marked woodcock to avoid pseudoreplication. We used the *Movebank* tracking data map (Kranstauber et al. 2011, Wikelski and Kays 2016) to identify clusters of location points and to classify points as spring migratory stopovers or breeding-period sites. We mitigated the influence of implausible Argos locations by using clusters of ≥2 successive Argos locations to define stopover sites (Douglas et al. 2012). Implausible locations were less of a concern with GPS tags, because woodcock migrate nocturnally nighttime locations could reflect migration rather than stopover sites. We thus classified clusters of ≥2 successive nocturnal GPS locations (taken every 3 days) as stopovers, whereas we classified single diurnal GPS locations as stopovers. We used location proximity, time between locations, and Argos location class to determine whether locations were clustered under the assumption that spatial and temporal autocorrelation confirm the validity of the location (Douglas et al. 2012). We chose reasonable criteria to define wintering, stopover, and breeding-period sites by defining the first wintering site as a site where a woodcock remained for >25 days and had no further movement >50 km southward. We defined subsequent sites as wintering sites until the first northward movement >25 km began. We classified sites between wintering-period and breeding-period sites as migratory stopovers. We determined the date of arrival at a breeding-period site using the date midway between the last known migratory location and the first location at a breeding-period site. We determined the coordinates of each stopover by taking the median center of all locations within the cluster (Arizaga et al. 2014). We did not consider arrival or departure dates when the gap between the last known location at a site and the first migratory location was >10 days (Martell et al. 2001, Arizaga et al. 2014, Olson et al. 2014). We defined the first breeding-period site as a site where a woodcock remained for >25 days and had no further northward movement >50 km. We chose these criteria to define breeding-period sites because they seemed reasonable and could be uniformly applied to our sample.

We determined the number of days spent at a stopover as the period between the first and last locations recorded at that site. Because transmitters typically had 48–72 hours off duty cycles, and because there were additional gaps from transmitters missing "on" duty cycles (low battery power, the PTT not being able to charge and/or transmit because of heavy vegetation cover), the number of days at each stopover is a minimum number of days at a site. In addition, we were not able to document stopovers shorter than the duration between consecutive "on" cycles; therefore, our estimate of the number of stopover sites is also a minimum. The SGS was developed to monitor changes in relative abundance of woodcock by exploiting the conspicuous courtship display of the male woodcock (Cooper and Kelley 2010); however, our sample of arrival dates at breeding-period sites consisted primarily of female woodcock (female: $n = 30$, male: $n = 7$). To generalize our data on spring migration arrival dates of female woodcock to both male and female woodcock, we tested for the effect of sex on arrival date using a one-way ANOVA.

We estimated the extent of SGS survey coverage by buffering the center point of each 10-degree block containing an official SGS route by 50 km (except in Quebec, where we buffered the starting point of each SGS route, Fig. 1). After experimenting with several buffer sizes, we chose the 50-km buffer because this distance produced a continuous surface between most adjacent survey points while limiting the amount of buffer extending into states that do not participate in the SGS. To determine if woodcock breeding-period sites were within SGS coverage we plotted breeding-period sites of transmitter-marked woodcock captured during the wintering-period in Texas and Louisiana over the polygon of SGS coverage and identified all sites north or west of coverage or within any coverage gaps. We used this sample of only woodcock captured during the wintering period to assess the spatial coverage of the SGS because preliminary analysis of these tracked woodcock indicated that most individuals exhibited fidelity to breeding-period sites among years (Moore 2016), and we used a sample of woodcock captured during either the breeding and wintering period to assess the temporal coverage. We compared the arrival dates of woodcock at breeding-period sites to the dates of the SGS survey windows to determine if any woodcock arrived in a survey zone after the close of the survey window, partially into the survey window, or were present in a zone when the survey windows were open and later moved to a breeding-period site in a different zone, state, or Management Region. To visualize the presence of transient migratory woodcock in reference to the start and close of the survey window in each zone, we plotted locations when woodcock were present at migratory stopovers against the latitude of locations of these migratory stopovers (Fig. 2). We then plotted a polygon enclosing the opening dates of each SGS window and the approximate latitudes of the southern and northern boundary of each SGS zone. SGS zone boundaries often follow state/provincial boundaries instead of latitude lines, so we approximated the boundaries of each zone using 36.5° north latitude as the southern boundary of zone 1, 39° north as the boundary between zones 1 and 2, 42° north as the boundary between zones 2 and 3, 44° north as the boundary between zones 3 and 4, 46° north as the boundary between zones 4 and 5, and 52° north as the northern boundary of zone 5. To visualize the arrival dates at breeding-period sites in reference to the start of the survey window in each zone, we plotted locations on arrival dates along with SGS zone boundaries (Fig. 3). We divided

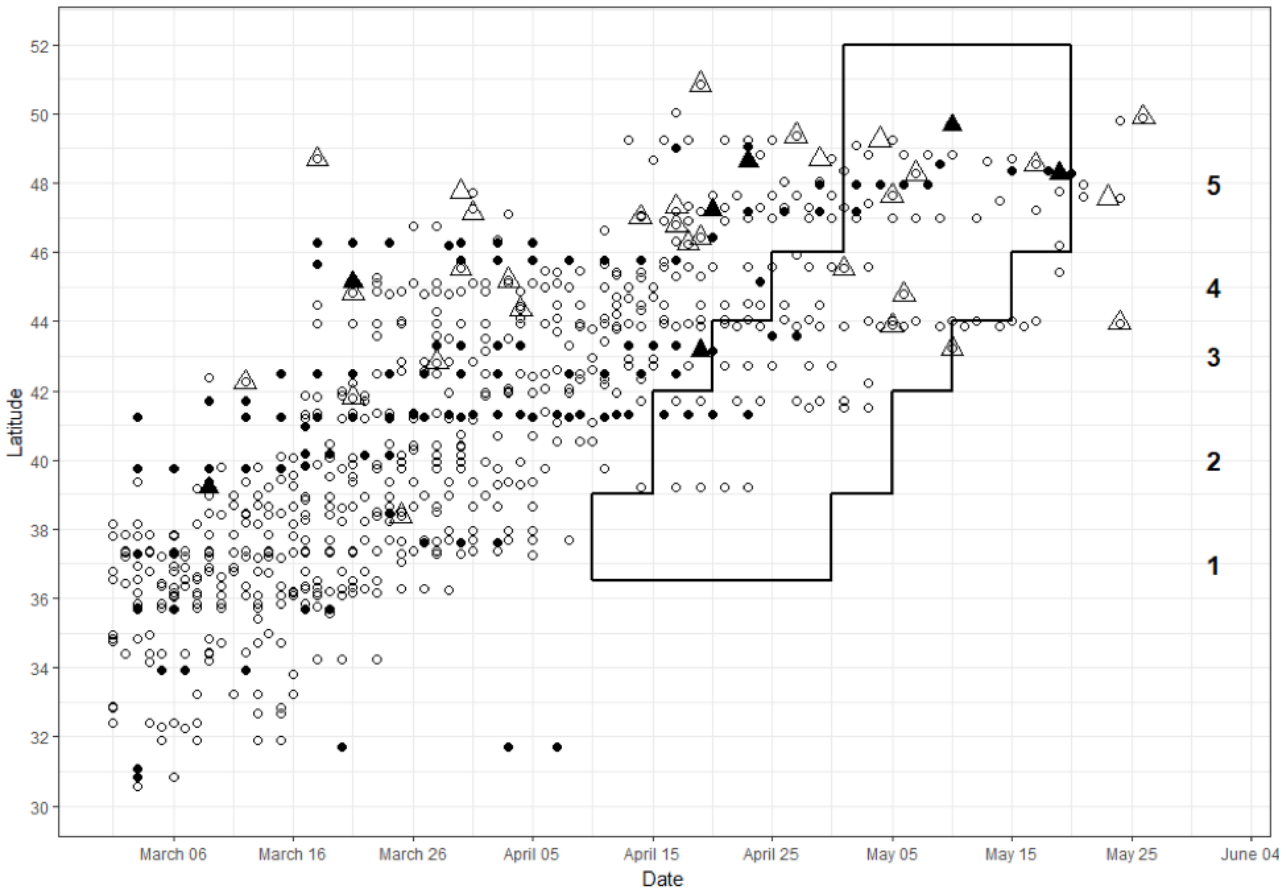

**Figure 2:** Date and latitude in which a PTT-marked American woodcock was present at a migratory stopover site (points), and date and latitude in which a PTT-marked woodcock arrived at a breeding-period site (triangles) for 40 PTT-marked woodcock during spring 2014, 2015, and 2016. Males are represented with solid points and triangles and females are represented with hollow points and triangles. The stair step polygon represents the opening and closing dates of each SGS survey window and the approximate latitude of the southern and northern boundary of each SGS zone. Points located to the left of the polygon represent migratory woodcock present at stopover sites before the start of the survey window. Points within the polygon represent transient woodcock that may have been present during a survey window before reaching their final breeding-season sites. Points to the right of the polygon represent woodcock at migratory stopover sites after the close of the SGS survey window in that zone. Triangles to the left of the polygon represent woodcock that arrived at breeding-period sites before the start of the SGS survey window, triangles within the polygon represent woodcock that arrived at breeding-period sites during the survey window, and triangles to the right of the polygon represent woodcock that arrived at breeding-period sites after the survey window.

and symbolized the breeding-period sites based on 3 categories: 1) woodcock that arrived at breeding-period sites before the start of the survey window, 2) woodcock that arrived at breeding-period sites during the survey window, and 3) woodcock that arrived at breeding-period sites after the close of the survey window.

## Results

We tracked 40 transmitter-marked woodcock throughout spring migration and determined their migratory stopover and breeding-period sites. We determined the date of arrival at breeding-period sites for 37 woodcock. Of the 37 woodcock for which we determined breeding-period site arrival dates, 30 were captured during the wintering period (Texas: $n = 8$, Louisiana: $n = 22$) and 7 were captured during the breeding period of the previous year (Michigan: $n = 3$, Minnesota: $n = 4$). Woodcock captured during the previous breeding period still had functional transmitters during spring migration, enabling us to determine breeding-period locations and arrival dates.

Mean arrival date at breeding-period sites was 18 April (range = 8 March – 25 May), and mean arrival date was similar for males (17 April, SE = 9.6 days) and females (18 April, SE = 3.9 days). There was no difference in the arrival date at breeding-period sites by sex ($F_{1, 35} = 0.034$, $P = 0.86$, males: $n = 7$, females: $n = 30$).

Of the 40 marked woodcock monitored during spring migration with known breeding-period sites, 33 were captured during the wintering period (Texas: $n = 9$, Louisiana: $n = 24$, male $n = 9$, female $n = 14$). Ten breeding-period sites (30%, male: $n = 5$, female: $n = 5$) were outside of potential SGS coverage (Fig 1), with woodcock breeding-period sites outside of coverage in Missouri ($n = 1$), Ontario ($n = 5$), Quebec ($n = 3$), and South Dakota ($n = 1$).

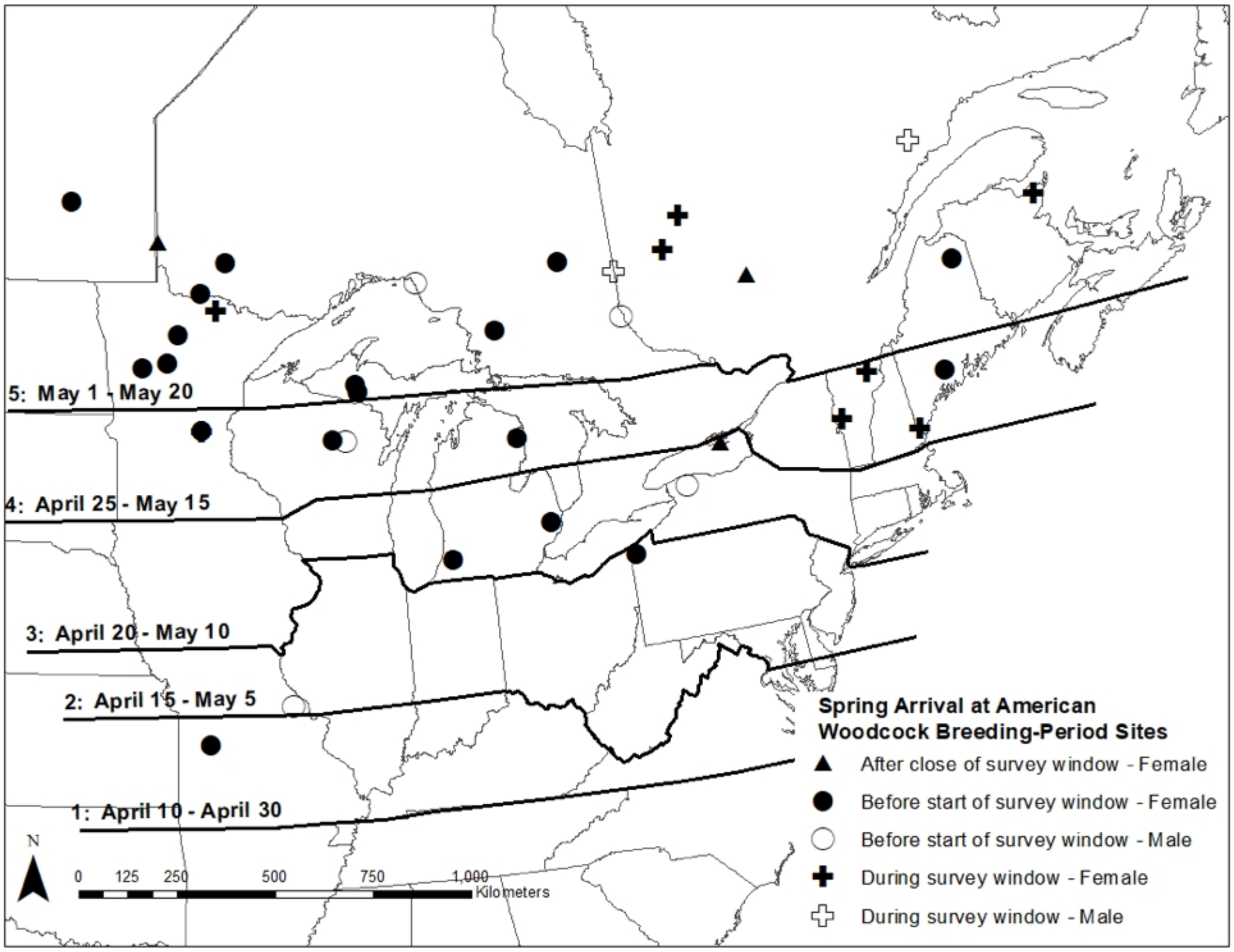

**Figure 3:** Timing of arrival of 37 PTT-marked American woodcock at breeding-period sites in relation to singing-ground survey (SGS) windows in each survey zone. Twenty-four woodcock (65%) arrived at breeding-period sites prior to the survey window. Three woodcock (8%) arrived after the survey window. Ten woodcock arrived during the survey window (27%).

Fourteen of the 33 monitored woodcock captured during the wintering period migrated to breeding sites in Canada, whereas the remainder *(n* = 19) migrated to breeding sites in the U.S. We documented 1 woodcock breeding-period site in zone 1, 2 in zone 2, 4 in zone 3, 7 in zone 4, and 19 in zone 5.

Transient woodcock were present in zones 2–5 during the survey window (Fig. 2). Transient male woodcock displaying during the survey window have the potential to be counted as breeding woodcock by the SGS. Thirteen (male: *n* = 2, female: *n* = 11) of the 37 monitored woodcock with known breeding-period site arrival dates (35%) were migrating through a survey zone during an active survey window. These woodcock fell into ≥1 of the following categories: woodcock that were present at stopover during an open survey window in a Management Region other than the Management Region of their breeding-period site *(n* = 2), woodcock that were present at stopover during an open survey window in a survey zone other than the survey zone of their breeding-period site *(n* = 7), woodcock that were present at a stopover site during an open survey window in a state/province other than the state or province of their breeding-period site *(n* = 7), and woodcock that were present at a stopover site during an open survey window in the same state or province as their breeding-period site *(n* = 7, see Fig. 4 for examples of each of these categories).

Most woodcock *(n* = 24, 65%) arrived in their respective breeding-period sites before the survey window opened (Fig. 3); therefore they were present during the entire survey period. Ten woodcock (27%) arrived at breeding-period sites after the start of the survey window but before the window closed (Fig. 3). Only 3 woodcock (8%) arrived at breeding-period sites after the close of the survey window. Of the 7 transmitter-marked males for which we determined breeding-season sites, 5 arrived at those sites before the start of the survey window and 2 arrived during the survey window. All 13 woodcock that arrived at breeding-period sites after the start of survey windows settled on breeding-period sites in zones 3–5, with most in zone 5 *(n* = 8), followed by zone 4 *(n* = 4), and zone 3 *(n* = 1).

## Discussion

Our ability to monitor satellite-marked woodcock over the course of spring migration allowed us to determine where individuals were with respect to the survey windows for each zone of the SGS. Previous attempts to set zone windows were based on observations of unmarked woodcock (Goudy 1960, Duke 1966, Tautin et al. 1983) for which migratory status was unknown. Our results provide the first assessment of the match between when woodcock return to breeding-season sites and the survey windows for the SGS, and can be used to assess whether current zone windows are effective at minimizing bias from inclusion of transient woodcock.

Stopover locations of migrating woodcock with respect to each SGS zone window indicated that in all zones, except in zone 1, some migrating woodcock were present during a survey window before reaching their final breeding-season sites. This pattern was more evident in the more northern zones 3, 4, and 5. Woodcock are known to display courtship behavior during spring migration (Jacobs 2001), and may therefore be considered resident woodcock if they are present and detected in a zone other than the zone of their breeding-season site under the SGS protocol. However, limitations to our study include: (1) our sample consisted of both male and female woodcock whereas the SGS counts only males, (2) the difference in the extent of display between transient and resident woodcock is unknown, and (3) a woodcock present in an active survey zone may not be present at a SGS survey stop and would therefore not affect survey results.

Counting migrating woodcock as residents has consequence. During our study, 7 transmitter-marked woodcock (17.5 %) were present at a migratory stopover in a zone when the survey window was open and later moved to a breeding-period site in a zone farther north. Male woodcock following these patterns could be misclassified as resident woodcock or counted in >1 zone, state/province, or Management Region. The ramification of these possible movements is that counts recorded during the SGS (typically expressed as the mean number of males per survey stop) may be biased upward or downward, with the magnitude of bias determined by the prevalence of such double counting within zones. These biases may in turn influence short-term trends or perceived spatial variation in relative woodcock abundance. Movement among smaller-sized states/provinces would be more likely than among larger-sized states/provinces or Management Regions simply because of the distances involved. For example, a woodcock could easily move from Vermont to New Hampshire in a short period relative to moving from, for example, western Ontario to eastern Quebec during that same period. Under those circumstances, the indices/trends in these smaller political units (e.g. states/provinces) could be more affected by such movements than in larger political units. No monitored woodcock chose breeding-period sites in zones 1 or 2. This may be due to bias from capturing woodcock in only a portion of their range. Therefore, our analysis of SGS timing and extent is most relevant to the three northernmost zones. To better understand range-wide patterns, woodcock would need to be captured in additional states or provinces and similarly monitored.

Arrival of resident birds before the start of the survey window may result in lower detection probability during the survey window. Duke (1966) addressed seasonal variation in woodcock singing during the breeding season. Early in the breeding season, both resident and migrating woodcock were present based on the observation that territorial interactions were frequent. Territorial behavior is when one male chases another male in the singing ground while uttering the characteristic "cackling call" (Mendall and Aldous 1943). According to Duke (1966:699), "Overt territorial behavior did not last beyond the first week of April…and does not affect the survey." Once migrants moved through the study area, Duke (1966) concluded that courtship activity decreased and was constant through mid-May during a "stable" period when no migrants were present. This period was analogous to Goudy's (1960) "central period," which was defined as the period when courtship activity was consistent based on a series of similar SGS counts. Goudy (1960) concluded that the timing of this central period varied annually based on differences in weather conditions—earlier in warm springs and later in cold springs. Dwyer et al. (1988) documented that VHF radio-marked woodcock in Maine moved among singing grounds over the course of the breeding season and that these movements could entail territorial disputes. Bergh (2011) estimated detection probabili-

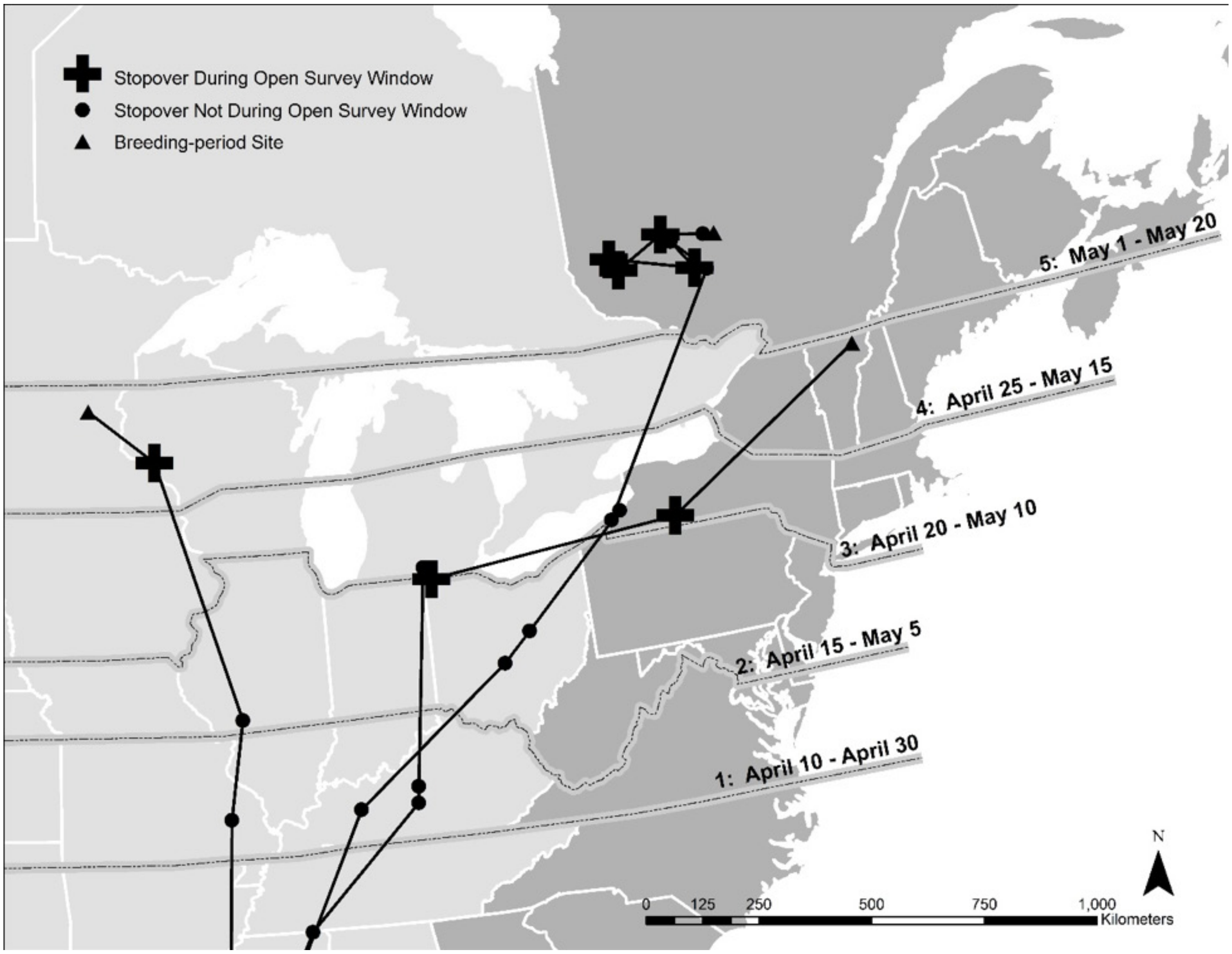

**Figure 4.** Spring migration paths of 3 transmitter-marked American woodcock that were present at a migratory stopover during a survey window of the SGS. The paths are representative of woodcock that were present at stopover during an open survey window in a Management Region other than the Management Region of their breeding-period site (breeding-period site furthest east), woodcock that were present at stopover during an open survey window in a survey zone other than the survey zone of their breeding-period site (breeding-period site furthest east), woodcock that were present at a stopover site during an open survey window in a state/province other than the state or province of their breeding-period site (breeding-period site furthest west and breeding-period site furthest east), and woodcock that were present at a stopover site during an open survey window in the same state or province as their breeding-period site (breeding-period site center).The Central Management Region is shown in light gray and the Eastern Management Region is shown in dark gray.

ties of unmarked woodcock along 8 routes (4 SGS routes and 4 randomly located routes) in Minnesota. Bergh (2011) divided her sampling period into 3, 2-week periods (early, mid-, and late spring), and found substantial support for a model that allowed detection to vary by period. The peak of detection was in the last week of April and first week of May, and was lower both before and after this middle period. She suggested that the peak in woodcock detections was coincident with Goudy's (1960) stable period, and that narrowing the SGS zone window dates to coincide with the peak display period may present logistical challenges. However, Bergh (2011) worked with unmarked woodcock, so was not able to determine whether individual woodcock singing rates change over the season. Further studies with marked woodcock would likely be necessary to determine whether the stable period of Goudy (1960) and Duke (1966) varies both within and among years.

Woodcock arriving at breeding-period sites before the start of the survey have the potential to be surveyed at the correct site throughout the entire survey window. This is the circumstance for which the SGS was designed (Duke 1966, Cooper and Kelley 2010). Alternatively, woodcock arriving during the survey window cannot be surveyed at their breeding-period sites during the period before they arrived; woodcock arriving after the close of the survey window cannot be surveyed at their breeding-period sites. These 2 situations result in undercounting in the areas where woodcock arrive after the beginning of the survey window. In our sample of transmitter-marked woodcock, late-arriving individuals were concentrated in the 2 northernmost zones, whereas transient woodcock present during a survey window were concentrated in zones 2–5 (Fig. 3). The combination of these situations may result in the SGS weighing too heavily the contribution of routes in southern portion of the primary breeding range while weighing too lightly the routes in the northern portion of the primary breeding range. One solution to these problems would be to open survey windows later, provided that the survey window does not extend later than the "stable" period described by Goudy (1960) to avoid undercounting. Delaying each zone opener by 2 weeks would reduce, but not eliminate, the effect of woodcock migrating through a zone during a survey window (Fig. 2). Whether such a delay should be focused more on certain zones is unclear, but based on our observations, zone 5 might most benefit delaying beginning of the survey window. We note that altering survey windows is not trivial and many issues need to be considered. For example, in Canada, altering survey windows would require consideration of weather conditions, road conditions, and the availability of staff and volunteers (K. Jones, Bird Studies Canada, pers. communication). Additionally, changes to survey windows would have ramifications for interpreting long-term trends. Although we found no difference in arrival dates based on sex, our sample consisted of only 7 males. Future research focused on tagged males may provide additional insight into survey windows that minimize mismatch between timing of surveys and presence of male woodcock at breeding-season sites. Future modeling simulating migration may help elucidate how transience affects trend estimation and how changes to survey zone timing may alter interpretation of SGS trends.

Our results indicate that SGS coverage encompassed the majority of woodcock breeding-period sites within the U.S. (*n* = 17, 92%) and approximately half of the breeding period sites in Canada (*n* = 6, 43%). Canadian locations outside of SGS coverage were mostly north of the area currently covered by the survey (Fig. 1). Incomplete coverage in Canada may obscure population trends, especially if woodcock range shifts north due to climate change or changes in land use. As Sauer et al. (2006) suggested, survey cooperators need to better-define the northern extent of the SGS, especially if evidence indicates a northward expansion of the woodcock breeding range. However, increasing the area covered by the SGS in Canada is not trivial for the same reasons as altering zone dates, and because of the associated logistical considerations for surveying road-based routes in remote areas.

Finally, it is not clear whether the relative contribution of woodcock recruitment among zones is changing with changing climatic conditions (Galbraith et al. 2014). Thogmartin et al. (2007) predicted woodcock abundance based on the SGS in the U. S. and estimated that the lowest abundances occurred in zone 1 and the highest abundances occurred in zone 5, which suggests that improving the timing of zone 5 window dates and expanding the survey extent in Canada could result in more accurate abundance estimates upon which to make management decisions.

## Management Recommendations

We suggest that additional information is necessary to evaluate whether current SGS zone windows are sufficient, or whether they need to be changed. We recommend that future studies continue to use PTT and GPS technology to monitor migration of individual woodcock captured across the species' range. Advancements in transmitter technology will likely result in lighter transmitters produced for reduced expense, allowing for increased sample sizes, especially of male woodcock. An expanded effort to monitor woodcock migration will allow a more in-depth and robust examination of SGS windows and survey extent. The results of our study suggest that survey windows could be delayed by 2 weeks to avoid counting migrating woodcock and that the survey extent could be expanded northward in Canada to provide more coverage of that portion of the woodcock breeding range with the highest breeding density.

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# Estimating Density and Effective Area Surveyed for American Woodcock

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**ABSTRACT** The American Woodcock (*Scolopax minor*; hereafter, woodcock) Singing-ground Survey (SGS) is conducted annually during the woodcock breeding season, and survey points along survey routes are set 0.4 mile (0.65 km) apart to avoid counting individual birds from >1 listening location. The effective area surveyed (EAS) at a listening point is not known, and may vary as a function of land-cover type or other factors. To define the relationship describing distance between vocalizing woodcock and an observer and how cover types influence that relationship, we broadcast a recording of woodcock vocalizations in 2 land-cover types (forest and field) at varying distance. We evaluated the proportion of call broadcasts detected as a function of distance and fit regression curves to detection data to estimate a distance (r*) where the area above the curve at distances <r* was equal to the area under the curve at distances >r*, which allowed determination of the radius of an area where detection probability was effectively 1.0. This EAS had a radius (r*) of 198 m for forest, 384 m for field, and 309 m for both of these land-cover types combined, and an estimated size of 12.3 ha for forest, 46.3 ha for field, and 30.0 ha for both land-cover types combined. We used this information to estimate density of displaying male woodcock based on counts from the SGS in east-central Minnesota that incorporated variation in EAS, probability of detection, survey date, and survey route. Our density estimates (5.0 birds/100 ha in 2009 and 7.1 birds/100 ha in 2010) represent the highest density of singing male American woodcock yet reported, and indicated a substantive increase in density between years.

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**KEY WORDS:** American woodcock, detection distance, effective area surveyed, Minnesota, *Scolopax minor*

The American woodcock (*Scolopax minor*; hereafter, woodcock) Singing-ground Survey (SGS), coordinated by the U. S. Fish and Wildlife Service (FWS) and the Canadian Wildlife Service, is conducted during the woodcock spring breeding season. This roadside survey is conducted in the evening when males make a distinctive vocalization called peenting as part of their breeding display (Keppie and Whiting 1994). Each male occupies its own open area called a singing ground where it peents to attract female woodcock and advertise occupancy to conspecific males. Woodcock use a variety of openings (natural openings, clearcuts, agricultural fields, etc.) for this display.

The SGS has been conducted annually throughout the primary woodcock breeding range in the eastern U.S. and adjacent southern Canada since 1968, and is used as an index of abundance and population trend. There are approximately 1,500 SGS routes that are 3.6 miles (5.8 km) in length and have 10 listening points spaced 0.4 miles (0.65 km) apart (Seamans and Rau 2017). Observers begin surveys shortly after sunset and record the number of woodcock heard peenting at each listening point during a 2-min listening period. From 1968 to 2017, the number of singing male woodcock counted per route on the SGS has declined (Seamans and Rau 2017) in both the Eastern and

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Central Management Regions, with a more recent period (2007–2017) of stability in the Central Management Region and across the breeding distribution as a whole. Concerns about this decline have led to harvest restrictions (summarized in Seamans and Rau 2017), a woodcock conservation plan (Kelley et al. 2008), and a need to better understand how counts of woodcock on the SGS are related to woodcock abundance and population trends.

As currently implemented and analyzed, the SGS provides an estimate of males per route rather than males per unit area. The SGS protocol is designed to maximize detection probability of singing male woodcock by defining the conditions under which surveys are conducted, and by controlling for several factors that influence detection probability (Bergh 2011). However, detection probability on SGS surveys was not previously known, and by accounting for factors that influence detection, evaluation of trends in woodcock abundance could be improved. One factor that likely influences detection is the distance from a bird to the observer. Recent experiments (see Simons et al. 2007, McClintock et al. 2010) documented that detection probability decreases with distance, especially in the presence of ambient noise. Increasing distance can lead either to misidentification or to false-positive or false-negative detections. Therefore, it is important to estimate the proportion of birds detected as a function of distance and to understand factors that influence detection.

The farthest distance at which an observer can detect various songbirds has been investigated empirically by broadcasting recordings of calls. For example, Emlen and DeJong (1981) introduced the idea of detection threshold distances (DTDs), which they defined as the distance at which a bird song becomes inaudible in a natural setting. These DTDs could then be translated to detection areas (DAs) and applied to counts of singing birds along a survey route. A DTD would be determined for a particular species and cover type, eliminating the need for an observer to estimate the distances to singing birds during a survey. However, the use of a single threshold number was questioned by Wolf et al. (1995) when they fit a theoretical function to describe the relationship between distance and detectability. The value of interest (D50) described the distance where one-half of the birds of a given species were audible during a point count, so that the probability of hearing a bird within that distance was equal to that of missing a bird beyond that distance. These studies provided crude estimates of the farthest distance at which an observer could detect various vocalizing songbirds in a forest and provided a basis for evaluating detection distance on the SGS.

The SGS protocol was developed partly on evaluations conducted by Duke (1966) of factors related to woodcock peenting. Duke (1966) estimated the distance at which peenting woodcock could be heard, and concluded that none were detected beyond 257 yards (235 m). He recommended that the FWS maintain a 0.4-mile (0.65-km) interval between stops on SGS routes to avoid counting individual birds from >1 listening location. This resulted in a 0.2-mile (approximately 330-m) radius around each listening point and an estimated effective area surveyed (EAS) of 34.2 ha (assuming all woodcock peenting were detected). Alternatively, Gregg (1984) assumed that an SGS observer would hear all peenting male woodcock within a 220-yard (201-m) radius of a listening point for an EAS of 12.7 ha. However, after calculating a very low density of woodcock along Wisconsin SGS routes with this presumed area surveyed, Gregg (1984) concluded that the estimate of the area within which woodcock were detected along routes may have been too large. More recently, Kelley et al. (2008) suggested a listening-point radius of 250 m, which amounts to an EAS of 19.6 ha. These estimates of the area within which woodcock are detected at SGS survey locations vary widely, with the largest estimate from the current SGS protocol.

A reliable estimate of the EAS can be used to estimate density of male singing woodcock. Several studies have attempted to estimate density without having directly estimated the EAS for an SGS listening point. Gregg (1984) compared breeding woodcock densities in the literature based on singing-grounds/100 acres (40.7 ha) in the Midwest and northeastern United States. He assumed an occupied singing-ground was equivalent to 1 singing male woodcock. His density estimates ranged from 0.7 to 4.2 singing-grounds/100 acres (1.7 to 10.4 singing-grounds/100 ha). Dwyer et al. (1988) estimated woodcock density on Moosehorn National Wildlife Refuge in Maine by counting all singing males in a study area of known size and assuming that no birds were missed. Their density estimates ranged from 1.3 to 2.2 singing males/100 ha over a 10-yr study period. In the American Woodcock Conservation Plan, density estimates were made for all the counties within the breeding distribution of woodcock. Kelley et al. (2008) used a radius of 250 m, but this estimate of detection distance was not based on empirical data. Kelley et al. (2008) were interested in comparing woodcock populations from 1970–1975 to those of 2000–2004 and used the average number of singing males per route during those periods. They represented counties by their official SGS routes, and resulting density estimates for Pine County, Minnesota, USA (the location of our study), were 0.88 singing males/100 ha for 1970–1975 and 0.75 singing males/100 ha for 2000–2004.

To date, there has not been a thorough evaluation of the relationship between distance and detection of peenting woodcock at a listening point on the SGS, which precludes using SGS data to estimate woodcock density. Furthermore, many factors likely influence woodcock detection probability, such as land-cover type (e.g., forest, agriculture, urban, etc.), environmental conditions under which surveys are conducted, and abilities of observers. Therefore, our objectives were to estimate the EAS at SGS listening points with respect to land-cover type using both open field and forested locations. We predicted that land-cover type would affect the probability of detecting a peenting woodcock as a function of distance. We also incorporated EAS and detection probability with SGS counts to derive estimates of male woodcock density in Pine County, Minnesota, USA.

## Study Area

We derived distance-detection relationships from trials we conducted in open field and forested land-cover types in Pine County, Minnesota, in 2009 and 2010. Pine County is located in east-central Minnesota, and our study sites were located near the town of Finlayson (46.203 N, -92.956 W). Pine County is situated in the Mille Lacs Uplands subsection under the Ecological Classification System hierarchy (Minnesota DNR 2006). This subsection is characterized by drumlin ridges with depressions between the ridges containing peatlands with shallow organic material. There are extensive wetlands in the area with total annual precipitation of about 75 cm. Large areas in eastern Pine County are heavily forested. The county is dominated by aspen-birch (*Populus* spp.-*Betula* spp.) forest with small areas of jack-white-red pine (*Pinus* spp.) forests. Land ownership in the Mille Lacs Uplands subsection is 17.7% public and 82.2% private, and land use is approximately 40% forest, 24% row crop, 17% wetland-open, 13% pasture, and 6% water (Minnesota DNR 2006).

## Methods

### DATA COLLECTION

We conducted call-broadcast trials at 9 sites, 4 that we categorized as forest and 5 that we categorized as open field. Forest sites were topographically flat and vegetated by mixed pine forest, mature aspen forest interspersed with alders (*Alnus* spp.) in a wet area, mixed pine forest and pine plantation, and mixed pine forest with birch, aspen, and a willow (*Salix* spp.) and alder wet area. Open field sites were also topographically flat; 2 were horse pasture, 2 were hayfields, and 1 was a restored native prairie. Two of the forest sites were public land, whereas the remaining sites were located on private land.

To estimate the farthest distance at which we could detect peenting woodcock, we broadcasted a recording of a woodcock peent through speakers at a sound level between 70 and 80 decibels (field trials and e.g., Brackenbury 1979, Simons et al. 2007). While 1 observer stood blindfolded on a road, another individual held a game caller (FOXPRO FX3, FOXPRO Inc., Lewistown, PA) at a distance unknown to the observer and either played or did not play the recording. Broadcast distances were set at 50-m increments between 100 and 450 m (open field) or 100 m and 300 m (forest) based on preliminary assessments. The observer listened for 2 min and recorded whether they heard peenting. We recorded wind speed, precipitation, and level of ambient noise during the trial following the official SGS protocol (e.g., we did not conduct trials in heavy wind or precipitation). We conducted broadcast trials primarily in the hours during and after sunrise (06:00–09:00) to simulate the conditions during which the official SGS is conducted. We did not conduct trials during the hours around sunset because observers were conducting woodcock surveys during that period as part of a companion study. We conducted trials in April and May of 2009 and 2010 over multiple days and sites in the 2 land-cover types (open forest and open field) to estimate detection distance and to compare detection distance between land-cover types. Observers had their hearing professionally evaluated prior to conducting trials and were trained to listen for woodcock.

### DATA ANALYSIS

We calculated the proportion of peent broadcasts detected at each distance and in each land-cover type (Fig. 1). Based on the proportion of broadcasts detected and with the assumption that all broadcasts at 0 m from the observer would be detected, we used program R (R Development Core Team 2010) to analyze 4 different curves (half normal, inverse normal, negative exponential, and logistic) to determine the detection curve with the best fit. We ranked these 4 *a priori* candidate models using Akaike's Information Criterion adjusted for sample size ($AIC_c$) for the field and forest land-cover types to identify the model best sup-

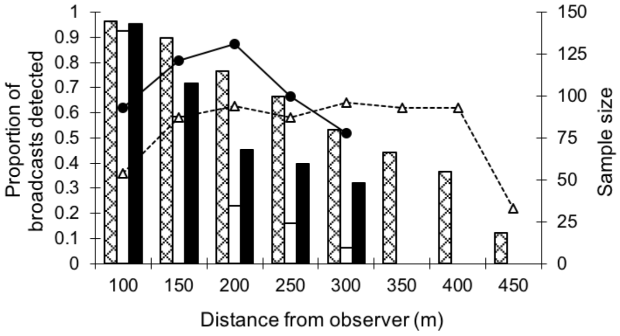

**Figure 1.** Proportion of broadcasts of American woodcock "peents" detected at increasing distance (m) from an observer in open field (crosshatch), forest (white), and overall (black) land-cover types in Pine County, Minnesota, 2009–2010. Lines show sample sizes for open field (dotted) and forest (solid) land-cover types at each distance.

ported by the data (Burnham and Anderson 2002). We then used the best-supported detection curve (half-normal) to estimate the EAS, following the procedure outlined in Roberson et al. (2005) where probability of detection is a function of distance. In that procedure, the ideal probability of detection ($P_i$) is equal to 1 out to a given distance (x, y) from the source of the broadcast (0, 0) and zero beyond that distance. The next step is to set the double integral of $P_i$ equal to that of $P_t$, the probability of detection as a function of distance based on the data. We then solved for r*, the radius of the EAS (and the x coordinate on the detection curve), which is the distance at which the area above the probability of detection curve at distances <r* equals the area under the curve at distances >r*. For a half-normal curve the r* can be calculated by

$$r^{*} = 2\ (\surd \int Pt\ (r)\ dr)$$

where $P_t$ is the probability of detection at distance t and r is the radius from the location where the peent call was broadcast. Following integration, the equation for r* was reduced to

$$r^{*} = \sqrt{2\sigma^{2}}$$

where σ is the standard deviation from a half-normal distribution. We used this radius to determine the effective area surveyed:

$$\mathrm{EAS} = \pi(r^{*})^{2}$$

We calculated a 95% bootstrap confidence interval for r* with 1,000 bootstrap samples using program R to assess uncertainty in the EAS. We repeated this procedure for forest, open field, and forest and open field combined land-cover types.

We then used bootstrapping to estimate density of peenting male woodcock in Pine County. We estimated density for each year (2009 and 2010) using our estimates of EAS, detection probability (*p*; 0.625 pooled from the 2009 and 2010 estimates of detection probability, Bergh 2011), and observed counts of woodcock on each of the county's 8 routes during the official SGS window for central Minnesota (25 April–20 May). We conducted 2,000 simulations, randomly selecting 8 routes (with replacement, i.e. bootstrapping the routes), the same number of dates for each year-route combination (i.e., bootstrapping the dates), EAS based on cover type and its estimated mean and variance (parametric bootstrapping the EAS), and detection probability (*p*) based on its estimated mean and variance (parametric bootstrapping *p*). When sampling for EAS, we used a shifted gamma random variable by sampling from a gamma distribution with a given shape, then multiplying by a given scale, then adding a given shift to match the mean (*m*), 2.5% quantile (*a*), and 97.5% quantile (*b*) of the estimated distribution of EAS in each of the 3 cover types (described above). To determine the shape of the gamma distribution, we computed the ratio:

$$(m - a)/(b - a)$$

and then used that ratio to define a gamma distribution to achieve the same ratio. To determine the scale, we computed:

$$(b - a)$$

and divided that difference by the corresponding quantity for a standard gamma with the derived shape. Finally, the shift parameter is *m* minus the product of shape and scale. When sampling for *p*, we used a normal distribution with mean 0.625 and variance 0.0176 (Bergh 2011).

For each replicate in the simulation (*n* = 2,000), we therefore allowed for variation in EAS, *p*, survey date (within the SGS window), and route and estimated density by summing the adjusted number of woodcock observations and dividing by the sum of estimated EAS across all points on all routes. We assigned the appropriate EAS to each point on each route from U.S. Farm Service Agency aerial photos and ground observations (Bergh 2011). We used the 2.5% and 97.5% quantiles of the distribution of replicates in the simulation to represent 95% confidence intervals around point estimates of woodcock density (birds/100 ha) for 2009 and 2010 in Pine County.

## Results

### EFFECTIVE AREA SURVEYED

We conducted a total of 1,160 woodcock broadcast trials at 5 distances in the forest land-cover type and 8 distances in the open field land-cover type, for an average of approximately 90 trials per distance in each land-cover type. We conducted trials over 19 days in 2009 and 25 days in 2010. The percentage of broadcasts detected ranged from 96.3% and 92.5% at 100 m in the open field and forest land-cover types, respectively, to 12.1% at 450 m in the open field land-cover type and 6.4% at 300 m in the forest land-cover type. Detection probability decreased less rapidly as a function of distance in the open field land-cover type than in the forest land-cover type (Fig. 1).

The best-fit detection curve for all 3 datasets (forest, open field, both land-cover types combined) was half-normal (Table 1, Fig. 2). No other models received substantial support; therefore we used the parameter estimates from the half-normal curve defined by our data to calculate the EAS. The EAS radius (r*) was 198 m (95% bootstrap CI = 174–231 m) for the forest land-cover type, 384 m (95% bootstrap CI = 321–440 m) for the open field land-cover type, and 309 m (95% bootstrap CI = 273–372 m) for both land-cover types combined. The EAS for SGS listening points in Pine County was 12.3 ha (95% bootstrap CI = 9.46–16.8) for the forest land-cover type, 46.3 ha (95% bootstrap

CI = 32.4–60.8) for the open field land-cover type, and 30.0 ha (95% bootstrap CI = 23.4–43.4) for both land-cover types combined.

### DENSITY

Mean density of singing male woodcock was 5.0 birds/100 ha (95% confidence interval 2.2–9.6) in 2009 and 7.1 birds/100 ha (95% confidence interval 3.6–12.6) in 2010, suggesting an increase in abundance between years. Bootstrapping *p* made relatively little difference in the lower bound of our confidence intervals, but increased the upper bound (up to approximately 2 birds/100 ha). Bootstrapping route lowered the lower bound of our confidence intervals and increased the upper bound slightly (up to approximately 1–2 birds/100 ha). Bootstrapping EAS and date had relatively little influence on confidence interval bounds derived via simulations.

## Discussion

### EFFECTIVE AREA SURVEYED

We estimated the EAS for American woodcock in open field and forest land-cover types in east-central Minnesota based on call broadcast trials conducted under a variety of conditions within the limitations of the SGS protocol, in relatively flat terrain, and during the hours around sunrise. We conducted trials over many days in a variety of environmental conditions, wind speeds and directions, ambient noise levels, and precipitation. Therefore, our estimates of the EAS should be considered averages over the conditions under which SGSs are conducted. Although these trials were conducted in the hours around sunrise, instead of around sunset (as during the SGS), environmental conditions around sunrise are similar to those around sunset, and male woodcock display at both dusk and dawn (Sheldon 1967). Therefore, we conducted our trials around sunrise in conditions nearly identical to those around sunset, in terms of factors that influence detection of peenting woodcock.

The EAS in the open field land-cover type was greater than that in the forest land-cover type, likely because of sound attenuation in forest vegetation (Wiley and Richards 1982). Our estimate of EAS radius across land-cover types (field and forest combined) was 309 m, which is similar to previous estimates of 201 m, 235 m, 250 m, and 330 m (Gregg 1984, Duke 1966, Kelley et al. 2008, SGS protocol, respectively). However, only Duke's (1966) estimate was determined based on empirical data—the farthest distance he and others could hear 3 known singing males in 28 trials. Our detection distances were considerably farther than the 235 m reported by Duke (1966), especially in the field land-cover type. We do not know why our distances were farther than those reported by Duke (1966), but suspect detection distance is likely related to differences in land-cover type, observer's hearing abilities, and our more extensive and controlled testing protocol. These results also suggest that spatial or temporal comparisons of counts that do not account for detection probability may need to be made with caution. When combining data from both land-cover types, our estimate of the EAS was 30.0 ha, which extrapolates to a total of 300 ha effectively surveyed on a single SGS route (with 10 listening points).

**Table 1.** Akaike's Information Criterion adjusted for sample size ($AIC_c$), the difference in $AIC_c$ ($\Delta AIC_c$), $AIC_c$ model weights ($\omega_i$), and number of parameters in the model *(k)* from the best-supported model for 4 *a priori* models of the relationship between American woodcock detection and distance in a forest, open field, and both land-cover types combined in Pine County, Minnesota, 2009–2010.

| Land-cover type | Model | $AIC_c$ | $\Delta AIC_c$ | $\omega_i$ | *k* |
|---|---|---|---|---|---|
| Forest | Half Normal | 0.6230 | 0.000 | 0.9591 | 2 |
| | Negative Exponential | 6.942 | 6.319 | 0.0407 | 2 |
| | Logistic | 19.17 | 18.55 | 0.0001 | 3 |
| | Inverse Normal | 19.63 | 19.01 | 0.0001 | 3 |
| Open field | Half Normal | -8.513 | 0.000 | 0.9508 | 2 |
| | Negative Exponential | -1.357 | 7.156 | 0.0266 | 3 |
| | Logistic | -0.8730 | 7.640 | 0.0208 | 3 |
| | Inverse Normal | 3.984 | 12.497 | 0.0018 | 2 |
| Both combined | Half Normal | -6.477 | 0.000 | 0.6058 | 2 |
| | Negative Exponential | -4.707 | 1.770 | 0.2500 | 2 |
| | Logistic | -2.276 | 4.201 | 0.0742 | 3 |
| | Inverse Normal | -2.160 | 4.317 | 0.0700 | 3 |

### DENSITY

The density estimates we derived for male singing woodcock in Pine County (5.0 birds/100 ha in 2009 and 7.1 birds/100 ha in 2010) are considerably greater than those previously estimated in other locations. The highest estimated density reported in the published literature was 2.2 birds/100 ha at Moosehorn National Wildlife Refuge (NWR) in Maine (Dwyer et al. 1988). The study area on Moosehorn NWR had high quality woodcock habitat that had recently undergone management specifically to benefit woodcock prior to the study (Dwyer et al. 1988), whereas our study was located in a mix of public and private lands that were not managed for woodcock. Estimated density for woodcock in Pine County presented in the American Woodcock Conservation Plan (Kelley et al. 2008) was also much lower than our estimates, indicating the potential impor-

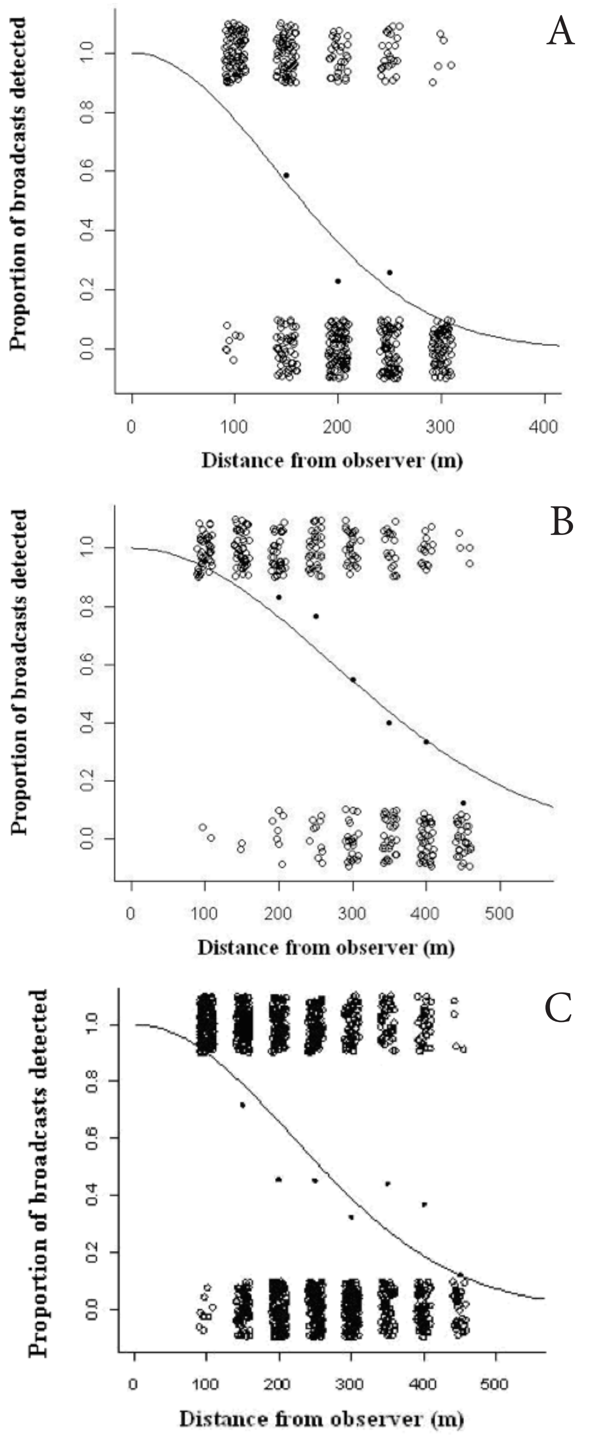

**Figure 2.** Proportion of broadcasts of American woodcock "peents" detected at increasing distance (m) from an observer in open field (crosshatch), forest (white), and overall (black) land-cover types in Pine County, Minnesota, 2009–2010. Lines show sample sizes for open field (dotted) and forest (solid) land-cover types at each distance.

tance of incorporating detection probability into density estimates. In addition, raw counts and density estimates indicated a 39–42% increase in woodcock abundance on our routes from 2009 to 2010, suggesting that estimated abundance can vary substantively between years.

## Management Implications

Based on our estimates of EAS in forested and open field land-cover types in east-central Minnesota, the 330 m radius currently used for SGS points appears adequate to ensure that woodcock are not counted on >1 survey point, unless consecutive survey points are completely surrounded by flat, open field. In that case the same bird has the potential to be counted at consecutive survey points, which violates the assumption of independent survey points. Recording the cardinal direction and approximate distance to a peenting woodcock in this situation might prevent an observer from counting the same bird twice. Not counting uncertain detections (i.e., birds heard faintly that are likely beyond reliable detection distance) will increase confidence in (1) reducing double counting of the same bird from consecutive points and (2) counting birds only within the EAS. In forested land-cover types, in contrast, observers likely would not detect woodcock beyond 198 m, suggesting that one must consider land-cover type when comparing counts between locations.

Our estimates for the EAS at an SGS point can be used to calculate density of singing male woodcock. With technology such as remote sensing, SGS points may be easily classified into the 3 general land-cover categories we used in our study. The unique EAS estimates for each SGS route could also be evaluated periodically to account for changes in land cover. Our results also highlight the importance of accounting for detection probability and EAS on woodcock surveys at the scale of a county in east-central Minnesota. Detection probability and EAS are likely different in different landscapes, and may need to be assessed more broadly to assess how topography and other forest cover types are related to detection probability and EAS.

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# Detection Probability and Occupancy of American Woodcock during Singing-ground Surveys

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**ABSTRACT** The Singing-ground Survey (SGS) was designed to exploit the conspicuous breeding-season display of male American woodcock (*Scolopax minor*; hereafter, woodcock) to monitor these otherwise inconspicuous birds. The SGS was standardized in 1968 and has since been conducted annually to derive an index of abundance and population trend. Counts of singing male woodcock on the SGS have generally declined through time, but without knowledge of the relationship among counts, woodcock abundance, and the factors affecting detection, considerable uncertainty remains in interpretation of SGS data. Using modified SGS protocols, we surveyed SGS routes in Pine County, Minnesota, in 2009 and 2010 and developed models to assess factors associated with detection probability and estimated occupancy. The intercept-only model (i.e., constant detection and occupancy probabilities across sites and no covariates) included overall detection probability of 0.59 (SE = 0.018) in 2009 and 0.66 (SE = 0.017) in 2010 with an occupancy estimate of 0.74 (SE = 0.049) in 2009 and 0.81 (SE = 0.044) in 2010. The best-supported model of detection probability for both years combined included detection as a function of woodcock abundance, observer, date, disturbance level (i.e., ambient noise that interfered with detecting woodcock), and wind speed. High wind speeds were negatively related to detection, different observers had different detection probabilities, date was quadratically related to detection (indicating a mid-period peak in detection), and high woodcock abundance and low disturbance levels were positively related to detection. We provide suggestions for incorporating these resulting into SGS protocol and analyses.

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**KEY WORDS:** American woodcock, detection probability, Minnesota, occupancy, *Scolopax minor*

The American woodcock (*Scolopax minor*; hereafter, woodcock) is a migratory game bird that occurs in forested landscapes in eastern and central North America. During the spring, male woodcock perform distinctive courtship behavior in a variety of openings (e.g., natural openings, clearcuts, agricultural fields) called singing grounds. Woodcock are pursued as game birds in southern Canadian provinces from Manitoba eastward, and throughout the central, eastern, and southeastern United States (U.S.); they are migratory and are managed federally under auspices of the Migratory Bird Treaty Act in the U.S. and the Migratory Birds Convention Act in Canada. Woodcock populations are monitored via the North American Woodcock Singing-ground Survey (SGS), coordinated by the U. S. Fish and Wildlife Service (FWS) and the Canadian Wildlife Service. This survey has been conducted throughout primary woodcock breeding range since 1968, with results used as an index of abundance and to estimate population trends (Seamans and Rau 2016). From 1968 to 2016, the numbers of singing male woodcock counted on SGS routes declined 0.93% per year in the Eastern Region (southern Quebec, the maritime Canadian provinces, and the northeast and mid-Atlantic U.S., east of the Appalachian Divide) and 0.68% per year in the Central Management Region (south-

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ern Ontario and the Midwestern U.S. south to the Ohio River Valley; Seamans and Rau 2016). Concerns about declines in the number of woodcock detected on the SGS have led to harvest restrictions (summarized in Seamans and Rau 2016), development of a woodcock conservation plan (Kelley et al. 2008), and a need to better understand how counts of woodcock on the SGS are related to woodcock abundance and population trends.

As with most indices of abundance, the SGS is based on an assumed relationship between counts and abundance that is not well documented (Anderson 2001). One important and untested assumption underlying the SGS is that all male breeding woodcock occupying a listening point are heard peenting (the vocalization made by displaying male woodcock) on the night of the survey, or that a constant proportion of males present are detected among years (Thogmartin et al. 2007). However, the relationship between number of woodcock heard on surveys and number of woodcock present is unknown (e.g., Kozicky et al. 1954). Furthermore, a number of factors can influence detection probability of displaying male woodcock during the SGS, including weather, observer ability, woodcock behavior, woodcock density, ambient noise levels, land cover surrounding SGS listening points, and distance from and orientation of a peenting woodcock relative to the listening point. How these factors influence SGS counts is not well documented.

The SGS was designed to minimize the influence of environmental factors on woodcock counts by prescribing conditions under which a survey is conducted, and optimizing conditions that influence whether male woodcock display and whether displaying woodcock are detected (e.g., Goudy 1960, Duke 1966). The SGS protocol precludes surveys during heavy precipitation, strong (>19.3 km/hr; 12 mph) wind, or temperatures below 4.4° C (40° F). However, weather conditions may still affect detection of woodcock on the SGS. Simons et al. (2007) found that the proportion of breeding songbirds heard under breezy (10–25 km/hr) conditions decreased by 28% compared to calm conditions. Furthermore, ambient noise level ("disturbance"), which includes traffic noise and other human-caused or natural (e.g., frogs, other birds) sounds, can affect the ability of observers to detect woodcock. Simons et al. (2007) reported that proportion of birds detected decreased by 41% in the presence of other singing birds (1–3 singing birds) and 42% with addition of 10 dB of white noise. Ambient noise level is not taken into account in SGS analyses by the FWS.

Ability to detect woodcock likely varies among observers and may change through time, although observer ability is not directly assessed in SGS analyses. Duke (1966) recommended hearing tests for observers, specifically for the frequency range of woodcock peenting. Simons et al. (2007) recognized that age-related hearing loss combined with and compounded by a general increase in ambient noise in occupied habitats through time has the potential to decrease detection probabilities of birds. Current analyses of SGS counts incorporate the observer-route combination and first year for observers (Sauer et al. 2008), but the magnitude of variation among observers is unknown.

Presence and behavior of neighboring woodcock could also affect likelihood of or rate that woodcock display, which in turn could influence woodcock counts during the SGS. For example, Duke (1966) found that in some instances peenting rates were greater during a 2-min listening period when woodcock were alone compared to when they were close to 1 or 2 other woodcock. McAuley et al. (1993) noted that dominant males peented consistently throughout the evening, whereas subdominant males remained quiet or peented intermittently. Similarly, Godfrey (1974) reported that subdominant males moved to various singing grounds during the evening display period and peented intermittently near the dominant male of that singing ground. It is not clear how presence of other woodcock influences displaying birds, or how this might influence SGS counts, and the influence of other woodcock on detection probability has not been assessed.

To address how environmental, observer, and conspecific factors influenced detection probability of male woodcock during the SGS, we quantified effects of these factors on detection probability of woodcock under the conditions of the SGS in east-central Minnesota, USA. Because the primary goal of monitoring woodcock is to estimate abundance and population trends, we also estimated detection-corrected occupancy of woodcock on SGS routes. Incorporating detection probability to estimate woodcock occupancy may provide an alternative approach to assessing trends in woodcock abundance, potentially improving interpretation of SGS counts.

## Study Area

We conducted our study in Pine County, Minnesota, USA during the springs of 2009 and 2010. Pine County is located in east-central Minnesota (~92°17.5′ - 93°8.5′ W and 45°43.3′ - 46°24.7′ N) and is characterized by drumlin ridges with depressions between the ridges containing peatlands with shallow organic material, and extensive wetlands. During the period of our study, large areas in eastern Pine County were heavily forested, dominated by aspen-birch (*Populus* spp.-*Betula* spp.) forest with small areas of pine (*Pinus* spp.) forests. Land use was dominated by 40% forest, followed by 24% row crop, 17% wetland-open, 13% pasture, and 6% water (Minnesota DNR 2006). Mean maximum temperatures by month during our study ranged from 11.6° C to 19.6° C and mean minimum temperatures ranged from -1.4° C to 5.3° C (Minnesota Climatology Working Group 2010).

## Methods

### DATA COLLECTION

In April and May we surveyed the 4 established SGS routes in Pine County (routes 77, 80, 86, and 91), and 4 additional randomly located routes (included to increase sample size) following the official SGS protocol for conducting surveys, except that we initiated surveys earlier than the period prescribed by the SGS protocol (see below). Locations of established SGS routes were determined by the FWS (see Seamans and Rau 2016) and consisted of 10 listening points evenly distributed along 5.4 km of secondary road. We visited the starting point of each route and digitized route locations using a Geographic Information System (ArcMap 9.3; use of trade names does not imply endorsement by either the U.S. Government or the University of Minnesota). We located reference routes randomly by selecting a Universal Transverse Mercator coordinate within Pine County using Hawth's Analysis Tools (Hawth's Analysis Tools for ArcGIS Version 3.27, www.spatialecology.com/htools, accessed 10 February 2009) then locating, using a randomly selected cardinal direction (Microsoft Office Excel 2003), the nearest secondary road.

Five (2 in 2009, 2 in 2010, and 1 in both 2009 and 2010) different observers conducted surveys on both SGS and reference routes. Observers had their hearing evaluated and we trained them to listen for woodcock by conducting surveys along the established SGS routes in Pine County before the start of the sampling period. We surveyed each of the 8 routes (10 points per route) once on each of 4 days during 3 of the 6 weeks during the breeding-season study period, resulting in 80 points surveyed 12 times over the course of the survey period. We also recorded the cardinal direction and estimated distance to each woodcock we detected on each survey to identify woodcock displaying at approximately the same location among surveys during the same year, and treated woodcock detected displaying at the same location as individuals in our analyses of covariates associated with detection (see below). Based on this experimental design, we made the assumption of a closed population (i.e., no changes in occupancy) and assessed trends in detection throughout the spring. It took 2 weeks to survey all 8 routes, starting with the southernmost routes and progressing north. The 6-week survey periods were 12 April – 21 May 2009 and 10 April – 19 May 2010. We initiated surveys earlier than the SGS protocol-recommended 25 April because we needed a longer period than the <6-week period prescribed by the SGS protocol to survey each route 12 times. We also wanted to allow for the possibility that woodcock may return earlier to breeding areas than they have in the past to account for potential effects of climate change on the timing of spring behavior of birds (e.g., Murphy-Klassen et al. 2005, Jonzén et al. 2006).

We recorded temperature, wind speed, sky condition, precipitation, and disturbance level (see below) for each survey in the same manner as the official SGS protocol. Disturbance level described the ambient noise at each listening point in 1 of 4 categories: none, low, moderate, and high. Because these categories are subjective, we grouped them into quiet (none or low) and noisy (moderate or high; e.g., Kissling et al. 2010). The official SGS protocol includes 5 categories of precipitation: none, mist, snow or heavy rain, fog, and light rain. Because fog never occurred during surveys over the course of our 2-year study period and mist only occurred 4 times, we grouped fog and mist with light rain to indicate presence of light precipitation. This study was conducted under protocol 0801A24506 approved by the Institutional Animal Care and Use Committee at the University of Minnesota.

### DATA ANALYSIS

We estimated occupancy ($\psi$) and detection probability ($p$) of male woodcock based on the detection history from repeated surveys at each listening point along routes using the approach of MacKenzie et al. (2002, 2006). The repeated surveys assess occupancy in a population assumed to be closed [i.e., an individual woodcock remains associated with its singing ground(s) throughout the survey period and displaying male woodcock do not immigrate into the study area during the survey period]. This method uses a closed-population model to estimate occupancy rates when detection probabilities are <1 and allows for the inclusion of covariate information via a logistic model. A detection history of ones (detection) and zeroes (no detection) at $N$ sites over $T$ visits is recorded along with all covariate data associated with each listening point.

We used program PRESENCE (PRESENCE2-Software to estimate patch occupancy and related parameters, mbr-pwrc.usgs.gov/software/presence.html, accessed 2 June 2009) to estimate detection probability and occupancy across survey points for survey data from 2009, 2010, and 2009–2010 combined. We also used PRESENCE to assess whether occupancy changed within years across the sampling period as an evaluation of whether we met our assumption of population closure, by estimating occupancy for each third of the survey period (mid-April, late-April through early May, and mid-May).

PRESENCE estimates both occupancy and detection probability in a hierarchical model. Therefore, to preclude confounding factors associated with both detection probability and occupancy, we use repeated measures logistic regression (R Version 2.11.1, www.r-project.org, accessed 29 June 2010) to identify factors (e.g., wind speed, observer, date; Table 1) associated with detection probability of individual woodcock (woodcock detected at the same location among surveys, see above). The probability that we detected an individual male woodcock as a function of the measured covariates was:

$$logit\,(p) = \beta_0 + \beta_1 x_{i1} + \beta_2 x_{i2} + \cdots . + \beta_U x_{iU}$$

We examined factors related to detection probability in a sequential model-selection approach (Burnham and Anderson 2002), where we first evaluated single-covariate models, and then added multi-covariate models based on Akaike's Information Criterion (AIC; Akaike 1973), similar in concept to the approaches used by Yates and Muzika (2006), Amundson and Arnold (2010), and Daly et al. (2015). We considered 7 single-covariate models [neighbor, wind, temperature, precipitation, observer, date, quiet], the global model (all covariates), and the intercept-only (null) model for 2009, 2010, and 2009–2010 combined. We included Julian date as a quadratic covariate to account for a peak in singing activity by males during the breeding season (Goudy 1960, Sheldon 1967). We included year as a covariate when combining data from both years to indicate surveys conducted in 2009 or 2010.

We ranked single-covariate models using AIC and used the single-covariate model with the lowest AIC value as the base model for considering additional covariates. We sequentially added covariates to this base model, in the order of support of covariates based on AIC values, until adding a covariate did not reduce the AIC value of the multi-covariate model by ≥2 (e.g., Yates and Muzika 2006, Popescu and Gibbs 2009, Kissling et al. 2010). We then used AIC to identify the models in the set of single-covariate models, the global model, the null model, and the subset of multi-covariate models best supported by our data and to calculate AIC model weights ($w_i$; Burnham and Anderson 2002). We considered competing models to be the model best supported by the data (i.e., having the lowest AIC value) and models within 2 AIC units ($\Delta AIC \leq 2$) of that model that also improve model fit (as measured by a decrease in model deviance if they include additional covariates, Arnold 2010). We also evaluated 10,000 bootstrap samples of global models to test for overdispersion of the data, which is indicated by a variance inflation factor ($\hat{c}$) > 1.0 (Burnham and Anderson 2002). We used the variance inflation factor to modify AIC by:

$$QAIC = -[2log - likelihood\ /\ \hat{c}] + 2K.$$

**Table 1.** Covariates considered in assessing factors related to detection and occupancy of American woodcock on Singing-ground Surveys in Pine County, Minnesota, 2009–2010.

| Variable | Description |
|---|---|
| Year | Indicates 2009 or 2010 survey. |
| Observer | Indicates which of 5 observers conducted a survey over the 2-year study period. |
| Wind | Wind speed at the time of the survey. Categorical variable per SGS guidelines. |
| Date | Julian date. Included a quadratic term to represent a peak in detections. |
| Temperature | Temperature at the start of the survey. Four categories: 2–3.9°C, 4–9.5°C, 9.6–15°C, >15.1°C. |
| Precipitation | Presence or absence of any type of light precipitation (rain, mist, fog) during the survey. |
| Neighbor | Presence and detection of ≥2 displaying woodcock at a listening point. |
| Quiet | Ambient noise level at each listening point as in official SGS protocol (4 categories: none, low, moderate, high). An indicator variable for none or low ambient noise with null indicating moderate or high ambient noise. |

We compared occupancy and detection probability estimates between years and among categories based on 95% confidence intervals and assessed relative importance of model covariates by summing model weights across all candidate models (Burnham and Anderson 2002) that included each covariate. We evaluated evidence for statistical significance based on whether 95% confidence intervals around parameter estimates contained zero, and report model-averaged parameter estimates (Burnham and Anderson 2002) for covariates associated with detection probability. Finally, we compared detection frequency of individual woodcock across surveys using a chi-squared test (Microsoft Office Excel 2003) to evaluate whether there was evidence of differences in woodcock association with individual singing grounds between years.

## Results

In 2009, we conducted surveys on each of our 8 routes ($n$ = 80 listening points) 12 times, and identified 125 individual woodcock (based on cardinal direction and estimated distance from a listening point) at 59 (74%) listening points. In 2010, we also conducted surveys on each of our 8 routes ($n$ = 80 listening points) 12 times, and identified 177 individual woodcock at 65 (81%) listening points. The proportion of surveys in which we detected individual woodcock within a year ranged from approximately 0.08 (1 survey; approximately 20% of individual woodcock) to 1.0 (12 surveys; also approximately 20% of individual woodcock). The distribution of the proportion of surveys in which we detected an individual woodcock was similar between years ($\chi^2_9 = 3.68$, $P = 0931$), suggesting that individual woodcock used multiple singing grounds (McAuley et al. 1993) similarly between years.

### DETECTION PROBABILITY

The intercept-only model with detection and occupancy probabilities constant across listening points and survey routes [$\psi(.)$, $p(.)$] derived using PRESENCE had an overall detection probability of 0.59 (SE = 0.018) in 2009 and 0.66 (SE = 0.017) in 2010. The 95% confidence intervals for these 2 years did not overlap: (0.56, 0.63) and (0.63, 0.70) for 2009 and 2010, respectively, suggesting that detection probability across survey points was slightly lower in 2009 than in 2010.

The best-supported single-covariate model of detection probability (based on repeated measures logistic regression) for 2009 included neighbor and ranked below the global model (ΔAIC = 6.3; Table 2). In 2010, the best-supported single-covariate model of detection probability included neighbor, and also ranked below the global model (ΔAIC = 7.7; Table 2). Similarly, when we combined data from 2009 and 2010, the best-supported single-covariate model of detection probability included neighbor, which ranked considerably below the global model (ΔAIC = 23.6; Table 2).

After considering addition of covariates to the best-supported single-covariate model, the best-supported model of detection probability for 2009 included the covari-

**Table 2.** Covariates in models of detection probability of individual male American woodcock, Akaike's Information Criterion (AIC), difference of AIC between a model and the model with the lowest AIC (ΔAIC), model weights ($w_i$), number of parameters in the model ($K$), and model deviance (Dev) for the 6 candidate models we used to evaluate factors related to detection of individual American woodcock on Singing-ground Surveys in Pine County, Minnesota, for 2009, 2010, and 2009–2010 combined.

| Model | $\text{AIC}_c$ | $\Delta\text{AIC}_c$ | $\omega_i$ | $K$ | *Dev* |
|---|---|---|---|---|---|
| **2009** | | | | | |
| Neighbor + Observer + Quiet + Wind | 1783.4 | 0.0 | 0.792 | 6 | 1771.4 |
| Neighbor + Observer + Quiet + Wind + Date[a] | 1787.3 | 3.9 | 0.113 | 8 | 1771.3 |
| Neighbor + Observer + Quiet | 1788.3 | 4.9 | 0.068 | 5 | 1778.3 |
| Global | 1790.4 | 7.0 | 0.024 | 10 | 1770.4 |
| Neighbor + Observer | 1794.8 | 11.4 | 0.003 | 4 | 1786.8 |
| Neighbor | 1796.7 | 13.3 | 0.000 | 2 | 1792.7 |
| Null | 2139.4 | 356.0 | 0.000 | 1 | 2137.4 |
| **2010** | | | | | |
| Neighbor + Date + Quiet + Observer | 1973.6 | 0.0 | 0.448 | 7 | 2351.3 |
| Neighbor + Date + Quiet + Observer + Precip[a] | 1974.8 | 1.2 | 0.245 | 8 | 2350.5 |
| Neighbor + Date + Quiet | 1975.3 | 1.7 | 0.191 | 5 | 2360.7 |
| Neighbor + Date | 1977.3 | 3.7 | 0.070 | 4 | 2363.1 |
| Global | 1978.3 | 4.6 | 0.045 | 10 | 2349.9 |
| Neighbor | 1986.0 | 12.4 | 0.001 | 2 | 2378.4 |
| Null | 2450.5 | 476.8 | 0.000 | 1 | 2448.5 |
| **2009–2010** | | | | | |
| Global | 4153.7 | 0.0 | 0.349 | 13 | 4127.7 |
| Neighbor + Quiet + Observer + Wind + Date | 4154.2 | 0.5 | 0.272 | 10 | 4134.2 |
| Neighbor + Quiet + Observer + Wind + Date + Precip | 4154.5 | 0.8 | 0.234 | 11 | 4132.5 |
| Neighbor + Quiet + Observer + Wind | 4155.8 | 2.1 | 0.122 | 8 | 4139.8 |
| Neighbor + Quiet + Observer | 4159.1 | 5.4 | 0.023 | 7 | 4145.1 |
| Neighbor + Quiet | 4167.6 | 13.9 | 0.000 | 3 | 4161.6 |
| Neighbor | 4177.3 | 23.6 | 0.000 | 2 | 4173.3 |
| Null | 5077.4 | 923.7 | 0.000 | 1 | 5075.4 |

[a] Not a competing model, based on model deviance.

ates neighbor, observer, quiet, and wind, and received 7 times more Akaike model weight (AIC $w_i$) than the second-ranked model. Wind was negatively related to detection probability, one observer had higher detection probability than the other 2 (although 95% CIs overlapped), and neighbor and quiet were positively related to detection probability. The cumulative model weights for individual covariates across candidate models were neighbor = 1.0, observer = 1.0, quiet = 0.997, wind = 0.929, date = 0.137, temperature = 0.024, and precipitation = 0.024 (Table 2). The best-supported multi-covariate model of detection probability for 2010 included the covariates neighbor, date, quiet, and observer. Akaike model weight for the best-supported model was 2 times greater than for the second-ranked model. As in 2009, one observer had a higher detection probability than the other 2 observers (although 95% CIs overlapped), date had a quadratic relationship with detection probability, and neighbor and quiet were positively related to detection probability. The cumulative model weights for individual covariates were neighbor = 1.0, date = 0.999, quiet = 0.929, observer = 0.738, precipitation = 0.290, wind = 0.045, and temperature = 0.045 (Table 2).

The best-supported model of detection probability for 2009 and 2010 combined was the global model, which had a lower deviance and a higher number of parameters than the rest of the candidate models. Wind was negatively related to detection probability, Observer 1 had a higher detection probability than the other 4 observers (although 95% CIs overlapped), date had a quadratic relationship with detection probability (Fig. 1), and neighbor and quiet were positively related to detection probability (Table 3). The 95% confidence interval around the parameter estimates (βi's) contained zero for year, precipitation, and temperature, suggesting these covariates did not have a strong relationship with detection probability, even though they appeared in the best-supported model. The cumulative model weights for individual covariates were neighbor = 1.0, quiet = 1.0, observer = 1.0, wind = 0.977, date = 0.855, precipitation = 0.583, and temperature = 0.339 (Table 2). Bootstrap simulations for 2009 and 2009–2010 combined provided no evidence of overdispersion in the data ($\hat{c}$ = 0.33, 0.43, respectively) whereas 2010 showed slight overdispersion ($\hat{c}$ = 1.2).

### OCCUPANCY

Based on the intercept-only model with constant detection and occupancy probabilities and no covariates [ψ(.),*p*(.)], we estimated woodcock occupancy across survey points at 0.74 (SE = 0.049) in 2009 and 0.81 (SE = 0.044) in 2010. Occupancy appeared to increase (although 95% CIs overlapped across the sampling period) through our sampling period in 2009, but not in 2010 (Fig. 1). The point estimate of occupancy in 2009 was lower than in 2010 for the early- and mid-spring periods, but similar between years during the late-spring period (Fig. 2), although 95% CIs overlapped among periods within years, indicating no strong indication of a peak in occupancy.

## Discussion

We estimated detection probability and occupancy of male woodcock at survey points along 4 SGS routes and 4 routes patterned after SGS routes in east-central Minnesota, and documented relatively high occupancy in both 2009 and 2010. Thogmartin et al. (2007) identified east-central Minnesota as an area of high woodcock abundance, based on their landscape-scale models. Our observations of high occupancy (0.74 in 2009 and 0.81 in 2010) also suggest high woodcock abundance in this landscape.

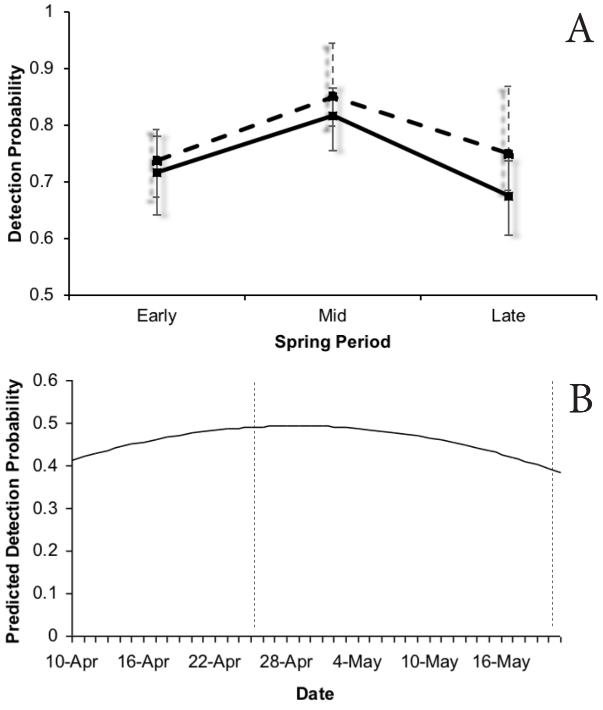

**Figure 1.** Detection probability (a) estimates (with 95% confidence intervals) of American woodcock during repeat surveys of 8 routes using the Singing-Ground Survey protocol from the model [ψ(.),*p*(period) in PRESENCE; see text for model description] for the 3 2-week spring sampling periods [Early (mid-April), Mid (late April – early May), Late (mid-May)] in Pine County, Minnesota, USA, 2009 (solid) and 2010 (dashed), and (b) estimates of detection probability of American woodcock by date from the model [ψ(.),*p*(date)] from 2009 and 2010 data combined from Pine County, Minnesota, USA. Dashed lines indicate the start and end dates of the Singing-ground Survey protocol for Pine County, Minnesota, USA.

We observed differences between years in estimated occupancy, which may be a consequence of the dynamic nature of use of singing grounds among years by woodcock as described by Godfrey (1974) and McAuley et al. (1993), or of real change in abundance of woodcock between years.

The detection probabilities we estimated were lower (0.59 in 2009 and 0.66 in 2010) than perfect detection ($p$ = 1.0), suggesting that accounting for factors influencing detection in standardized surveys with single visits to individual listening points could improve estimation of occupancy and description of trends in woodcock abundance. We identified 4 factors that were related to detection probability of woodcock using the SGS protocol; neighbor, observer, date, and quiet. Neighbor, which indicated the presence of >1 woodcock singing at an SGS listening point during a survey, had a strong positive relationship with detection, perhaps due to social facilitation (i.e., motivation to call in the presence of a conspecific) and the competitive nature of male woodcock during the breeding season (Sheldon 1967). Our study area in east-central Minnesota had a higher estimated abundance of woodcock than many other areas (Thogmartin et al. 2007), so whether presence of a conspecific would be related to detection at lower woodcock density is unknown. If calling by one woodcock elicits peenting from neighboring woodcock, call broadcasts could increase detection probability, potentially most effectively at low woodcock abundance.

**Table 3.** Model-averaged parameter estimates (β) and 95% confidence interval limits for detection probability covariates included in the global model of factors related to detection probability of individual American woodcock in Pine County, Minnesota, 2009–2010.

| Variable | β | 95% lower CL | 95% upper CL |
|---|---|---|---|
| Intercept/ Observer5 | -1.72 | -2.42 | -1.03 |
| Date | 0.022 | -0.007 | 0.050 |
| Date$^2$ | <-0.000 | -0.001 | <-0.000 |
| Observer1 | 0.049 | -0.202 | 0.299 |
| Observer2 | -0.241 | -0.625 | 0.143 |
| Observer3 | -0.116 | -0.497 | 0.265 |
| Observer4 | -0.288 | -0.534 | -0.042 |
| Precipitation | -0.123 | -0.494 | 0.241 |
| Wind | -0.044 | -0.082 | -0.006 |
| Temperature | 0.009 | -0.003 | 0.021 |
| Quiet | 0.283 | 0.122 | 0.445 |
| Neighbor | 2.11 | 1.96 | 2.26 |
| Year | 0.112 | -0.160 | 0.385 |

Our models also indicated an observer effect, although approximately half the time the 95% confidence interval for these coefficients contained zero. Even though observers in our study were tested for hearing and possessed the ability to hear woodcock peenting (unlike the SGS, where observers are not screened for auditory acuity), we still documented observer effects. It is probably not feasible to assess the ability of SGS observers to detect peenting woodcock, in part because many cooperators are volunteers, but differential ability of observers to detect woodcock likely adds considerable random variation, and approaches to control this variation may be warranted.

Our results also suggested the presence of a peak in detection probability during the spring, as evidenced by the inclusion of a quadratic date covariate in the best-supported models of detection probability. A mid-spring peak in detection was also evident when we plotted detection probability through time (Fig. 1), and likely can be explained by a peak in displaying by male woodcock (Goudy 1960, Sheldon 1967). If surveys were timed to be close to this peak, detection probability would likely be higher than if surveys were conducted earlier or later in the season. However, this peak was included within the official survey window for Pine County and it may not be logistically feasible to conduct surveys in a shorter window of time than identified in the current SGS protocol.

Quiet, which indicated that the ambient noise level was "none" or "low" at a listening point during a survey, also had a positive association with detection probability compared to surveys conducted during periods with higher ambient noise levels (i.e., "noisy"), although not as strong as did "neighbor." This covariate may have been con-

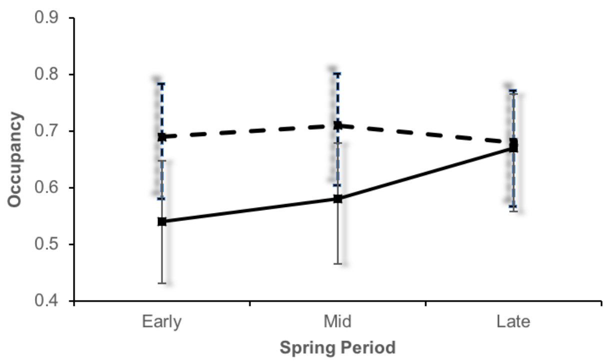

**Figure 2.** American woodcock occupancy estimates (with 95% confidence intervals) across listening points from the model [ψ(period),$p$(.)] for the 3 2-week spring sampling periods [Early (mid-April), Mid (late April – early May), Late (mid-May)] in Pine County, Minnesota, USA, 2009 (solid) and 2010 (dashed).

founded with precipitation because light rain, especially when leafout has occurred, can temporarily increase ambient noise during part or all of a survey. Also, on busier secondary roads where ambient noise level can be quite variable, accounting for this relationship would likely improve the accuracy of estimating short-term population trends as traffic noise during surveys likely varies among years.

We also note that detection probability in both 2009 and 2010 was similar even though we employed different observers and conducted surveys under variable spring weather conditions, which suggests that detection probability may be relatively constant among years, at least over the conditions we encountered. If this is the case, then at least at smaller spatial scales (e.g., the scale of our study), detection probability may be relatively constant through time. However, at larger spatial scales (e.g., the scale of states or Management Regions), whether there is spatial variation in detection probability is not known.

Finally, whether our assumption of population closure during our 3-week survey period was met is not clear. In Maine, individual male woodcock moved among singing grounds during the spring (McAuley et al. 1993), and similar movement by individual males among signing grounds in our study could have influenced our results in 2 ways. First, if movement by individual males resulted in singing grounds being unoccupied during some surveys, our occupancy estimates may be biased low, especially if such movement occurred disproportionately at sites where only 1 woodcock was present. In our study, the distribution of the proportion of surveys when we detected individual woodcock (identified as woodcock displaying at individual locations) was similar between years, suggesting that movement among singing grounds by individual males was also similar between years. Under that circumstance, our occupancy estimates between years are directly comparable, although they may be biased low for both years. Second, if our assessment of covariates associated with detection probability of individual woodcock included multiple individuals identified as the same individual at a particular singing ground, variation among those individuals may have resulted in lower power to detect associations. In that case, the strength of the associations we identified may have been under-estimated. Finally, at a broader spatial scale, some male woodcock may be present along survey routes for only a portion of the SGS window (Moore et al., this volume). The magnitude and extent of such movements is not well documented, although in our study, the potential influence of such movements would be similar to the influence of smaller-scale movements, described above.

## Management Implications

We suggest that, to better document and understand the influence of factors related to detection at a larger spatial scale than we were able to assess in our study, a subset of SGS routes at various locations throughout the woodcock breeding range could be surveyed repeatedly and environmental factors measured to assess their association with detection probability. This could lead to quantifiable guidelines on when to conduct surveys and what factors are most important to consider when interpreting data resulting from the SGS.

First, for each latitudinal region, the survey window could be evaluated and possibly condensed to ensure that surveys are being completed during the peak display period. Second, observer variation in the SGS is likely at least as large as in our study, and training and testing observers would likely reduce this variation. Third, routes could be evaluated to determine if the road(s) being used has experienced increases in traffic levels since the routes were established in 1968. SGS routes with unsafe road conditions can be replaced through official protocol, and an assessment of continued inclusion of routes with high vehicle traffic or other sources of noise seems warranted. Finally, detection probability of woodcock on SGS routes decreases in precipitation stronger than a mist, likely due to a decrease in the observer's ability to hear woodcock over the noise of the precipitation. Data resulting from surveys of routes on the SGS during such conditions likely under-represent woodcock abundance and we suggest that they should be discarded.

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# Influence of Weather on the Eurasian Woodcock's Breeding Display

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**ABSTRACT:** Counts of displaying male Eurasian woodcock (*Scolopax rusticola*) form the basis for breeding Eurasian woodcock surveys in many regions across Europe and provide the only practical method of assessing the species' abundance. This paper investigates the effect that weather may have on the results of these surveys, principally considering its influence upon Eurasian woodcock display behavior and detectability by surveyors. We assessed data from an annual Eurasian woodcock survey conducted in the Britain during 2004–2015 and correlated them with a number of weather variables. This is supplemented by tracking data gathered from 19 male Eurasian woodcock to assess how weather might affect each individual's decision to display. We found that counts of roding Eurasian woodcock were positively related to the amount of rainfall in the 2 weeks preceding the survey and negatively related to wind speed on the evenings that surveys were conducted. The likelihood that tagged male Eurasian woodcock displayed decreased in relation to wind speed and increased in relation to minimum air temperature. To guarantee that counts of displaying males provide a representative measure of abundance, we recommend that surveys consist of at ≥3 visits to each site within each year, that visits are spread as widely as possible across the peak displaying season, and that analyses are based on maximal counts rather than means to reduce the effects of surveys conducted in sub-optimal weather conditions.

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**KEY WORDS:** abundance, census, Eurasian woodcock, national survey, rainfall, remote-sensing, *Scolopax rusticola*, temperature, UK

The breeding display flight of the Eurasian woodcock (*Scolopax rusticola*) offers a unique opportunity to survey a species that is otherwise rarely observed. Eurasian woodcocks' cryptic plumage and behavior means that encounter rates during the breeding season are generally low and that traditional diurnal bird surveys, such as those used for other woodland birds (e.g., Hewson et al. 2007, Hewson and Noble 2009), are unrepresentative. The display flight, known as 'roding', contains conspicuous visual and vocal signals that provide an effective means of assessing site occupancy and the relative abundance of Eurasian woodcock.

Display flights are performed over roding grounds ranging in size from 43 to 134 ha (Hirons 1980) and are accompanied by a continuous repeated 2-part call (Hoodless et al. 2008). The roding grounds of several males may overlap (Hirons 1980) and the behavior appears to be a signal for female mate selection rather than male-male territoriality (Hirons 1980). Males perform their displays at dawn and dusk between February and July, with roding behavior peaking during May and June (Hoodless et al. 2006).

Counts of roding Eurasian woodcock form the basis of breeding Eurasian woodcock surveys in several European regions, including Switzerland, France, the Azores, and

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western Russia (Estoppey 2001, Ferrand et al. 2008, Machado et al. 2008, Fokin and Blokhin 2013), where measures of Eurasian woodcock activity or 'roding intensity' are used as an indicator of Eurasian woodcock abundance. The Eurasian woodcock is a quarry species in most European countries (Lutz 2005), and these surveys can be used to guide more sustainable hunting practices, particularly where migrant and resident Eurasian woodcock populations overlap.

A national survey of Eurasian woodcock in Britain, for instance, uses a calibration equation to convert surveys of roding activity into estimates of population size (Hoodless et al. 2009), and found a 29% decline in the British breeding population between 2003 and 2013 (Heward et al. 2015). Roding surveys are the only effective way of detecting breeding population trends as alternative methods conducted in winter, such as hunting bag analyses (e.g. Seamans and Rau 2017), are confounded by the large numbers of migrant Eurasian woodcock that winter alongside British breeders (Hoodless et al. 2013). In Britain, voluntary guidelines for hunters were produced in an attempt to minimize the impact of hunting on the declining resident component of the wintering population (Game & Wildlife Conservation Trust 2017). Continued monitoring of the resident population will help gauge the effectiveness of these measures and, if necessary, could form the grounds for tighter control in the future.

The British breeding Eurasian woodcock survey was conducted at approximately 800 randomly selected sites in 2003 and 2013 (Heward et al. 2015). A non-random sub-sample of these sites, surveyed on an annual basis in the intervening years, demonstrated a yearly decline of 4.9% (Heward et al. 2015). However, these annual surveys were also characterized by a high degree of annual variation, and weather was suggested as a possible cause for these fluctuations. There is already evidence that roding activity can be influenced by weather conditions during the roding period, although Hoodless et al. (2006) suggest that these must be relatively severe before they have a significant effect. If more subtle variations in weather influence the roding behavior of Eurasian woodcock, these need to be considered in the design and interpretation of roding Eurasian woodcock surveys. Moon phase may also influence the behavior of crepuscular species, although this has been demonstrated more clearly for mammals (Prugh and Golden 2014) than for birds (Mills 1986). We propose 4 ways in which weather might influence the results of roding Eurasian woodcock surveys: 1) if weather has a direct impact on survival or productivity in the previous breeding season, 2) if the prevailing weather prior to a survey affects individual fitness and therefore the likelihood of display behavior, 3) if weather during the survey period affects the likelihood of display behavior, or 4) if weather during the survey period affects detectability by the surveyor.

We investigate the relationship between roding survey results and weather, using Eurasian woodcock survey data collected over a 12-year period. The influence that weather has on the display behavior of male Eurasian woodcock is assessed using the tracking data gathered from a sample of 19 male Eurasian woodcock tagged with archival GPS loggers.

## Methods

### REPEAT RODING EURASIAN WOODCOCK SURVEYS

Roding Eurasian woodcock surveys were conducted at woodland sites across Britain between 2004 and 2015. These followed a large-scale national Eurasian woodcock survey conducted in 2003 in which counts of roding males were made at 807 randomly- elected 1 x 1-km squares across England, Scotland, and Wales (Hoodless et al. 2009). Observers taking part in the 2003 survey were encouraged to continue their counts on a yearly basis, resulting in a sub-sample of sites, all of which were occupied by Eurasian woodcock, receiving repeated visits in subsequent years. These were supplemented by 2 additional sites conducted in non-random squares. Ideally, these repeat surveys would have been conducted at an entirely random selection of sites, but this was not possible without increasing the risk of reduced uptake or poor continuity of surveys.

Each survey site was visited up to 3 times per year between the start of May and the end of June, with each visit ≥1 week apart. Volunteers selected a suitable count point where roding could be observed, generally a woodland clearing or the intersection of 2 open trails where the absence of canopy cover allowed a clear view of the sky (British Trust for Ornithology 2013). The same count point was used in successive years unless the development of surrounding vegetation meant that the point had to be moved to a new, more suitable location nearby. Volunteers recorded each separate occasion that a Eurasian woodcock was seen or heard as a single 'registration'.

Volunteers recorded 3 weather variables for each visit. Cloud cover was assigned to 1 of 3 broad categories: 0 – 33%, >33 – 66%, >66 – 100%. Wind strength was rated as calm, light, or moderate (equivalent to 0, 2, and 4, respectively on the Beaufort Scale). Rainfall was categorized as 'no rain', 'drizzle' (very light, continuous rain) or 'showers' (moderate, intermittent rain). Surveys were not conducted if rain was persistent, or if the wind exceeded Beaufort Scale 4.

We obtained daily rainfall data from the Centre for Ecology and Hydrology's (CEH) CEH-GEAR dataset (Tanguy et al. 2016) and, for each survey, we calculated the total rainfall on the day of the survey ('survey day' $d = 0$), total rainfall for the week preceding the day of the survey ('survey week' = $d$ - 7 to $d$ - 1), and for the week before this ('previous week' = $d$ - 14 to $d$ - 8). For the same periods, we extracted mean and minimum temperature from the Met Office's UKCP09 dataset (Met Office 2017*a*). Both datasets are interpolated raster maps based on observations from national Met Office weather stations.

We sourced moon phase data from a moon phase generator available online (somacon.com 2011). This gives the date of each full moon and new moon within the study period. We then used these dates to assign surveys to 1 of 3 categories: if conducted on the night of a new moon or full moon, or within 3 days either side, they were classified as 'new' or 'full,' respectively, otherwise, they were classified as 'transitional'.

We placed survey sites into 1 of 4 geographic regions based on their location: Scotland, Northern England, East Anglia and the Midlands, and South-east England. These regions derive from natural groupings in the distribution of repeat survey sites and follow logical geographic divisions (Fig. 1). We extracted the total area of woodland within a 1-km radius buffer of the count point from the CEH's Land Cover 2007 dataset (Morton et al. 2011). Woodland area is known to have a strong effect on the number of Eurasian woodcock registrations recorded at a site (Heward et al. 2015), hence its inclusion in the analyses described below.

We analyzed data using a generalized linear mixed model (GLMM) with a Poisson distribution and a logarithmic link function. The analysis was conducted in R (R Development Core Team 2016) using the glmmPQL function within the Mass package (Venables and Ripley 2002). We specified the number of Eurasian woodcock registrations recorded on each survey as the dependent variable. The fixed effects were mean temperature on the survey day, during the survey week, and previous week; total rainfall on the survey day, during the survey week, and previous week; moon phase; cloud cover and wind during the survey as recorded by the surveyor; day of year; and wooded area. We specified site, nested within region then year (with year as a categorical variable), as a random effect. We did not include rain during the survey, as recorded by surveyors, as a factor given a very heavy bias towards surveys experiencing no rain at all (*n* = 838 / 886). We also re-ran this model substituting minimum temperature for the mean temperature and the natural log of the minimum temperature.

**Figure 1.** Map showing the 65 survey sites and the boundaries of the 4 regions used in our analysis: A = Scotland *(n* = 7), B = Northern England *(n* = 19), C = East Anglia and the Midlands *(n* = 12), D = South-east England *(n* = 27).

### TRACKING MALE EURASIAN WOODCOCK WITH GPS LOGGERS

We captured Eurasian woodcock in mist-nets in 2 large woods (each ca. 10–14 km$^2$), in Nottinghamshire, UK (Lat: 53.186 N Long: 1.093 W) during the breeding seasons of 2015–2016 (Heward et al. 2017). We tagged 19 male Eurasian (2015: *n* = 5, 2016: *n* = 15 (1 individual was tagged in both years)) with a 7.5-g tag combining an archival GPS logger (Lotek PinPoint 50, Newmarket, Ontario, Canada) and a VHF radio (Perdix Wildlife Supplies, Stratford-Upon-Avon, UK). For most captured Eurasian woodcock (68%), roding behavior immediately prior to capture indicated that the individual was a male. When we could not determine sex based on behavior, we identified males based on the appearance of the cloaca [as described for other Charadriiformes (Tomkovich and Soloviev 1996, Giunchi and Pollonara 2007)], lack of a brood patch, or using biometric data (Ferrand and Gossmann 2009). We aged captured individuals as juvenile (first-breeding season) or adult (≥2 breeding seasons) based upon their wing molt (Ferrand and Gossmann 2009). We attached tags to the skin of the synsacrum and a small number of surrounding feathers using a gauze mount and cyanoacrylate glue. Tagging was conducted under a license issued by the British Trust for Ornithology.

GPS loggers began recording 5 days after tagging, allowing individuals to acclimatize to the tag. Locations were recorded at 1-minute intervals during the typical dusk display period; beginning 15 minutes before sunset and continuing for 90 minutes. This schedule was repeated every subsequent evening for 1 to 6 days depending upon the rate of battery depletion. We recovered tags by recapturing the individual or by using the VHF radio signal to relocate tags once shed.

We obtained weather data from the UK Met Office's observation station at Watnall, UK (Lat: 53.005 N Long: 1.250 W; Met Office 2017*b*), approximately 20 km from the tracking locations. We extracted daily rainfall, daily minimum temperature, and daily mean wind speed for each evening on which tracking data were recorded.

We classified each Eurasian woodcock, for each evening it was tracked, as 'roding' or 'non-roding' based upon its tracking data; for most individuals the distinction between the 2 types of behavior was obvious. Tracking data from roding individuals showed a period of almost constant movement for ≥30 minutes during the core of the roding period. For non-roding individuals, movements were short in duration and direct, typically consisting of a single flight between a roost site and a presumed feeding area (Fig. 2).

We assessed the correlates of 'roding' and 'non-roding' behavior using a binomial GLMM with a logit link function in R's MASS package. The independent variables tested were total rainfall, minimum temperature, and mean wind speed on the day that tracking data were recorded, and the individual's age. We specified 'individual' as a random effect to account for differences among tagged individuals. As a comparison, we created a 'null' model in which age and day of year were the only explanatory variables.

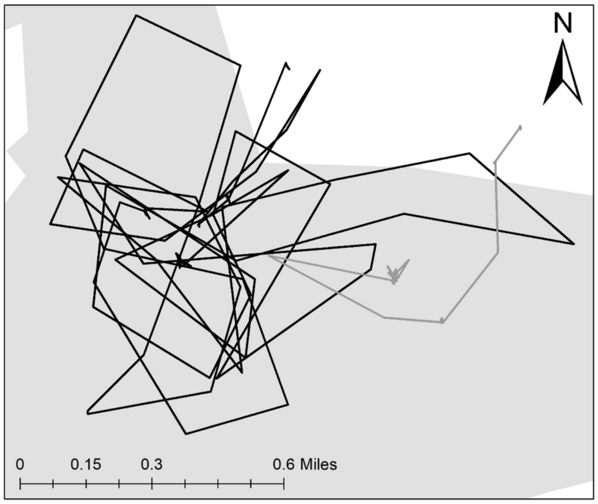

**Figure 2.** Map showing typical 'roding' (black) and 'non-roding' (gray) location data from 2 Eurasian Eurasian woodcock tagged with GPS loggers. Each example shows 1 90-minute tracking period. The gray shaded area shows the extent of woodland.

## Results

### RODING EURASIAN WOODCOCK SURVEY SITES

In total, 65 survey sites received repeated visits (Fig. 1). Few sites were visited every year between 2004 and 2015, but on average each site was surveyed 5.0 different years during the 12-year period. We excluded from analysis sites that were visited in fewer than 3 of the 12 years. The average number of sites visited per year was 26.6. Because of their self-selected nature, the average number of contacts with Eurasian woodcock recorded at these 65 sites [mean registrations = 9.57 ± 0.26 (1 SE)] was higher than the national average [mean registrations = 7.45 ± 1.03 (1 SE) at occupied sites] recorded in the large-scale national survey of 2003.

### RODING SURVEYS AND WEATHER

The multivariate analysis of Eurasian woodcock survey data revealed significant relationships with 3 weather variables: 2 measures of rainfall and the wind speed variable. There was a positive relationship with rainfall during both the survey week (glmmPQL: $t_{550} = 2.81$, $P = 0.005$, 0.051 ± 0.018) and the previous week (glmmPQL: $t_{550} = 2.70$, $P =$

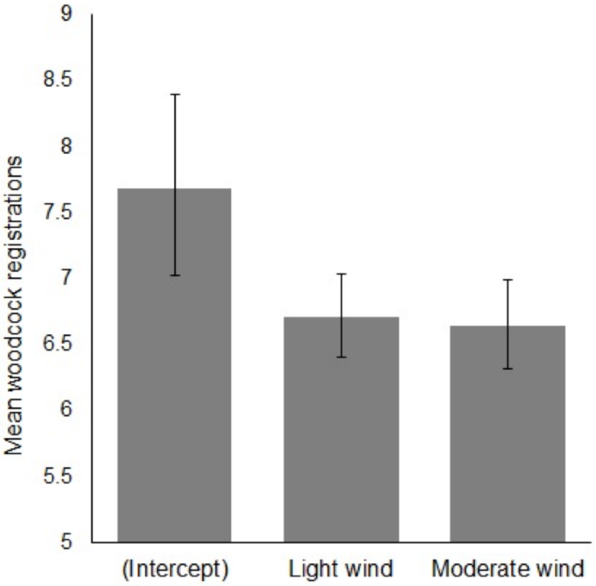

**Figure 3.** The mean number of Eurasian woodcock registrations recorded on roding surveys, in relation to three categorical wind variables: still, light wind (approximately 1–2 on the Beaufort Scale), and moderate wind (approximately 3–4 on the Beaufort Scale). Values are back-transformed from our roding survey GLMM to account for the effects of other explanatory variables. Error bars show 1 SE.

0.007, 0.046 ± 0.017) but no relationship with total rainfall on the survey day.

Wind during the 75-minute survey period was correlated with the number of Eurasian woodcock registrations (Fig. 3), with the number of registrations being lower when wind was classified as 'light' (glmmPQL: $t_{550} = -2.95$, $P = 0.003$, -0.136 ± 0.046) or 'moderate' (glmmPQL: $t_{550} = -2.98$, $P = 0.003$, 0.151 ± 0.051) compared to 'still'.

No significant relationships were found between the number of Eurasian woodcock registrations recorded and the minimum temperature variables. When the model was re-run using the natural logs of minimum temperature, however, the temperature during the survey week was associated with the number of Eurasian woodcock registrations (glmmPQL: $t_{550} = 2.19$, $P = 0.029$, 0.055 ± 0.024). In the model using mean, rather than minimum, temperatures we found no significant relationships with temperature, and relationships with other weather variables remained consistent with those in the model that included minimum temperature.

Moon phase, day of year, and total wooded area were not related to the number of Eurasian woodcock registrations, nor was cloud during the survey, but for the latter, P-values were close to statistical significance when comparing between cloud cover of 66–100% and 0–33% (glmmPQL: $t_{550} = -1.90$, $P = 0.058$, -0.083 ± 0.046).

### TAGGED EURASIAN WOODCOCK AND WEATHER

The probability of Eurasian woodcock roding was related to minimum temperature and mean wind speed. As the daily minimum temperature increased, so did the likelihood of display behavior being observed (glmmPQL: t32 = 3.51, $P = 0.001$, 3.574 ± 1.016; Fig. 4a). For tagged individuals, roding became less likely as wind speed increased (glmmPQL: t32 = -2.25, $P = 0.031$, -1.711 ± 0.757; Fig. 4b). There was no significant effect of rainfall or Eurasian woodcock age. In the 'null' model, containing only age and day of year, neither variable was significantly related to probability or roding.

## Discussion

### RAINFALL

The number of Eurasian woodcock registrations recorded during roding surveys was positively related to rainfall, but only when rainfall was measured over a week or more prior to the survey. Lower rainfall in spring or summer is likely to drive the soil-dwelling invertebrates on which Eurasian woodcock feed deeper into the soil (Gerard 1967, Hoodless and Hirons 2007), and poorer foraging conditions may leave Eurasian woodcock with less energy to expend on display during dry spells. Dry summers have been demonstrated to have a negative effect on reproductive success in Eurasian woodcock populations (Guzmán and Arroyo 2015), but the potential effect on adult body condition remains unclear.

Had there been a significant relationship with rainfall during the survey, a negative association might be expected, assuming that heavy rain reduces the male's ability to see or hear receptive females and makes display behavior less profitable [as for tawny owls (*Strix aluco*): Lengagne and Slater 2002]. This was true of American woodcock (*Scolopax minor*), for which display activity was reduced by even light rain (Blankenship 1957). We found no relationship with rainfall on the day of the sur-

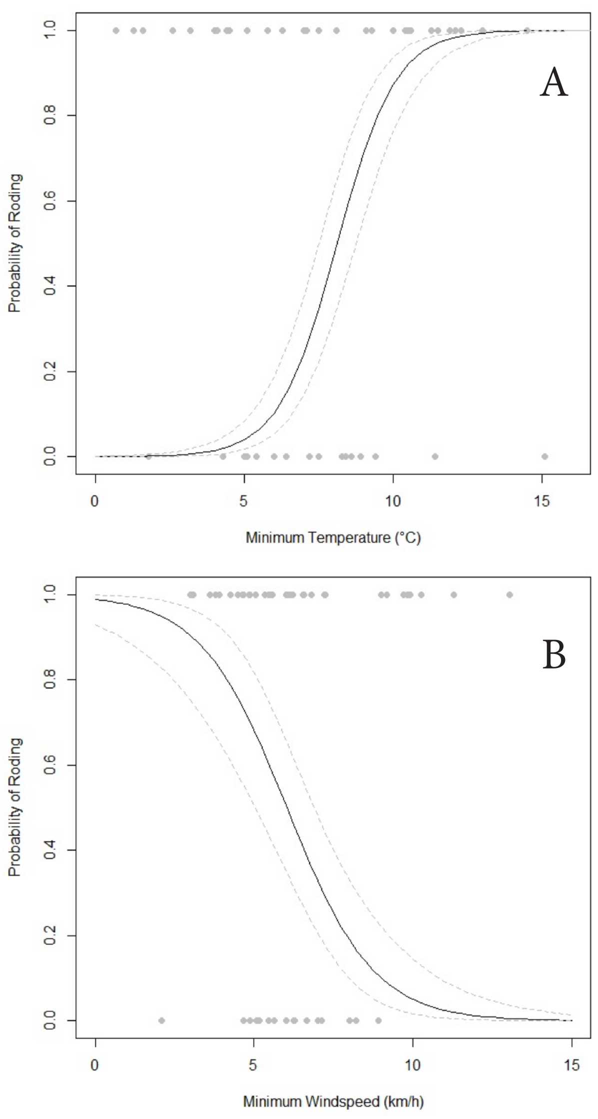

**Figure 4.** Predicted likelihood of tagged Eurasian woodcock roding relative to a) daily minimum temperature and b) mean wind speed, plotted using the 'effects' package (Fox 2003) in R. This accounts for the relative effect of the 3 other explanatory variables and 1 random effect included in the model. Dashed lines signify 1 SE.

vey, but this was probably because surveys were not conducted during heavy or persistent rain, and most experienced no rainfall at all, reducing the degree of variation in our model. Our tracking data also showed no correlation with rain on the day of recording, although our daily rainfall variable does not identify whether rain fell during the logger's recording period. Whilst rain during the roding period might inhibit roding behavior, at other points during the day it might encourage roding. This was proposed for American woodcock (Blankenship 1957) and, based on personal observation, appears to be the case for Eurasian woodcock, perhaps because rainfall during the day provides the opportunity for diurnal feeding.

#### TEMPERATURE

We found that display behavior in tagged individuals was positively related to minimum daily temperature. This could be the product of an underlying relationship with the time of year, if both temperature and roding intensity vary in a linear fashion over the course of the breeding season, but our analyses are focused only on the peak of the roding season when roding activity tends not to show a consistent linear trend. This is reflected in our 'null' model, which found no direct correlation between the number of Eurasian woodcock registrations and the day of the year.

Woodcock may be less likely to rode on cooler evenings or following cooler days because the cost of maintaining a constant body temperature is greater and the demand to feed, rather than display, is increased. Woodcock are able to survive in much harsher conditions during the winter than are typically experienced in spring, but during the breeding season males carry minimal fat reserves (Owen and Krohn 1973) and bear greater energetic costs associated with the maintenance of reproductive physiology (Vézina and Salvante 2010) and the roding flights themselves. Alternatively, temperature might be a natural stimulus to breeding behavior as documented in other bird species (Garson and Hunter 1973). Whatever the reason, the same effect of temperature on display behavior is recorded for several other species (Slagsvold 1977, O'Connor and Hicks 1980, Gottlander 1987, Santos et al. 2009), including American woodcock (Blankenship 1957, Goudy 1960).

Whilst this relationship with temperature was not immediately apparent in the roding survey data, it became clear when minimum temperature values were logged. This probably suggests that the relationship with temperature is non-linear and that high air temperatures can also have an inhibitive effect on roding owing to lower rainfall, high rates of evaporation, and dry soils.

#### WIND

During roding Eurasian woodcock surveys in which the observer rated the wind as a light or moderate breeze, fewer Eurasian woodcock were encountered than during evenings that were still. Increased environmental noise could impede detection by surveyors (Alldredge et al. 2007), but our tracking data showed that tagged Eurasian woodcock were less likely to rode on windier nights, supporting a change in Eurasian woodcock behavior rather than just detectability. Males may be discouraged from roding on windier nights because their roding call is less likely to be heard by potential mates. Increased wind speeds were shown to influence the results of other bird surveys (O'Connor and Hicks 1980, Santos et al. 2009) including the Singing Grounds Survey (SGS) used to detect American Eurasian woodcock (Bergh and Andersen, this volume, Estimating density and effective area surveyed for American woodcock), and this has also been attributed to changes in Eurasian woodcock activity rather than just detection by surveyors (Blankenship 1957, Goudy 1960).

#### CLOUD AND MOON PHASE

We found no significant relationship between roding activity and moon phase. There are a few examples of moon phase influencing bird behavior, but these mostly relate to behavior that is truly nocturnal rather than crepuscular (Mills 1986, Dodd 1998, Mougeot and Bretagnolle 2000). Increased ambient light levels could reduce roding activity if associated with an increased predation risk (Mougeot and Bretagnolle 2000, Prugh and Golden 2014), or lengthen or delay the roding period if they improve visual signaling between males and females. This would assume dusk light levels correspond to moon phase, which seem far more dependent upon cloud cover.

Although not confirmed by our analysis, there may be a correlation between cloud cover and roding activity, particularly because the *P*-values associated with cloud cover were only marginally greater than the 0.05 threshold. Light intensity was the main stimulus for the onset of display behavior in American Eurasian woodcock and starting times were earlier in relation to sunset on cloudy evenings (Duke 1966). It seems likely the same is true for Eurasian woodcock (Heward et al. In press), which would alter survey results if it meant a proportion of the roding activity fell outside of the 75-minute survey period.

### Management Implications

It appears that the display behavior of Eurasian woodcock is affected by the weather and that this can, in turn, influence the results of roding surveys. Factors such as heavy rain and strong wind were already known to discourage roding (Hoodless et al. 2006) and as a result, the British breeding Eurasian woodcock survey methodology stipulates that counts should not be conducted in these conditions (British Trust for Ornithology 2013). The more comprehensive study presented here suggests that more subtle variation in survey weather can have a detectible effect on count data. Further tightening the conditions in which surveys should be conducted is a possible solution, but could result in criteria that are impractically restrictive and difficult to forecast, and could discourage survey participation. Each survey site, in each year, is usually visited on 3 separate occasions, and estimates of local density are derived from the maximum count rather than the mean. This approach should provide some buffer to the effects of sub-optimal weather providing at ≥1 count is conducted during suitable conditions. Our findings reiterate the need for all 3 visits to be completed and the exclusion of sites that do not receive them all [which has not always been the case previously (Heward et al. 2015)].

The effects of more protracted weather events, such as extended dry spells, are harder to predict. If these events affect male fitness, they are likely to affect roding behavior and, as suggested here, surveys based upon counts of displaying individuals. This is countered to some degree by the fact that repeated visits are made within the year and that each visit is separated by ≥1 week. It may be sensible to separate visits with a longer interval to ensure that counts are spread over a larger portion of the breeding season and reduce the influence of seasonal variation in weather.

When unfavorable weather conditions become particularly protracted or severe, they may affect the results of roding surveys by reducing recruitment and perhaps increasing adult mortality rather than merely reducing the likelihood of Eurasian woodcock displaying. Weather has been shown to influence breeding success (Selås 2006, Guzmán and Arroyo 2015), and should therefore have an effect on roding surveys in the following year. How to separate the real demographic impacts of unfavorable weather from the behavioral responses of Eurasian woodcock based on their fitness is not currently clear. It would be possible to shed more light on these types of weather events by reanalyzing annual data to include weather variables based on the entire breeding season, not just those immediately prior to the survey. Such analyses could also incorporate measures of the weather conditions experienced in the previous breeding season and intervening winter.

There have only been 2 large-scale national surveys of breeding Eurasian woodcock in the UK to date (2003 and 2013) and these could be biased by the prevailing weather in the years they were conducted. All evidence points towards a decline in the British breeding Eurasian woodcock population that is real and long-term (Hewson and Noble 2009, Balmer et al. 2013, Heward et al. 2015), but its true scale will become clearer with each repeat of the national survey scheme as the longer time-series reduces the influence of weather in any single year. In the meantime, the complementary data provided by conducting repeat surveys at a subsample of the national survey's sites, such as those analyzed here, give some impression of annual variability in roding counts in response to weather. Repeat count data could also be used to test how successional habitat change at count points affects detection rates (Nelson and Andersen 2013). Continuing to account for weather in survey methodology, and improving the way in which this is done, will help strengthen the results of future surveys and management policies based upon them.

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# American Woodcock Singing-ground Survey: The Logistical Challenges Associated with Route Consistency through Time

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**ABSTRACT** The American Woodcock Singing-ground Survey (SGS) is a long-term roadside survey (1968–present) administered by the U.S. Fish and Wildlife Service (USFWS). The SGS was developed to provide indices to changes in American woodcock (*Scolopax minor*) abundance. The population index derived from the survey is the primary metric used for the United States (US) harvest strategy. Integral to any long-term wildlife-monitoring program (e.g., SGS) with replicated spatial point-count locations is accurate management of metadata related to those locations. Technological advances over the last 20 years have resulted in large-scale coordination and logistical planning changes for the SGS, including improved communication between stakeholders and the creation of a database that houses metadata for all point-count locations. These improvements revealed weaknesses in the historical record-keeping system used for official paper route-maps that may have led to point-count location inconsistencies over time. To summarize the scope of the problem, and make corrections, we compared submitted GPS coordinates for count locations on SGS routes against indicated route paths on official route maps. Across the entire SGS coverage area, we found that 9.9% of observer-submitted point-count coordinates did not match the route path highlighted on the official route maps. We also compared a subset of digitized Minnesota and Wisconsin submitted point-count coordinates and found that 20.9% did not match the route path highlighted on the official route map. We quantified and grouped Minnesota and Wisconsin route-map discrepancies to provide perspective on the types and magnitude of the discrepancies that occur throughout the SGS coverage area. Reasons for the mismatch were many. We share the many challenges of maintaining route consistency and provide recommendations on how to best alleviate route map discrepancies, thus improving the integrity of the SGS and its data.

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**KEY WORDS:** American woodcock, American Woodcock Singing-ground Survey, roadside survey, route consistency, route relocation, *Scolopax minor*, SGS, spatial data

The American Woodcock Singing-ground Survey (SGS) occurs throughout the core of the American woodcock (*Scolopax minor*; hereafter woodcock) breeding range in Canada and the United States (Fig. 1, Seamans and Rau 2017). This survey began in 1968 and is administered by the U.S. Fish and Wildlife Service (USFWS) in cooperation with the Canadian Wildlife Service (CWS), state (19) and provincial (6) natural resource agencies, Bird Studies Canada (BSC), other U.S. and Canadian government organizations, and volunteer observers. The Migratory Bird Program within the USFWS is responsible for program coordination and compiling, managing, and reporting the data, whereas the United States Geological Survey (USGS) is responsible for data analysis. More than 700 natural resource agency staff and volunteer observers collect data.

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The population index derived from the survey is the primary metric used for the United States (US) harvest strategy (U.S. Fish and Wildlife Service 2010). SGS data have also been used to develop population and habitat goals for the American Woodcock Conservation Plan (Kelley et al. 2008). Woodcock are managed on the basis of 2 regions, Eastern and Central, and the boundary between the 2 regions conforms to the boundary between the Atlantic and Mississippi Flyways; results from the survey are therefore designed to support management at a regional scale (Seamans and Rau 2017). Thogmartin et al. (2007) used data from this survey to develop spatially explicit models to show the relationship between woodcock abundance and landscape-level habitat variables.

### Field Methods

An index of woodcock population abundance is estimated by taking advantage of the conspicuous breeding call of male woodcock (Seamans and Rau 2017). Early studies demonstrated that counts of singing males provide indices to woodcock population abundance and could be used to monitor annual changes (Mendall and Aldous 1943, Goudy 1960, Duke 1966, and Whitcomb 1974). Before 1968, woodcock counts were conducted on non-randomly located routes. Data from these early surveys are not used in any current analysis. In 1968, state, federal, and provincial agency personnel randomly established SGS routes along lightly- traveled secondary roads in the center of randomly-chosen 10-minute degree blocks within each state and province within the central and northern portions of the woodcock's breeding range (Fig. 1). Each route is 5.4-km long and consists of 10 equally spaced listening point-counts (stops). The routes are surveyed once a breeding season within a designated temporal window. The SGS periods (windows) were assigned by latitude to coincide with peaks in courtship behavior of local woodcock populations (Seamans and Rau 2017). Routes are to be surveyed between 22 and 58 minutes after sunset (or, between 15 and 51 minutes after sunset on overcast evenings) by an assigned observer who drives to each of the 10 stops and records the number of woodcock heard peenting (the vocalization by displaying male woodcock on the ground). Additional guidance on survey protocols can be found within the SGS data entry website (U.S. Fish and Wildlife Service 2017).

The SGS is managed by a national coordinator in the USFWS Migratory Bird Program office who works directly with 1 Canadian and 2 US regional coordinators in the 2 designated management regions (Figs. 1 and 2, Seamans and Rau 2017). Historically, the management region coordinator's primary responsibility was to distribute survey materials to the state and provincial coordinators in their respective regions. Since the mid-2000s, the management region coordinator's main focus has been to assist in finding state and provincial coordinators as needed and to boost participation levels in the SGS. Since the inception of the SGS, 25 state and provincial coordinators have been responsible for the distribution of survey materials, finding observers for routes, and collection and/or entry of survey data. The observers (>700) are primarily responsible for conducting the survey following standard operating procedure (SOP) guidelines (U.S. Fish and Wildlife Service 2017). Observers are encouraged to scout their routes before conducting the survey to ensure the route is safe and roads are navigable. Since 2003, observers have also been responsible for acquiring the spatial data for their route per GPS data collection standards (U.S. Fish and Wildlife Service 2017). Once GPS coordinates for a route are submitted to the national coordinator, stop coordinates are not requested again unless a route changes or there appeared to be a discrepancy. Although direct communication does occur between observers and the national coordinator, it typically only occurs when questions arise during annual validation of the survey or data.

### Route Map Management

Historically, state and provincial coordinators have been responsible for making the official paper route maps (official route map). Map elements such as scale, content, labels and clarity were their responsibility (supporting information Fig. S1). Once established, they provided the official route map to the national coordinator who maintained them. The state and provincial coordinators retained a copy of the map, which they distributed

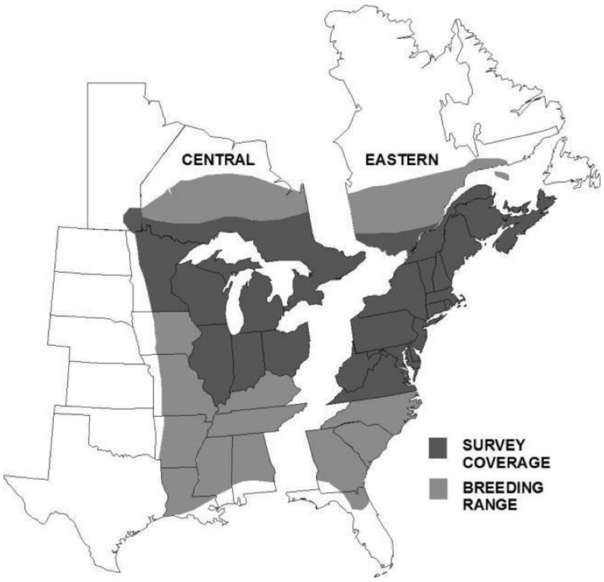

**Figure 1.** American woodcock management regions, breeding range, and Singing-ground Survey coverage (Seamans and Rau 2017).

directly to both regional coordinators and observers to facilitate route sampling. In some cases, the regional coordinator may have directly distributed maps to observers. If a route problem occurred (e.g., safety to an observer, road closure), it was incumbent on the observer to notify the regional (or state/provincial) coordinator. If a route change was warranted (U.S. Fish and Wildlife Service 2017), it was the state and provincial coordinators' responsibility to ensure official route map modifications and provide the replacement map to the national coordinator and to others in the survey management hierarchy (Fig. 2).

National, state, and provincial coordinators have authorized and documented many route changes over the 50 years of the SGS. SOPs allow route changes to occur when human population density and urbanization lead to personal safety hazards such as increased volume or high-speed traffic, loss of roadside shoulders, increased crime, or other unsafe conditions. Observer safety is the primary reason why route changes have occurred. Increased noise level along routes that preclude observers from hearing woodcock peenting is another reason for route relocation. Road conditions may also necessitate a route relocation if the observer is unable to complete the route or stop during the prescribed period or peak time of daily singing activity (Seamans and Rau 2017). Although these practices have been in existence for the duration of the survey, no consistent procedural system was in place to document why a route path changed before 2001. Nor was there a common system that forced observers, state or provincial coordinators, or the national coordinator to produce an official route map that shared common features across state or provincial lines. Whereas current efforts are made to provide guidance on what to include on an updated official route map, there is no 1 sole entity that produces every map in the survey that is distributed to observers.

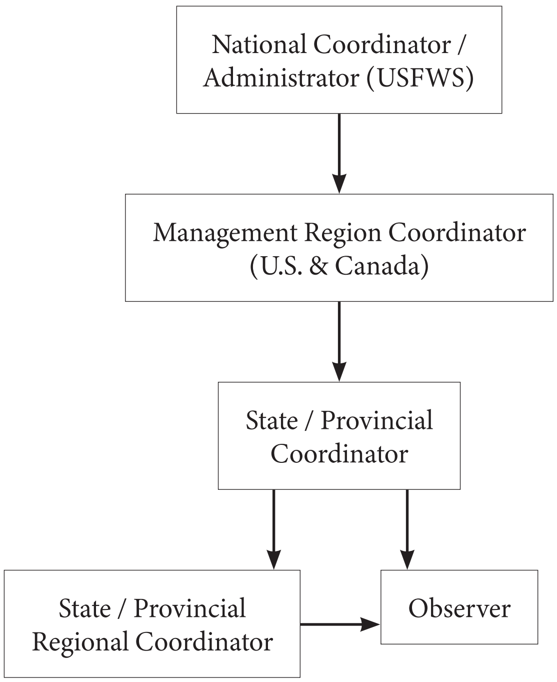

**Figure 2.** Historical coordination hierarchy of the American Woodcock Singing-ground Survey.

Currently, there is a SOP for authorized route changes when needed (U.S. Fish and Wildlife Service 2017). Once a potential new official route has been identified, there are several steps that must be completed. First, a new official route map must be produced indicating the starting location (stop 1) and ending location (stop 10), and the layout of the route is prepared by the observer or state or provincial coordinator. Second, GPS coordinates for each stop are collected by the assigned observer (U.S. Fish and Wildlife Service 2017), before surveying the new route for the first time. Third, copies of the new official route map, marking the year of establishment, along with the GPS coordinates must be sent to the national coordinator, and a copy should be retained by the state or provincial coordinator in a permanent file. The new route number will not be assigned until the new route map and GPS coordinates are received and approved by the national coordinator. Until that time, the previous route will remain in the national coordinator's database. If possible, both the original and relocated routes are to be surveyed during the year of transition by the same observer so that the data may be analyzed for short-term trend comparison (Seamans and Rau 2017). There is also an internal SOP checklist to assist the national coordinator when route changes occur. This procedure ensures new routes have maps and verified and accurate spatial data, suggested sunset times are adjusted based on the new starting coordinates, specific tables within the database are updated and associated metadata is included, new and discontinued electronic and hardcopy maps and files are updated appropriately and archived as appropriate, and communication between all parties is documented.

Undocumented route changes by observers occur, primarily due to poor communication or miscommunication between observers and coordinators, and are often discovered by chance. Insufficient map detail, staff turnover, misplaced route maps and/or observer stop descriptions, poor understanding of survey protocols, limited documentation, and the large numbers of people involved on an annual basis can contribute to these changes. Once an undocumented route change has been detected by a SGS coordinator, the problem is corrected through a set of procedures that allows the route path to revert back to its original design and/or the route number is retroactively adjusted within the database to account for the new route path.

## Technological Advancements

Since the initiation of the survey in 1968, survey logistics between and among coordinators have changed considerably. Primarily driven by paper-based, telephone, and in-person communications early on, the availability of increased data storage capacity, email communication, the Internet, and modernization of GPS and GIS technologies have allowed for large-scale coordination and logistical planning changes during the last 20 years. These new technologies have improved communication, transaction speeds, decision transparency, process documentation, and archiving. For example, survey materials are now electronically distributed and survey results are entered by the observer via the Internet (U.S. Fish and Wildlife Service 2017). The data are publicly accessible via the Internet, following a series of policy directives mandating broader public access to federal and federally-supported data and information (Executive Order 13642 2013 and OMB Memorandum M-13-13 2013). Moreover, GPS and GIS technologies have facilitated better route map management practices.

Technological advancements have facilitated better identification and understanding of potential issues with the SGS. For example, early comparisons of observer-submitted GPS coordinates (initiated in 2003) against official route maps indicated that many coordinates did not match the stop locations indicated on the map. Accurate spatial data are required to achieve various USFWS objectives: allowing researchers to show the relationship between woodcock abundance and landscape-level habitat variables, allowing the distribution of complete data coverages, and most importantly, enabling the USFWS to make more accurate and sound regulatory and management decisions in the future.

In light of changes in technology that allows for the assessment of route accuracy, and of indications from a recent study (Nelson and Andersen 2013) of unrecorded changes in route locations in Minnesota and Wisconsin, we evaluated the current accuracy in route-location records for the SGS. Our main objectives were to (1) assess all existing SGS route location spatial data and (2) quantify the common types of route map inconsistencies based on a review of SGS routes located in Minnesota and Wisconsin. Furthermore, we describe the challenges of maintaining SGS route consistency over time and provide recommendations on how to improve the SGS.

## Study Area

All routes were located along lightly-traveled secondary roads in the center of randomly-chosen 10-minute degree blocks within each state and province in the central and northern portions of the woodcock's breeding range (Fig. 1, Seamans and Rau 2017).

## Methods

To assess the accuracy of spatial data submitted by observers survey-wide, we first determined the status of spatial data for each route. We used route-location data from the route table within the SGS' relational database management system, which is administered by the national coordinator. The route table contained fields for each route (Table 1) indicating whether coordinates exist, the years GPS coordinates were submitted and for what stops, the verification status of the coordinates, and relevant verification user notes. From the table, we selected routes with 1 complete set of GPS coordinates. From within those routes, we created 3 groups: those where route coordi-

**Table 1.** Example entries from the American Woodcock Singing-ground Survey (SGS) route table layout showing the spatial status for a subset of Minnesota's routes.

| State Code | Route Code | FIPS[a] County Code | GPS Received? (Yes/No/Incomplete/ Multiple Years) | GPS Notes | PHAB[b] Verified? (Yes/No/Partial/Error/Flag/ Crosscheck) |
|---|---|---|---|---|---|
| 50 | 007 | 135 | Yes | 2009, stops 1–10 | Yes |
| *Verification notes: verified by TC in Nov. 2013* | | | | | |
| 50 | 025 | 137 | Multiple Years | 2009, stops 1–10. 2014, stops 1–10. | Yes/crosscheck |
| *2009 verified by TC in Nov. 2013, 2014 needs crosscheck with 2009 coordinates* | | | | | |
| 50 | 070 | 017 | Multiple Years | 2005, stops 1–10. 2009, stops 1–10. | Flag |
| *Mapped out coordinates for both years show the route running in a different location. Emailed observer to find out when route change occurred, but bounced back, TC will try to find out who could help us out -BR 11/26/13* | | | | | |

[a] FIPS is a Federal Information Processing Standard code which uniquely identifies counties in the United States, https://www.census.gov/geo/reference/codes/cou.html.

[b] Verified by the Population and Habitat Assessment Branch.

nates were known to match the stop locations on the official route map, those where route coordinates were flagged with discrepancies or needing follow-up, and unreviewed stop coordinates.

The verification process of each complete set (all 10 stops) of GPS coordinates was as follows: GPS coordinates were collected and submitted (U.S. Fish and Wildlife Service 2017) and entered online by the observer, state/provincial coordinator, or personnel within the Laurel USFWS office. These data went directly into the relational database management system that houses SGS spatial data. The national coordinator then compared these data to the official route map using a mapping program such as ArcMap (ESRI, ArcGIS Desktop, Redlands, CA, USA) or Google Earth Pro (Google, Inc., Mountain View, CA, USA). If documented as a correct match [count locations mirror that of the official survey route path, e.g., start and ending location match, count locations fall on the same roads and are equally distributed (0.6 km)] the route table was updated to reflect the accuracy of the GPS coordinates and a new map was created and distributed to the state/provincial coordinator and observer. The new map and GPS coordinates were stored in an electronic filing system and within route map binders at the USFWS' Laurel, Maryland, office.

We also examined the accuracy of spatial data from Minnesota (MN) and Wisconsin (WI) that had been previously reviewed and submitted to the national coordinator as part of a study assessing the relationship of woodcock counts with spatial variables measured along routes (Nelson and Andersen 2013). Nelson and Andersen (2013) chose a subset (*n* = 122 for MN and 65 for WI) of existing Minnesota (125) and Wisconsin (119) SGS routes in the Central Management Region and verified the location of these routes by asking the state coordinator to request that last known observers confirm route and stop locations derived from the official route maps or already existing verified GPS coordinates (supporting information Fig. S2). Based on specific observer feedback, Nelson and Andersen (2013) adjusted GPS coordinates and route maps and then provided these to the national coordinator for more detailed verification. Subsequently, we compared these maps (supporting information Fig. S2), revised based on observer feedback, to those maintained by state and national coordinators. We created a summary table for all routes within Minnesota and Wisconsin, regardless of whether they were included in the routes verified by Nelson and Andersen (2013), and recorded whether the verified stop coordinates not only matched those used in the study, but also matched the state and national coordinator official route maps. We noted whether the state coordinator and national coordinator route maps matched. Next, we incorporated any notes describing discrepancies associated with the GPS coordinates and/or route maps. We identified whether follow-up was needed for each route and who the last known observer was for the route in question. Next, we created a field that identified types of GPS coordinate discrepancies. The discrepancy types included: route run backwards or reverse order, route in a different location entirely, half the route on a different road, some or all stops have shifted, either or both the state/national coordinator map(s) not updated, the route did not yet officially exist (replacement routes), and clerical errors [GPS collection, transcription, or data entry errors or misinterpretation of route paths during the Nelson and Andersen (2013) map verification process]. We assumed that routes that fell into the first 4 category types above were incorrectly conducted by the observer at some point during their existence.

**Table 2.** Verification status of spatial data within the American Woodcock Singing-ground Survey (SGS).

| Route Status Description | Routes | Percent of SGS Routes |
|---|---|---|
| ≥1 complete set of stop-level GPS coordinates[a] | 1,469 / 1,566 | 93.8 |
| ≥1 set of verified GPS coordinates that match official USFWS route map[a] | 975 / 1,469 | 66.4 |
| Not verified or reviewed yet | 346 / 1,469 | 23.6 |
| Flagged with discrepancies or need attention/follow up | 145 / 1,469 | 9.9 |
| **Total in SGS** | **1,566** | |

[a] In some cases a route has >1 set of submitted GPS coordinates. Incomplete sets were submitted often. Over the years, different observers were not aware that coordinates were already submitted and resubmitted them. Early on there was miscommunication and observers thought they were to submit coordinates each year they conducted the survey.

## Results

We determined that stop-level GPS coordinates exist for 94% of all routes within the SGS, 66% of which have ≥1 complete set of verified GPS coordinates that match the official route map (Table 2). Our assessment indicated that 10% of the routes with GPS coordinates had discrepancies or required followup with state and provincial coordinators and/or observers. We did not analyze those 24% of routes (Table 2) with submitted GPS coordinates that had not been reviewed.

We determined that 21% (Table 3) of the combined Minnesota and Wisconsin GPS coordinates submitted by Nelson and Andersen (2013) did not match the official route map and/or the state coordinator map. This was double the rate (10%, Table 2) we found survey-wide for the routes that had been assessed to date.

We determined that 80% of the GPS coordinates for Minnesota matched the official route map and/or the state coordinator map, whereas 20% were flagged as not matching (Table 3). Of that 20%, 42% were clerical errors on the part of the observer and/or Nelson and Andersen (2013) and were therefore adjusted (Table 4). For Wisconsin, we determined that 77% were verified as matching the official route map, whereas the remaining 23% were flagged because they did not match. Just over 13% of the 23% that were flagged sets of GPS coordinates were clerical errors on the part of the observer and/or Nelson and Andersen (2013) and were adjusted (Table 4). The most common map discrepancies (Table 4) within the combined results for Minnesota and Wisconsin were shifted stop locations (26%) and clerical errors (31%). Fifteen percent of routes were in a different location entirely and 13% were run in reverse order. Both categories of routes with half the route on a different road and state and/or national coordinator maps not being updated were at 8% of discrepancies. Individual state results for Minnesota and Wisconsin are presented in Table 4.

## Discussion

As indicated, 10–21% of the routes we assessed using stop coordinates submitted by observers did not match the official route maps. For Minnesota and Wisconsin, we were able to categorize these discrepancies (Table 4); however, we were not able to categorize these discrepancies for our survey-wide assessment (Table 2). Our perception is that the discrepancies for these routes would be similar to those we identified for Minnesota and Wisconsin (Table 4).

We are not certain why the discrepancies were double for the routes assessed in Minnesota and Wisconsin (21%) compared to nationally (10%). We speculate that possible reasons include: 1) 1 person coordinated these 2 states that included 243 routes, which was a significantly higher oversight percentage than any other state or provincial coordinator, 2) most states and provinces were coordinated by a state or provincial employee who often had closer oversight for observers (mostly state and provincial employees, themselves) than a federal coordinator, and 3) lack of coordination on route issues between individual observers and the state coordinator.

Maintaining route consistency for an established, long-term, national roadside survey is a large effort that requires consistent communication and cooperation between and among individuals at all participation levels. Consequences occur when there are communication breakdowns, and these consequences compromise the quality of the survey and its data. To improve the integrity of the survey and its data, not only within Minnesota and Wisconsin, but for all states and provinces within the SGS, we recommend improving communication and coordination efforts. The development of robust SOPs, documented route changes, improved training methods in the form of workshops and webinars, and utilization of existing resources and available technology are all methods that will improve communication and coordination, and in turn, increase the accuracy of SGS data.

**Table 3.** Numbers of American Woodcock Singing-ground Survey (SGS) routes with submitted[a] GPS coordinates used by Nelson and Andersen (2013) for Minnesota and Wisconsin that match or don't match the official USFWS SGS route map and/or the state coordinator map.

| Status Description | Minnesota (*n* = 122 routes) | Wisconsin (*n* = 65 routes) |
|---|---|---|
| Match | 98 | 50 |
| Does Not Match | 24 | 15 |

[a] Nelson and Andersen (2013) did not submit GPS coordinates for certain Minnesota (19) and Wisconsin (66) routes because they did not get a response back from the observer or the routes did not fit into their study design: route did not exist yet, was discontinued, was not surveyed that year/recently, numbers heard were zero, or they were in a constant zero status (Seamans and Rau 2017) at some point during the years of interest.

**Table 4.** Types of map discrepancies for Minnesota and Wisconsin American Woodcock Singing-ground Survey (SGS) routes based on comparisons between responses from observers (Nelson and Andersen 2013) and SGS route maps.

| Discrepancy | Minnesota | Wisconsin |
|---|---|---|
| Shifted stop locations | 3 | 7 |
| Run backwards | 3 | 2 |
| Different location entirely | 4 | 2 |
| Half the route is on different road | 3 | 0 |
| USFWS map not updated to match state map | 1 | 2 |
| Clerical errors[a] | 10 | 2 |
| **Total Discrepancies** | **24** | **15** |

[a] This includes GPS collection, transcription or data entry errors, or misinterpretation of route paths during the Nelson and Andersen (2013) map verification process.

### ROBUST SOPS AND DOCUMENTATION

In the case of the SGS, verifying the accuracy of spatial data for each survey route is time-consuming, and the effort of the national coordinator to verify spatial data is limited by the level of existing resources. Enlisting the assistance of observers who submit data is the first step in ensuring the data are accurate. Requiring observers to map their GPS coordinates before submitting them to the national and state/provincial coordinator will prevent GPS collection, transcription, or data entry errors, identified as one of the most common map discrepancies (Table 4). Passing all submitted GPS coordinates through an approval process at the state or provincial level before submission to the national coordinator would prevent other route map discrepancies (Table 4). This process can prevent mismatched route maps between the national coordinator and the state/provincial coordinator (Table 4).

Ideally, route maps should be made by 1 agency, preferably within the USFWS' Laurel, Maryland office from which the SGS is coordinated. This would alleviate route map inconsistency among states and provinces as demonstrated in supporting information Fig. S1 and Table 4. If this is not feasible, however, a SOP should be developed that specifies the requirements for route maps. For example, all maps should indicate the state/province; route number; county code; date of creation; date of collection; start, finish and stop numbers along the route; correct GPS coordinates for each stop; street names of starting intersection (if one exists); creator of route map; and, if relevant, the number of the route it replaced and year of replacement.

When route changes occur, there needs to be an update of route information, including route relocation metadata that includes years of discontinuation, why it was discontinued, what route number replaced it, and who developed the new route. Although documentation exists since 2007 for almost all authorized route changes, it is not organized to be easily attainable or distributed. This lack of adequate documentation leads to route map or route number confusion by the observer, which can lead to observers conducting discontinued route paths rather than the replacement route. Although this route discrepancy was not specifically addressed in our results, because it can overlap multiple discrepancy categories, it likely occurs and can be prevented with additional information. In the case of Seamans and Rau (this volume), to estimate a potential annual indices bias of discontinuing routes and replacing them with new routes, a count comparison of woodcock at discontinued routes with counts from their replacement routes was needed. Historically, route relocation metadata were not documented in a table form and had to be created so they could be used to determine which routes were discontinued and what their replacement route numbers were. Such a table might also have been helpful to Nelson and Andersen (2013) as a source of discontinued routes when they were defining their study design.

### TRAINING AND WORKSHOPS

Many of the route map discrepancies identified in Table 4 have occurred because observers were either unaware of protocols for route changes or were unaware of the ramifications of unauthorized route changes. One way to mitigate miscommunication among the many people who coordinate and conduct the survey is to develop training presentations or online videos that describe the survey and its importance to woodcock management. The USFWS developed a required training presentation for all observers to view. The presentation details the responsibilities of the observer and the SOPs they must follow. It outlines why observers need to follow specific guidelines and highlights the consequences if they do not. Videos would be beneficial because observers can be shown conducting the survey, demonstrating common scenarios that often lead to stop location discrepancies demonstrated in Table 4. They can also offer up consistent solutions that observers might encounter during the survey, such as how to proceed when a stop is no longer safe or what to do in the event that a road is blocked.

Route inconsistency is often a product of high observer or office turnover, and of new observers being unfamiliar with the route or stop locations. For example, stops along their route may not been georeferenced, which is the case for 6.2% of the 1,566 routes in the survey, or the GPS coordinates associated with that route may not have been reviewed or verified, which is the case for 23.6% of the 1,469 routes with GPS coordinates (Table 2). Although the SGS protocol recommends that during a year of observer transition, the old and new observer run the route together, this is not always possible. To minimize the possibility of errors, we highly encourage coordinators to ask observers if they are willing to survey routes in future years, and check on observer status periodically to ensure they have time to find replacements or to create a transition team when needed. Ensuring coordinators are up to date on the participation status of observers also allows time for the newly selected observer to scout the route prior to a survey, review the official route map, and ask questions if they are not clear on SGS guidelines.

Conducting periodic training sessions in the form of webinars and workshops for state and provincial coordinators and observers could prove beneficial. These can be used as a forum to highlight specific SGS logistical concerns and would provide an opportunity for group discussion of resolutions. Training was recommended to Breeding Bird Survey (BBS) observers by a peer-reviewed panel after a programmatic review of the North American BBS, another long-standing roadside survey (O'Connor et al.

2000). That review highlighted how individual coordinators had very different approaches to meeting their responsibilities within the BBS and thus could create openings for complementing their efforts with respect to observer recruitment and retention. Improving communication among individuals will yield insight into new ways to stimulate participation and commitment.

### UTILIZING EXISTING RESOURCES OR AVAILABLE TECHNOLOGY

At the national coordinator level, resources and staff will be limited into the future. A partial solution to the backlog of GPS coordinates that need to be verified (Table 2) could be working with a volunteer or intern. Enlisting the help of the state or provincial coordinators to help verify or remedy specific flagged routes would also help speed up the verification process. Currently, each state and provincial coordinator receives an annual report indicating the GPS coordinate status for each route. The report indicates which routes have verified GPS coordinates and which have flagged GPS data and for what reason. This report should be distributed to observers, who can make corrections.

Another potential tool to increase the proportion of routes and stops with accurate spatial data would be development of an online system that allows all official route maps to be obtained through the Internet. Such a system could include a tool that allows not only for the entry of spatial data, but for verification of such data against the assigned route map already in the online system. Developing such an online system that includes a map repository and access to GPS coordinates could make the same current route maps available to all parties. Such a system would preclude having to verify route information before analysis, as was the case for Nelson and Andersen (2013). Developing an application that allows for the download of route maps to a mobile or GPS device would also be helpful in deciphering route path direction, a common route map discrepancy we detected. A system that facilitates map access for portable devices would also allow observers to instantly see if GPS coordinates are correct, and would assist observers who are submitting GPS coordinates for replacement routes.

Until the advent of an online system for route map verification, conducting periodic verification of route and stop locations would help minimize inaccurate location data. Such verification could start with comparing national coordinator route maps against state and provincial route maps followed by asking observers to verify the accuracy of maps.

Currently, survey materials are distributed (U.S. Fish and Wildlife Service 2017) through email from the national coordinator directly to state and provincial coordinators. The coordinators then distribute these materials directly to observers (via email or mail) or through another regional level within each state or province before reaching each observer. With the numerous steps and large volume of individuals involved in survey distribution there is a chance that not all materials will make their way to all observers. Placing all survey materials in 1 place on the Internet for direct access and download/upload would save time and effort, and would create a more direct line of communication. It would also discourage route map mismatch discrepancies. This could be implemented rather quickly if it is done at the same website where observers enter their survey data.

Although not directly part of this assessment, another issue we identified is the annual survey of routes. During the Nelson and Andersen (2013) study (Table 3), a large number of Wisconsin routes were not adequate for their study design, primarily because the routes were not surveyed during the study years (M. R. Nelson, *Fish-Lectronics*, personal communication). In 2007, the USFWS distributed a survey participation assessment report (unpublished) that identified areas where many routes were not surveyed. Incomplete routes often resulted from states and provinces lacking the resources to devote to the survey. Within Ontario, for example, 75% of the routes were not surveyed at the time the participation report went out. Subsequently, Bird Studies Canada, a volunteer citizen-science charity-based organization, was engaged to help administer the SGS and solicit volunteers for routes in areas where the Ministry of Natural Resources and Forestry observers lacked coverage. The number of conducted routes increased as much as 45% over the next 5 years. We recommend engaging similar citizen-science groups that can assist with the completion of survey routes in low participation areas.

## Management Implications

While numerous challenges exist in the coordination of any long-term, large-scale survey, route inconsistency is a particular problem for the SGS. Finalizing the verification of spatial data for all routes is crucial especially because spatially explicit data are essential for assessing the relationship of counts to habitat variables at multiple scales. We will continue our efforts to address discrepancies in the spatial data that have been submitted to date and continue to obtain spatial data for the remaining SGS routes with no stop-level coordinates. Implementing the recommended solutions will maximize route consistency through time and improve the overall quality of the survey data, thus enabling the USFWS to make more accurate and sound regulatory and management decisions.

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We thank D. E. Andersen and K. L. Pardieck for their helpful suggestions and recommendations during the internal review process. We would also like to thank all observers and state or provincial coordinators who obtained additional GPS coordinates or provided helpful insight into route map discrepancies. The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the U.S. Fish and Wildlife Service.

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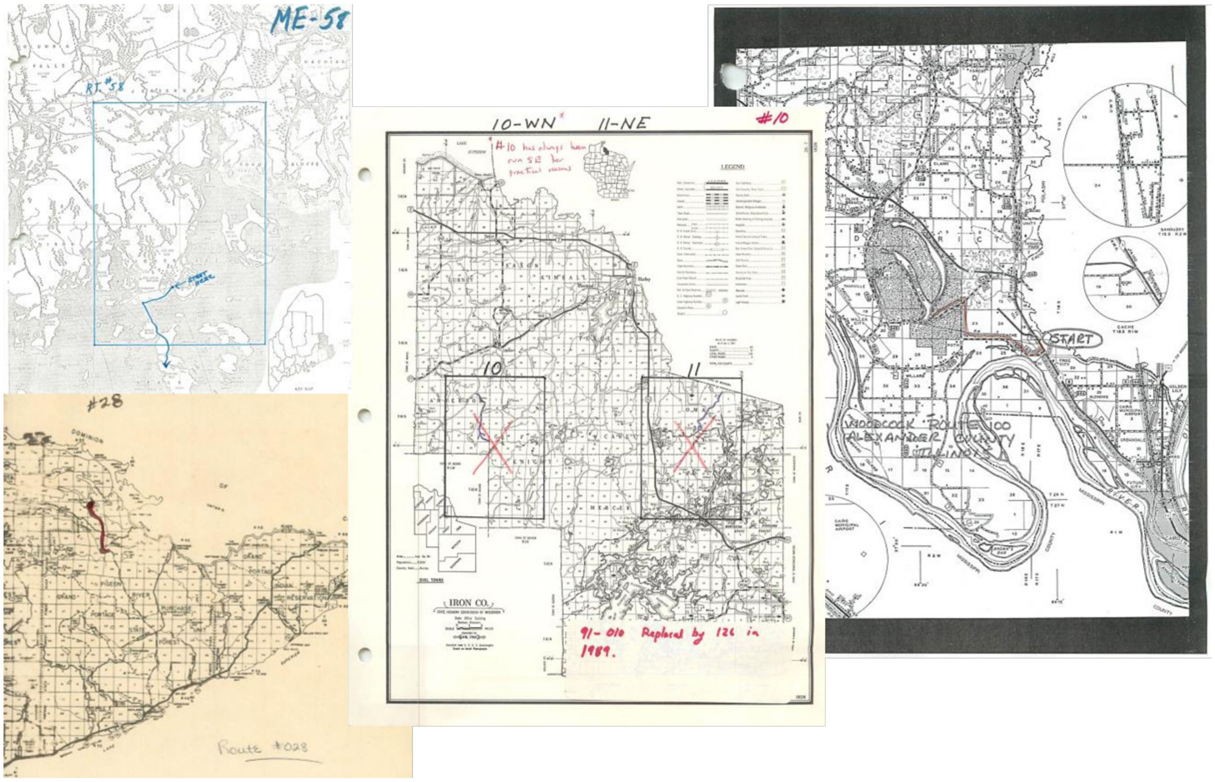

**Figure S1.** Examples of American Woodcock Singing-ground Survey (SGS) original route maps from various states or provinces.

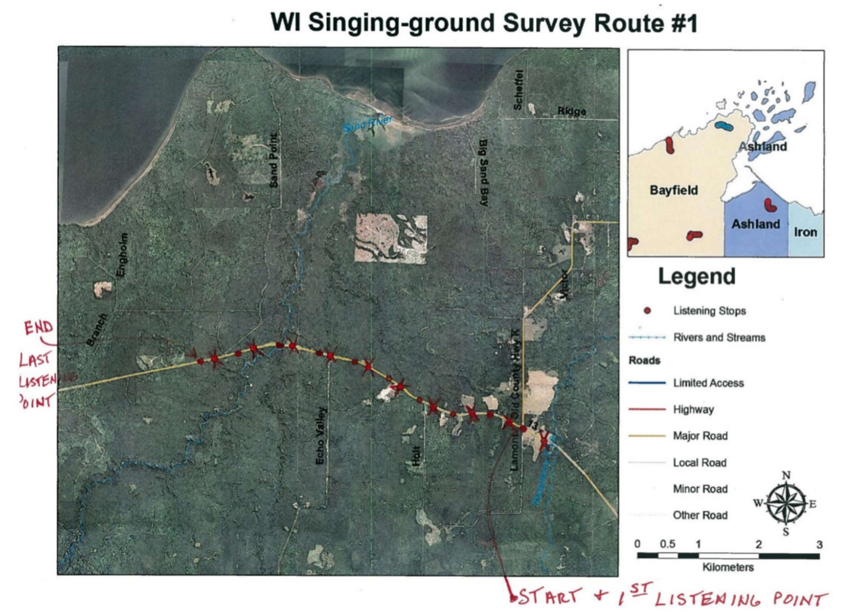

**Figure S2.** American Woodcock Singing-ground Survey Wisconsin route map verification example. Observer corrected the start, finish and each listening stop location along the route.

# American Woodcock Singing-Ground Survey Sampling of Forest Type and Age

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**ABSTRACT:** The American Woodcock Conservation Plan calls for halting and reversing declines of American woodcock (*Scolopax minor*) populations through creation and management of early successional forest (ESF). Counts of displaying male woodcock along routes of the American woodcock singing-ground survey (SGS) are used to assess regional population status and trends, and there is a need to assess whether SGS routes represent the region. We assessed whether individual SGS routes (330-m buffers) in the Boreal-Hardwood and Prairie-Hardwood Transitions of Minnesota, USA, represented land covers within local landscapes, defined using simulated 10-minute blocks, and whether the routes, in aggregate, represented land covers of our study region. Our land covers included non-forest classes, age-based ESF (20 years), and persisting classes for deciduous-mixed and evergreen forests and woody wetlands. We found that the median value of mean absolute differences (MAD) between percentages for route buffer and block cover classes was 3.78 percentage points. Twenty-two of 81 (27%) route buffers had MAD values 5 percentage points. Within Minnesota, more of these routes (19 of 22) occurred in the Boreal-Hardwood Transition than in the Prairie-Hardwood Transition. Relative to local landscapes, route buffers most frequently and strongly underrepresented open water, barren land, evergreen ESF, persisting woody wetlands, and woody wetland ESF and over-represented developed land and grassland-pasture. When we compared routes in aggregate to our study region, the magnitude of percentage point differences for individual covers did not exceed 5, except for open water. Given the relatively small differences we observed, we conclude that SGS routes well represent land covers within our study region.

***Proceedings of the American Woodcock Symposium 11: 227***

**KEY WORDS:** aggregation, American woodcock, compositional analysis, early successional forest, forest disturbance, roadside survey, *Scolopax minor*, singing-ground survey, young forest

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# Retrospective Analysis of American Woodcock Population and Harvest Trends in Canada

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**ABSTRACT** We used data from the Canadian component of the annual American Woodcock Singing-ground Survey (SGS) and data from the Canadian National Harvest Survey between 1975 and 2015 to assess temporal fluctuations in the population index, the number of American woodcock (*Scolopax minor*; hereafter, woodcock) harvested in Canada, and the proportion of successful hunters in Canada. We performed analyses via generalized additive mixed models that allowed us to identify periods when there were significant changes in temporal trends, and years during which there were significant changes in the direction of the temporal trajectory. We included climatic conditions before, during, and after the nesting and brood-rearing seasons (i.e., prior to the hunting season) as explanatory variables in our model. We did not find any effect of climatic variables on the SGS index. The SGS population index showed a slow overall negative decline in Canada, but there were only 2 significant periods of decline (1978–1984 and 1992–1994). Woodcock harvest and the proportion of successful woodcock hunters increased with the size of the SGS population index in the spring. The total harvest and the proportion of successful hunters remained fairly stable during the study period, but both indices showed a period of significant decline that started ca. 2006, and that was followed by a period of significant increase that started ca. 2009.

***Proceedings of the American Woodcock Symposium 11: 228–239***

**KEY WORDS:** American woodcock, generalized additive mixed model, population change, population trend, harvest, Singing Ground Survey

The American woodcock (*Scolopax minor*; hereafter woodcock) is a migratory game bird that inhabits early successional deciduous forests of eastern Canada and the United States. The woodcock is managed under the Convention for the Protection of Migratory Birds in Canada and the United States, and woodcock populations are monitored

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using the Singing-ground Survey (SGS), coordinated by the U. S. Fish and Wildlife Service (USFWS) and the Canadian Wildlife Service (CWS). The continental population of woodcock has shown long-term declines since the inception of the SGS in 1968 (Seamans and Rau, this volume). Although the most recent estimate (Seamans and Rau, this volume) indicates that population trends have stabilized in the Central Management Regions in the last 10 years, populations in the Eastern Management Region have declined during the same period, and concern remains over long-term woodcock population trajectories (Seamans and Rau, this volume). The current prevailing theory to explain the species' decline is loss of early successional forest in the southern part of its breeding range (McAuley et al. 1996, Kelley et al. 2008). These concerns have led to the development of a harvest strategy to regulate harvest in the United States, and the development of a conservation plan (Kelley et al. 2008).

Woodcock harvest is also monitored through harvest surveys. In Canada, this is done through the National Harvest Survey, which consists of the Species Composition Survey and the Harvest Questionnaire Survey. The Harvest Questionnaire Survey is mailed nation-wide to approximately 45,000 Migratory Game Bird Hunting Permit holders with questions mainly focused on waterfowl hunting. However, some information is collected for non-waterfowl game birds (e.g., woodcock). From these data, management agencies such as CWS can estimate the number of woodcock harvested, the number of successful woodcock hunters, and the average number of woodcock harvested in a hunting area (e.g., province or zone). Although these variables are used to inform harvest management of woodcock, they have never been used to identify potential population drivers, or to analyze potential long-term trends that would inform these management actions.

Effective management of a harvested population relies on the development of an effective monitoring program. This includes a mechanistic population model that explains why and how populations fluctuate, and a harvest-monitoring program that helps link harvest with population trends (Sutherland 2001, Ferrand et al. 2010, Evans 2012). Accordingly, 1 of the priorities that has been established in the woodcock recovery plan is development of a population model to assess the effect of harvest and habitat management on the population (Kelley et al. 2008). There have been few potential population drivers identified in the woodcock literature, but some studies have established links between weather conditions in the spring and woodcock productivity and survival. It has been demonstrated that spring climatic conditions can influence earthworm abundance and other foods consumed by woodcock (Vander Haegen et al. 1993) and the nesting and reproductive success of woodcock (Rabe et al. 1983), and that the amount of precipitation during spring and summer can affect woodcock adult and juvenile survival (Sepik et al. 1983, Daly et al. 2015).

Our first objective was to determine how spring climatic conditions affect the SGS population index and woodcock harvest in Canada. The second objective was to identify periods of significant long-term change in (1) the SGS population index, (2) the number of woodcock harvested in Canada, and (3) the proportion of successful hunters in Canada. We selected these 3 datasets as each contributes a component to overall understanding of trends in woodcock populations. The SGS population index provides valuable information on breeding population trends, while the National Harvest Survey tracks the fall woodcock population by utilizing the total harvest in the fall to inform managers of population trends and annual productivity. Total harvest data, however, can be biased due to unequal success rates for individual hunters. Harvest per unit of effort is usually positively skewed by more efficient hunters with high success rates, and these most-successful hunters are more likely to continue hunting regularly even in years of lower population numbers (Guthrey et al. 2004, Willebrand et al. 2011). The proportion of successful hunters (i.e., hunters that harvest ≥1 woodcock), therefore, can be utilized to detect any changes in composition of hunters that would influence the trend in the harvest.

## Study Area

Our study focused on the 5 Canadian provinces where woodcock regularly breed: Ontario, Quebec, New Brunswick, Prince Edward Island, and Nova Scotia. The study area is comprised of the Boreal Shield, Mixed Wood Plains, and Atlantic Maritime Ecoregions. Most of the land is covered by forest, with patches of row crop agriculture and urban areas concentrated in the southern portions of each province. Likewise, most private ownership of woodlands in our study area was located in the south, whereas more northern forests were generally under Crown tenure. The SGS spans the entirety of New Brunswick, Prince Edward Island, and Nova Scotia, but is limited south of the Boreal Softwood Shield Bird Conservation Region in Ontario and Quebec (Sauer et al. 2008). Hunting effort and harvest is concentrated in the southern hunting zones where the human population is concentrated (Gendron and Smith 2017).

## Methods

### DATA SOURCES

*SGS population index* Every year, a population index is derived from the SGS for the 2 broad management regions (Eastern and Central) and every province/state that participates in the survey. This index is based on the number of singing males that are counted via a roadside survey during the spring using a standardized protocol. Population trends are subsequently estimated using a hierarchical model (Sauer et al. 2008, Seamans and Rau, this volume). We obtained population indices between 1975 and 2015 from the 2016 American Woodcock population status report (Seamans and Rau 2016).

*Canadian harvest and hunter success data* We used the Canadian National Harvest Survey to obtain data on the number of harvested woodcock reported by hunters, the number of active non-waterfowl hunters, the number of days spent hunting by non-waterfowl hunters, and the number of successful woodcock hunters for each of the 5 provinces (Gendron and Smith 2017; Appendix 1). These variables were derived from Harvest Questionnaire Survey data. The complete methodology of the survey is available on Environment and Climate Change Canada's website (Environment and Climate Change Canada 2017). We used non-waterfowl hunters in our analysis, which included Mourning dove (*Zenaida macroura*), Wilson's snipe (*Gallinago delicata*), rails (*Rallus limicola and Porzana carolina*), and American coot (*Fulica american*a) hunters in addition to woodcock hunters, as the Harvest Questionnaire Survey is not directed only to woodcock hunters. We assumed that the proportion of woodcock hunters among non-waterfowl hunters has remained stable throughout the survey period. Woodcock wings are also collected during the Species Composition Survey, which can subsequently be used to estimate productivity. However, the dataset does not include wings collected before 1991 and does not include samples from Prince Edward Island, so we did not include these data in our analysis.

### ENVIRONMENTAL VARIABLES

*Snow cover* Late spring weather conditions can negatively affect survival of woodcock and recruitment into the population (Dwyer et al. 1982, Longcore et al. 1996). Using snow cover as a proxy for spring phenology, we acquired the Snow Cover Extent from the National Oceanic and Atmospheric Administration (NOAA) National Center for Environmental Information website (NOAA 2018). The dataset consists of weekly gridded data (1.0° x 1.0°) documenting the occurrence of snow on the ground for the northern hemisphere (Robinson et al. 2012). For each year, in each province, we retrieved the average week during which the snow cover permanently disappeared from the ground. For Ontario and Quebec, we restricted the extraction of the snow cover values south of 51.75°N to avoid including areas that were not part of woodcock breeding range (McAuley et al. 2013).

*Total precipitation* The amount and timing of precipitation has been shown to limit the survival of woodcock juveniles during the brooding season and the survival of juveniles and adults during the summer (Rabe et al. 1983, Sepik et al. 1983, Daly et al. 2015). We used the NOAA PRECipitation REConstruction over Land (PREC/L) dataset to measure the amount of precipitation that occurred during each year between 1 April and 31 July within each province. The dataset consists of monthly gridded (1.0° x 1.0°) interpolated precipitation predictions (Chen et al. 2002). We calculated the total amount of precipitation, in each province, before the nesting season (April), during the nesting/brooding season (May and June), and during the fledgling season (July). Similar to the snow cover index, we restricted the extraction of the data south of 51.75°N in Ontario and Quebec. We derived an index of wetness within each province by centering the data extracted on the log scale.

### DATA ANALYSIS

*General additive mixed-model framework* We used generalized additive mixed models (GAMM) in a Bayesian framework for our analysis. GAMM can accommodate nonlinear relationships, which can be advantageous if the user wishes to delineate the shape of a trajectory over time. In all analysis we included explanatory variables and added 2 time components to separate potential temporal effects that are not explained by the explanatory variables:

$$\mu_{i,t} = X\beta + S(t) + \varepsilon_{i,t} \qquad \text{eq. 1}$$

where $\mu_{i,t}$ is the mean on the link scale, X is a matrix of explanatory variables, β is vector of linear coefficients (i.e., fixed effects) to be estimated, S(t) is shared cubic splines smoothing component for all 5 provinces, and $\varepsilon_{i,t}$ is a random year effect at the provincial level. The smoothing component represents a global temporal trend, unexplained by the explanatory variables, that was shared across all 5 provinces. The random year effect represents the individual deviations from the global trend at the provincial scale. If, for some reason, a province did not share the temporal global trend present in the other provinces, the yearly random effect of this province would show a significant temporal trend (Knape 2016). To avoid spurious results, we checked for correlations among predictors for each model. All pairwise correlations were found to be well below the acceptable threshold (i.e., >0.6).

For each model, we estimated the first and second derivative of the cubic splines smoothing component from the posterior distribution to assess evidence for significant change in the temporal trend. Significant changes in either the first or second derivative indicated significant temporal changes that were unaccounted for by the explanatory variables included in the model. In both cases, we deemed a change significant if the 95% Bayesian credible interval of the estimate did not overlap zero. Years when the first derivative was significant indicated that the trend increased, or decreased, significantly from the previous year (Fewster et al. 2009, Knape 2016). Years when the second derivative was significantly positive indicated that the rate of change was turning upward (i.e., faster increase or slower decrease), whereas years when the second derivative was significantly negative indicated years of downturns (i.e., slower increase or faster decline). Years when the second derivative was significant are considered change points, and can help suggest external causes for the changes observed in a time series (Fewster et al. 2009, Knape 2016).

SGS population index in the provinces We analyzed the annual variation in SGS population index assuming a lognormal distribution. We included the effect of province, year, snow cover, and precipitation before the nesting season as fixed effect in the model. We expected that a late snow cover and a wet spring would have a negative impact on the SGS index because those conditions would make the breeding season difficult for males and negatively affect their inclination to display and their survival (Duke 1966). We also included the effect of snow cover during the previous year as a fixed effect in the model. We partitioned precipitation into 3 temporally explicit terms: 1) before the nesting season, 2) during the nesting/brooding season, 3) and during the fledgling season. We expected late snow cover to have a negative effect on nesting female success, wet conditions before and during the nesting and brood rearing seasons to negatively affect female productivity and juvenile survival, and dry conditions during the fledgling season to negatively affect both adult and juvenile survival. All of those factors should lead to a reduction in the fall woodcock population, and we expected the negative effects should be significant enough to persist during the winter and to be reflected in the SGS index the subsequent year.

*Total harvest in the provinces* We analyzed the harvest data using a Poisson distribution. We included year, province, SGS population index, snow cover, and precipitation as fixed effects in the model. We partitioned precipitation into the same temporally explicit terms as described above (i.e., before the nesting season, during the nesting/brooding season, and during the fledgling season). We expected that those variables would have an effect similar to the effects we hypothesized on the SGS population index and that the a reduction in the fall woodcock population would negatively affect harvest and hunter success (Schulz et al. 2010), given that juveniles are likely more vulnerable to hunting than adults (Reynolds 1987, Zimmerman et al. 2010). Values for total harvest for a given province were sensitive in part to the number of estimated active non-waterfowl hunters in the National Harvest Survey dataset during each year. Given that we were interested in how harvest changed over time independently of effort, we included the log of the numbers of active non-waterfowl hunters as an offset in the model. Thus, the results and predictions that are derived from the model reflect the annual variation in harvest if the number of hunters would be held constant during the period at hand.

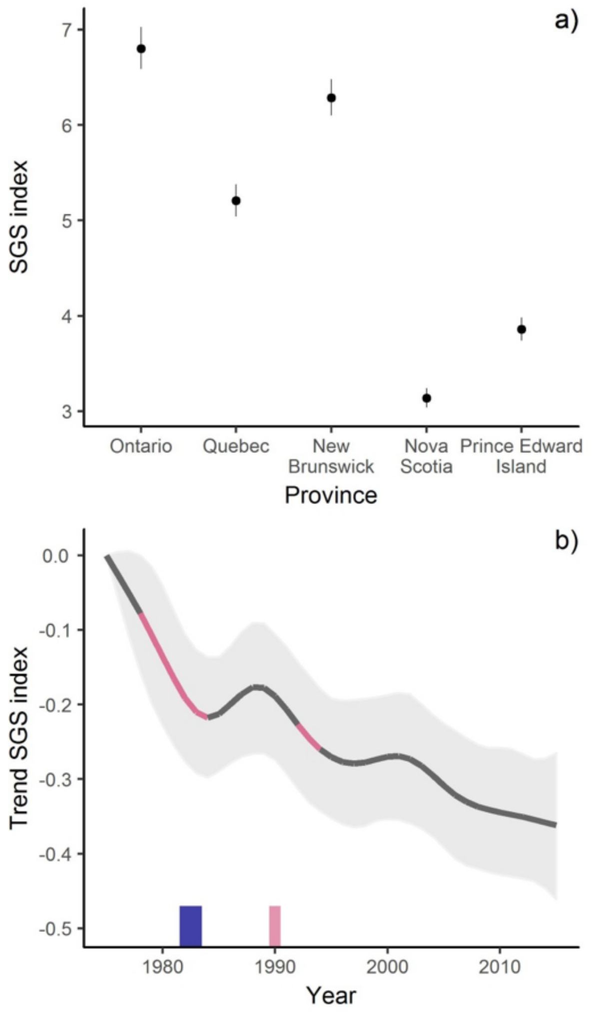

**Figure 1.** a) Estimated size of the American Woodcock Singing-Ground Survey (SGS) population index as a function of province at the beginning of the survey period (1975). Dots represent the mean and bars represent 95% Bayesian credible intervals. b) shared temporal trend for the SGS across all 5 provinces during 1975–2015.The solid line is the estimated long-term component of the trend, whereas the shaded area represents 95% Bayesian credible intervals. The trend line is colored for periods where there is a significant decrease (pink) in the trend. Periods where the curvature is significantly positive (e.g., upturn; blue) or negative (e.g., downturn, pink) are identified by bars along the x-axis.

*Proportion of successful hunters in the provinces* We used a logistic distribution to analyze the annual variation in the proportion of successful hunters in each province.

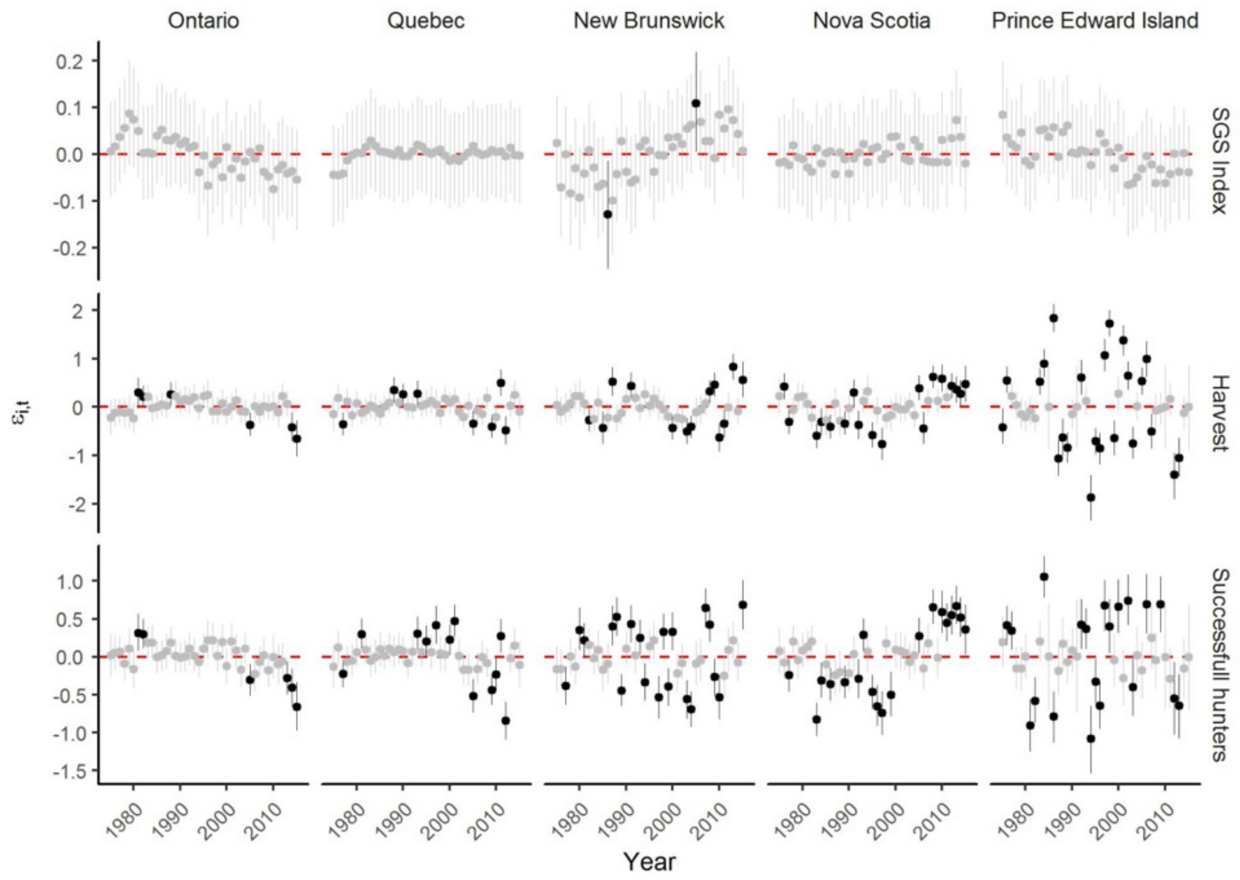

**Figure 2.** Deviation from the shared temporal trend at the provincial scale for the SGS index (top), the number of American woodcock harvested (middle), and the proportion of successful hunters (bottom) models. Dots represent the mean and bars represent the 95% Bayesian credible intervals. Black is used to denote years for which the deviation was significantly different than zero at the 95% level, whereas gray indicates years that do not deviate from patterns observed across all provinces.

We used the number of hunters who successfully harvested a woodcock as the numerator and the number of active non-waterfowl hunters as the denominator. We used the same suite of variables as for the Total Harvest analysis and expected they would have similar effects.

*Model fitting and inference* We fitted all models using Stan version 2.14.1 called via the RStan package in R (R Core Team 2016, Stan Development Team 2016). Stan implements Bayesian inference using a variant of the Hamiltonian Monte Carlo algorithm (Carpenter et al. 2016). We ran 3 chains, each of 500 iterations for the adaptation phase (discarded), followed by a further 1,000 iterations for inference. We checked for convergence by eye, and by using the Gelman-Rubin diagnostic test (Gelman et al. 2013). We deemed a parameter "significant" if the 95% Bayesian credible interval did not overlap zero and "weak" if the 90% credible interval did not overlap zero.

## Results

### SGS POPULATION INDEX IN THE PROVINCES

Predicted mean SGS survey index in Ontario was 6.80 males per route. The mean population index was significantly lower in Quebec (5.21; 95% BCI = 5.04 – 5.38), New Brunswick (6.29; 95% BCI = 6.10 – 6.48), Nova Scotia (3.14; 95% BCI = 3.04 – 3.12), and Prince Edward Island (3.86; 95% BCI = 3.74 – 3.98). Spring snow cover ($\hat{\beta}$= 0.00; 95% BCI = -0.01 – 0.01) and the amount of precipitation before the nesting season ($\hat{\beta}$ = -0.02; 95% BCI = -0.06 – 0.03) did not significantly affect the SGS index over time. The lagged effect of snow cover ($\hat{\beta}$= -0.01; 95% BCI = -0.02 – 0.01), the amount of precipitation before the nesting season ($\hat{\beta}$= -0.02; 95% BCI = -0.07 – 0.03), the amount of precipitation during the nesting season ($\hat{\beta}$= 0.02; 95% BCI = -0.06 – 0.09), and the amount of precipitation during the fledgling season ($\hat{\beta}$= 0.02; 95% BCI = -0.03 – 0.06) did not influence significantly the SGS population index.

The population index declined by 70% (95% BCI = 63 – 77%) between 1975 and 2015 (Fig. 1b). The decline was slow and steady except for 2 periods of steeper decline; the first occurred during 1978–1984, and the second during 1992–1994. There was a significant period of upturn during 1982–1983 at the end of the first period of significant decline. There was also a significant period of downturn in 1990, just prior to the second period of significant decline. There was no significant deviation from the national pattern at the provincial level for the population index trend (Fig. 2).

### TOTAL HARVEST IN THE PROVINCES

Mean annual harvest of woodcock in Ontario at the beginning of the study period was estimated at 3,379 individuals (95% BCI = 1,534 – 6,561; Fig. 3a). Mean harvest was significantly higher in Quebec (4,327; 95% BCI = 2,396 – 7,214), and significantly lower in Prince Edward Island ($\hat{\beta}$ = 453; 95% BCI = 289 – 679) compared to Ontario. Mean harvest in New Brunswick (3,349; 95% BCI = 1,636 – 6,267) and Nova Scotia (2,714; 95% BCI = 1,915 – 3,745) was comparable to harvest in Ontario. The SGS population index had a positive effect ($\hat{\beta}$ = 0.17; 95% BCI = 0.07 – 0.27) on the number of woodcock harvested. Based on model predictions, increasing the SGS population index by 1.0 would increase the harvest by 16% (BCI = 4 – 28%). Spring snow cover had a negative effect on harvest ($\hat{\beta}$ = -0.05; 95% BCI = -0.10 – 0.00). Our model predicted that a delay of 2 weeks in snow cover, the largest delay observed in Ontario, would decrease hunter harvest by 10% (BCI = -19 – 0%). The amount of precipitation during the nesting season had a weak negative effect on woodcock harvest ($\hat{\beta}$ = -0.27; 95% BCI = -0.57 – 0.04), whereas the amount of precipitation during the fledgling season had a weak positive effect on the number of woodcock harvested ($\hat{\beta}$ = 0.21; 95% BCI = -0.01 – 0.44). As with snow cover, we used our model to predict the impacts of an abnormally wet breeding season and an abnormally wet fledgling season using the most extreme data point observed across years in Ontario. Our model predicted that if breeding season precipitation was 180 mm over the average, harvest would decrease by 9% (BCI = -20 – 1%), whereas an abnormally wet fledgling season, with precipitation 83 mm over the average, would increase the harvest by 7% (BCI = 0 – 15%). The amount of precipitation before the nesting season did not influence the number of woodcock harvested ($\hat{\beta}$ = -0.10; 95% BCI = -0.31 – 0.12).

There was a significant downturn in the Canadian harvest trend in 2004, and the harvest subsequently declined significantly during 2006–2010 (Fig. 3b), independently of the explanatory variable in the model. Subsequently, there was a significant upturn in the harvest during 2009–2014, and the trend in woodcock harvest reversed and increased significantly during 2013–2016. There were many significant deviations from the national trend at the provincial level, but there was no consistent trend within a province (Fig. 2). Prince Edward Island was the province with the most significant deviations from the national trend, but this is more likely due to the small sample of hunters who

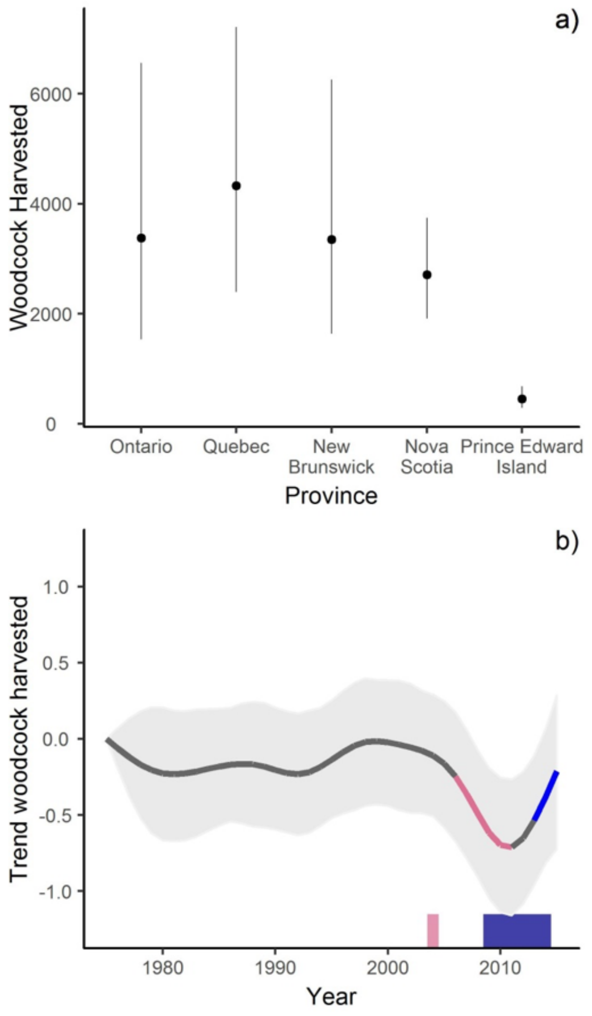

**Figure 3.** a) Estimated number of American woodcock harvested annually in each Canadian province at the beginning of the survey period. Dots represent the mean and bars represent the 95% Bayesian credible intervals. b) Shared temporal trend for woodcock harvest across all 5 provinces. The solid line is the estimated long-term component of the trend whereas the shaded area represents 95% Bayesian credible intervals. The trend line is colored for periods where there is a significant increase (blue) or decrease (pink) in the trend. Periods where the curvature is significantly positive (e.g., upturn; blue) or negative (e.g., downturn, pink) are identified by rectangle at the bottom of the figure. Predictions were made with a constant effort across region and time.

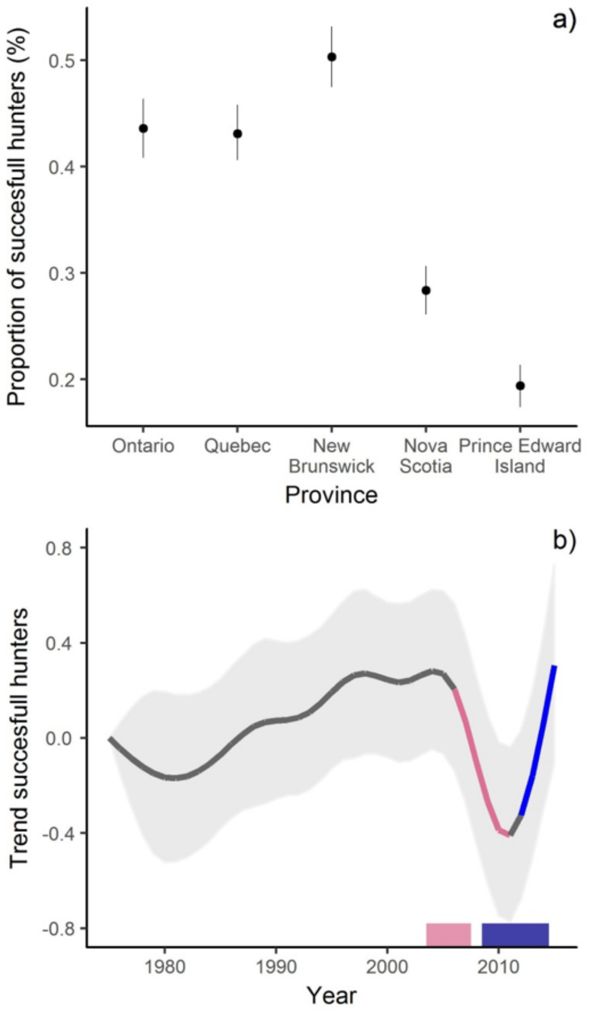

**Figure 4.** a) Estimated proportion of successful American woodcock hunters (number of hunters who harvested a woodcock over the total number of non-waterfowl hunters) in each Canadian province at the beginning of the survey period. Dots represent the mean and bars represent the 95% Bayesian credible intervals. b) Shared temporal trend in the proportion of successful woodcock hunters across all 5 provinces. The solid line is the estimated long-term component of the trend whereas the shaded area represents 95% Bayesian credible intervals. The trend line is colored for periods where there is a significant increase (blue) or decrease (pink) in the trend. Periods where the curvature is significantly positive (e.g., upturn; blue) or negative (e.g., downturn, pink) are identified by rectangle at the bottom of the figure.

participated in the harvest survey in this province during these years. Woodcock harvest in Nova Scotia was consistently higher than the national average during the last 5 years of our study period.

### PROPORTION OF SUCCESSFUL HUNTERS IN THE PROVINCES

On average, 44% (95% BCI = 41 – 46; Fig. 4a) of the non-waterfowl active hunters in Ontario harvested a woodcock. The proportion of successful hunters was significantly higher in New Brunswick (0.50; 95% BCI = 0.47 – 0.53), and significantly lower in Nova Scotia (0.28; 95% BCI = 0.26 – 0.31) and Prince Edward Island (0.19; 95% BCI = 0.17 – 0.21) compared to Ontario. Quebec hunter success (0.43; 95% BCI = 0.41 – 0.46) was comparable to that in Ontario. The population index ($\hat{\beta}$= 0.16; 95% BCI = 0.08 – 0.25) had a positive effect on the proportion of hunters who were successful. According to model predictions, increasing the SGS population index by 1 would increase the proportion of successful hunters by 3% (BCI = 1 – 5%). Spring snow cover ($\hat{\beta}$= -0.03; 95% BCI = -0.07 – 0.01) presented a weak negative effect on the proportion of hunters who were successful. Our model predicted that a delay of 2 weeks in snow cover would decrease the proportion of successful hunters by 1% (BCI = -3 – 1%). Neither the total amount of precipitation before the nesting season ($\hat{\beta}$ = -0.14; 95% BCI = -0.33 – 0.04), during the nesting and brood rearing seasons ($\hat{\beta}$= -0.03; 95% BCI = -0.28 – 0.21), nor during the fledgling season ($\hat{\beta}$= 0.05; 95% BCI = -0.12 – 0.22) had a noticeable effect on the proportion of hunters who were successful.

The trend in the proportion of successful hunters showed an increase during 1990–2005, but there were no significant changes during this period (Fig. 4b). There was a sharp significant decline in the proportion of successful hunters during 2006–2011, but this decrease was counteracted by a sharp significant increase during 2012–2014. There was also a period of significant downturn in hunter success during 2004–2006, prior to the period of significant decline, and a period of significant upturn in the proportion of successful hunters during 2009–2014. At the provincial level, the success in Nova Scotia was consistently higher than the national average during the last 7 years of our study period, whereas it was consistently lower during the last 3 years in Ontario (Fig. 2). The other provinces did not show any consistent patterns.

## Discussion

Climatic variables did not appear to influence the SGS population index in the Canadian provinces, but we did find support for climatic variables influencing woodcock harvest numbers. Both spring snow cover (i.e., the timing of snow melting in the spring) and breeding season precipitation negatively impacted woodcock harvest, whereas precipitation during the fledgling season increased the harvest. The discrepancy between the impacts seen in hunter harvest and in the SGS likely stems from the differential impact of climatic conditions on singing males and females/juveniles. Within 1 year (the temporal scale at which we analyzed these data) the spring conditions likely do not adversely affect the ability of breeding males to establish a singing territory, thus there is no detectable impact in the SGS. The same climatic conditions, however, may negatively impact female productivity and juvenile survival. A decrease in female productivity and juvenile survival would translate into a smaller fall population with fewer juveniles. Hunter success would diminish both in response to the overall smaller population and to the change in population age structure, given that juveniles are more vulnerable to hunting than adults (Reynolds 1987, Zimmerman et al. 2010). However, the effect of spring conditions on productivity and breeding season juvenile survival do not appear to carry over to the subsequent SGS population index in our model, which suggests that the climatic conditions on the breeding grounds are not a major limiting factor in the annual life cycle of woodcock in Canada.

### CLIMATIC CONDITIONS IN THE SPRING

Hunting quality has often been linked directly to increased opportunities and hunter success (Decker et al. 1980). Schulz et al. (2010) proposed that the quality of the spring nesting season would be one of the most important factors affecting quality of the fall hunting season for woodcock. Our results partially support that contention. Late snow cover during the spring significantly decreased harvest and tended to decrease hunter success. Late spring snow cover can delay the start of egg laying, which can be detrimental to productivity by reducing time available to renest (Vander Haegen et al. 1993, McAuley et al. 1990). Persistent frost can also drive earthworms deeper into the ground, which limits the amount of energy available for nesting females (Rabe et al. 1983, Vander Haegen et al. 1993). In those instances, nesting females may reduce clutch size from 4 to 3 to compensate for the lack of available food (Sheldon 1971, Rabe et al. 1983, Vander Haegen 1992). The amount of precipitation during the nesting and brooding seasons, and the amount of precipitation during the fledgling season, also tended to affect harvest; the effect of precipitation, however, varied depending on season. Heavy rainfall during the nesting season was associated with a decrease in fall harvest, whereas a wet fledgling season was associated with an increase in harvest. The change in the direction of the effect is supported by previous studies. Abundant precipitation during the spring can limit the survival of pre-fledged woodcocks (Daly et al. 2015). In contrast, prolonged drought during summer can limit earthworm availability, which negatively affects woodcock survival (Rabe et al. 1983, Sepik et al. 1983). However, our analyses indicated that the effects of climatic variables on woodcock harvest and hunter success were weak at best, and any apparent within-year impacts on productivity by climatic variables did not produce a lasting effect reflected in the subsequent year's breeding population index. Favorable weather conditions during the breeding season are therefore likely to increase the subsequent fall's recruitment, and indirectly impact hunter success and woodcock harvest. However, the effect is unlikely to persist and govern population fluctuations to the same level seen, for example, in waterfowl nesting in the prairies (Feldman et al. 2016, Roy et al. 2016). The high mortality rate reported on the wintering grounds (Krementz et al. 1994, Pace 2000, Elizondo 2018) could act as buffering mechanisms against favorable weather conditions on the breeding grounds in the annual life cycle of woodcock. This question could be elucidated with a full annual life cycle model similar to those that have been developed for waterfowl populations (Robinson et al. 2016, Koons et al. 2017).

### LONG-TERM TRENDS

SGS population index The most important decrease in the SGS population index occurred at the beginning of the survey in the late 1970s. There was a brief period of population stabilization in the late 1980s, but since then the population has decreased slowly, except for a short period during 1992–1994 when there was a sharp significant decrease in the population index. Although decreases in early successional forest have been well-documented during this period in the eastern United States, this decrease in early successional habitat is less clear in eastern Canada (McAuley et al. 1996, Dessecker and McAuley 2001, Kelley et al. 2008). Undeniably, there has been some loss of early successional forest in each eastern Canadian province due to urbanization from the 1960s to the 1970s. However, urbanization accelerated in the late 1980s (Dupras et al. 2016, Nazarnia et al. 2016), after the main period of woodcock population decline had abated. The agro-forested landscapes in eastern Canada also experienced modifications in the type of crop grown over this period, generally changing from hay and pasture to grain crops due to the decline in livestock production (Javorek et al. 2016). The amount of forest cover within agro-forested regions of eastern Canada, however, has remained either fairly stable or increased weakly because of the additions of hedgerows and windbreaks between fields and the increased amount of abandoned farmlands (Moss and Davis 1994, Jobin et al. 2014).

Major forest harvesting operations began during the 1950s and 1960s in eastern Canada and increased until the early 1980s, when the industry went through a major decline that slowed operations (Burton et al. 2003, Burton et al. 2006). As such, the 1960s and 1970s correspond to a period when the amount of early successional forest increased on the landscape in eastern Canada (Etheridge et al. 2005, Boucher et al. 2006). The period of significant decrease in the number of woodcock detected in Canada is, therefore, not concomitant with a large-scale loss of habitat. A more thorough analysis at a smaller spatial scale could help elucidate this question. However, past studies at the local scale have questioned the representativeness of the SGS and even suggested that woodcock habitat might have been overrepresented in the early years of the survey, thereby biasing data from those years (Klute et al. 2000, Morrison et al. 2010). The decrease observed during the 1970s could therefore represent a return to a more normal representative population index (Morrison et al. 2010).

The continued long-term decline in woodcock abundance from the 1980s onward is more concomitant with a large-scale decrease in the amount of woodcock habitat in southern Canada due to the combination of urbanization and changes in forestry and agricultural practices. It is important to note, however, that SGS coverage is currently limited in the northern range of the woodcock distribution, an area where timber harvesting has probably created the widest expanse of early successional forest (Keppie et al. 1984, Sauer et al. 2008). The northern region of Quebec also experienced a disproportionate amount of abandoned farm fields because of rural depopulation (Hamel et al. 1999 Roy et al. 2010, 2015). Woodcock could thus have shifted their distribution northward within their historical range, and the decline seen in the SGS could represent a trend that is only representative of the southern breeding population in Canada. A recent study by Sullins et al. (2016) lends credence to this hypothesis. Using stable isotopes analysis, they estimated that >50% of the woodcock population could be missed by current SGS coverage. Nevertheless, woodcock harvest occurs in the southern Canada where the population declines have most likely occurred. Given the positive relationship we found between the SGS index and harvest, the low population index observed in southern Canada should be of concern for managers because it could affect hunter retention and recruitment (Roy et al., this volume, Factors influencing American woodcock hunter satisfaction in Canada). More targeted research programs in southern Canada could help identify areas of concerns that could be targeted for protection and enhancement.

*Harvest and number of successful hunters* Once effort and the spring population size were accounted for, our results suggest that harvest remained relatively stable over time. However, the proportion of successful hunters tended to increase, which supports in part the contention that only the most dedicated woodcock hunters are still practicing the sport (Guthrey et al. 2004, Willebrand et al. 2011). The decline in harvest and the proportion of successful hunters from ca. 2006 was unexpected, as there have been no regulatory amendments that could explain this pattern. Daily bag limits remained stable during the period of the analysis, and the mandated use of non-toxic shot for hunting migratory game birds in Canada in 1999 did not apply to woodcock. However, it is possible that the drop in both metrics was due to issues related to productivity. The period of population decline corresponds roughly to a period of decline in annual indices of woodcock recruitment estimated by CWS from the Species Composition Survey (M. Gendron, unpublished data), and also to a period when the weighted annual indices of recruitment estimated by the USFWS were at their lowest in the Eastern Management Region (Seamans and Rau, this volume). It is therefore possible that woodcock productivity, and hence harvest, declined during this period due to factors that were omitted from our analysis.

## Management Implications

Our finding showing that spring weather conditions are related to the subsequent fall harvest of woodcock in Canada brings some insight about the importance of extrinsic factors in affecting woodcock productivity. Given that our results suggest productivity could play a key role in hunter success, it would be worthwhile to investigate more directly the factors that drive female productivity and juvenile survival on the Canadian breeding grounds with more thorough field studies. Developing a full annual life cycle model would also be useful to identify the limiting factors and period for woodcock populations (Robinson et al. 2016).

The prolonged declines observed in the SGS population index in the Canadian provinces remain unexplained, and it would be useful to invest resources in analyzing the SGS index data at a finer scale. This analysis should help identify regions where declines were more pronounced and identify the drivers of this decline at a local scale. This undertaking should be facilitated by recent efforts that have been deployed to geo-reference SGS routes (Rau and Cooper, this volume).

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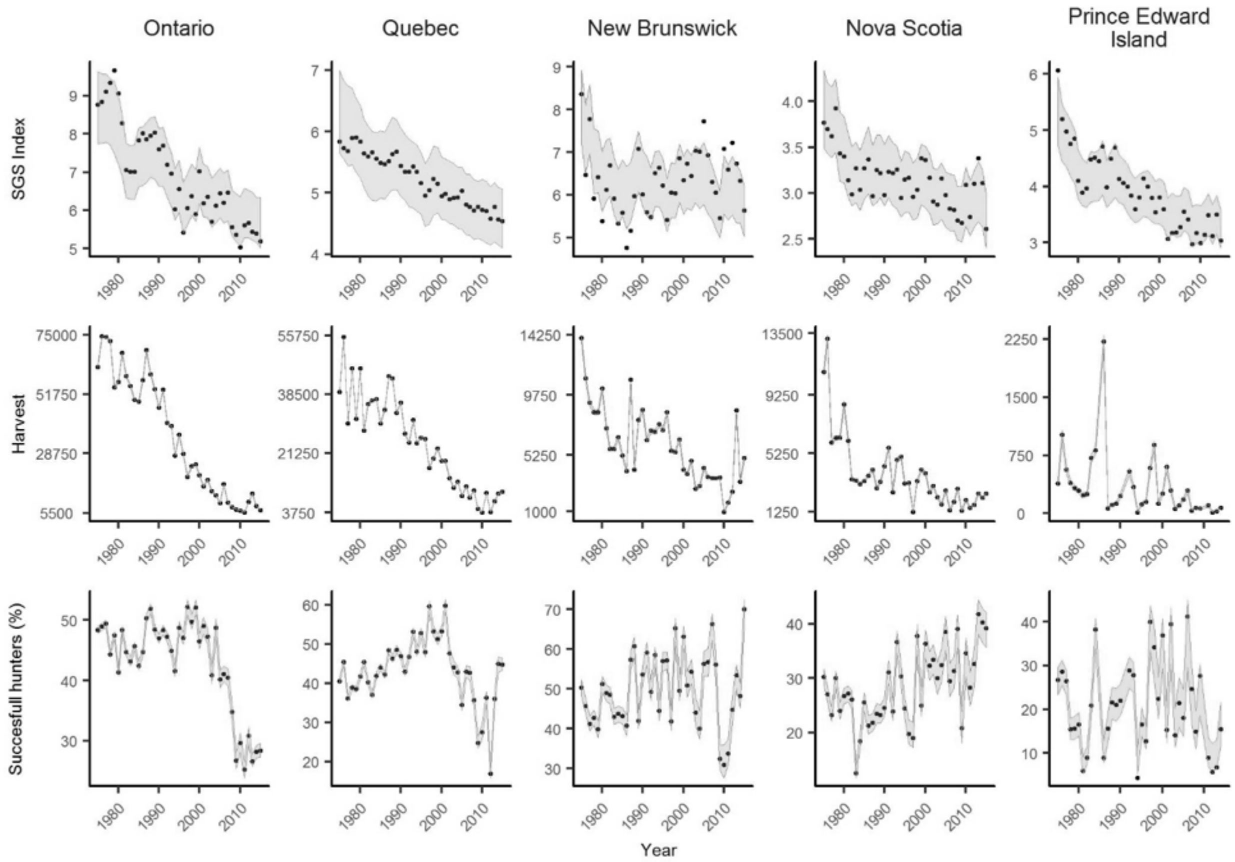

**Appendix 1.** Observed (black dots) and predicted data (shaded area) for the Singing-Ground Survey (SGS) index, number of American woodcock harvested, and percentage of successful woodcock hunters in Canada between 1975 and 2015. Shaded area represents the 95% Bayesian credible interval.

# Survey of Wintering Eurasian woodcock in Western Europe

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**ABSTRACT** The Eurasian woodcock (*Scolopax rusticola*) is a mostly migratory wader (Charadriiformes) that is broadly distributed across the Palearctic. This species winters in or migrates through all European countries and is an important quarry species in many of them. Sustainable management of the species requires information regarding abundance and demographic parameters to be collected regularly. This is a complex task given that different phases of its annual life cycle occur in different countries and, due to the species' secretive behavior, Eurasian woodcock populations cannot be properly evaluated by common bird-census techniques. In Europe, woodcock hunters from different countries have joined in the Federation of Western Palearctic Woodcock Associations (FANBPO), collecting data on hunting activity that can be used to annually evaluate relative abundance and demographic parameters. To investigate variation in Eurasian woodcock relative abundance during and between hunting seasons, we fitted generalized additive mixed models (GAMMs) to data collected in France, Spain, and Portugal (Franco-Iberian region; 2006–2007 to 2015–2016) to analyze the variation in the number of different Eurasian woodcock seen per hunting trip. For these countries and for Switzerland, Italy, Ireland, and Wales, we also analyzed demographic parameters (the ratios of female:male and juvenile:adult) from bagged birds. In the Franco-Iberian region the relative abundance during the autumn-winter period increased from September to the beginning of December, and remained high thereafter with a slight decrease until the end of February; in the last 10 years, relative abundance has remained stable during autumn migration and winter. The sex ratio remained stable in the Swiss-Franco-Iberian and Swiss-Italian regions, but the former had a higher proportion of females. The age ratio varied among hunting seasons and regions. This research is an example of the effective use of data collected through citizen science that aims to maintain a favorable conservation status of the Eurasian woodcock while allowing a rational use of its populations via sustainable and controlled hunting.

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**KEY WORDS:** relative abundance estimation, breeding success estimation, Eurasian woodcock, hunting, *Scolopax rusticola*, sex ratio estimation, survey, western Europe, wintering

The Eurasian woodcock (*Scolopax rusticola*) is a mostly migratory wader (Charadriiformes), widely distributed in the Palearctic (Ferrand and Gossmann 2001, Van Gils et al. 2015), with sedentary populations on the Atlantic islands (Azores, Madeira, and Canaries) and in some southwestern maritime countries (Snow and Perrins 1998; Fig. 1). The Eurasian woodcock that winter in Europe mainly originate from breeding areas in the northern, eastern, central, and parts of western Europe, and from western Siberia (Hoodless and Coulson 1994; Gossmann et al. 2000; Bauthian et al. 2007; Hobson et al. 2013a,b; Arizaga et al. 2014). Across this region the Eurasian woodcock population is estimated to number c.10–26 million individuals, the majority of which winter in western and southern Europe and northern Africa (Nagy et al. 2015, Wetlands International 2017). The European population is estimated at 13.8–17.4 million mature individuals and the population in the EU27 (European Union 27 member states; 1 January 2007–30 June 2013) is estimated at 1.5–2.9 million mature individuals (BirdLife International 2015). Due to the secretive behavior of the species, these estimates are mostly based on specialists' opinions rather than on objective data collected in the field. The exceptions are the British Isles and France, where the breeding population is estimated based on counts of roding birds (Hoodless et al. 2008, Heward et al. 2015, Ferrand et al. 2008).

Currently, the Eurasian woodcock's global conservation status is evaluated as Least Concern (LC; Birdlife International 2016). The only regional assessment available on trend concerns Europe, where the population trend appears to be stable. Within the EU27, the population size is estimated to be decreasing but by <25% in 18.9 years (3 generations), and is thus evaluated as LC (BirdLife International 2015). The main factors that negatively affect the population within its breeding range seem to be the increased area of conifer plantations, which typically offer low diversity of age and stand type and are poor in shrub cover, and the increasing average age of woodland (Ferrand

and Gossmann 2001, 2009*b*; Heward et al. 2015). Outside the breeding season, negative factors are the disappearance of permanent grasslands and the intensification of agricultural practices (e.g., the destruction of hedges, decreases in the number of permanent grazed meadows, and the impoverishment of soil fauna as a result of plowing and chemical application) (Ferrand and Gossmann 2001, 2009*b*; Duriez et al. 2005*b*). In addition to habitat changes, Eurasian woodcock are hunted in most European countries during the autumn migration and wintering periods, with the largest numbers taken in Greece (c. 1 million), France (c. 740,000), Ireland (c. 125,000), United Kingdom (c. 125,000), Italy (105,000), and Spain (35,000) (Hirschfeld and Heyd 2005, Ferrand et al. 2017). Spring hunting still occurs in Russia, taking annually c. 166,000–213,000 individuals (Blokhin et al. 2015). With the exception of countries with good monitoring systems (e.g., France), some of these values are rough estimates.

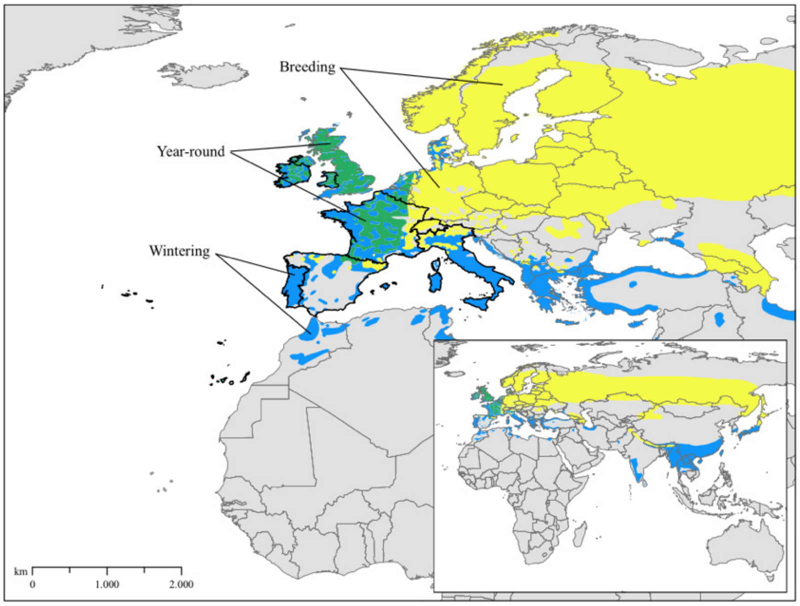

**Figure 1.** Eurasian woodcock (*Scolopax rusticola*) distribution in the Palearctic region. Countries with ≥1 hunting association member of the Federation of Western Palearctic Woodcock Associations (FANBPO) are outlined in black (Portugal, Spain, France, Switzerland, Italy, Ireland, and Wales).

The management of game species must be based on a strong scientific knowledge of their biology and ecology and on information regularly collected from their populations, especially regarding abundance and demography. For a sedentary species or population, the entire annual life cycle can be followed in the same area, but for migrants like the Eurasian woodcock, different phases of the annual life cycle occur in different areas, encompassing different countries, and thus different policies making their management a complex task.

The Eurasian woodcock is a solitary, elusive, and cryptic species. It is among those species that are not effectively evaluated by common bird-census techniques and that require the application of specific census methods to evaluate their abundance (Ferrand 1993, Hoodless et al. 2008). Hunting activity has been demonstrated to be useful in providing data to annually evaluate relative abundance and demographic parameters (Fadat 1979; Ferrand et al. 2006, 2008, 2010; Faragó et al. 2013; Rodrigues et. al. 2013; Guzmán and Arroyo 2015; Boidot et al. 2015; Christensen et al. 2017). An index of Eurasian woodcock abundance estimated from hunting trip data strongly correlates with another index of abundance obtained from nocturnal banding sessions, and is considered a valid approach to evaluated winter abundance variation (Ferrand et al. 2006, 2008, 2010). Hunting activity also can give crucial information on autumn migration and winter phenology, information important in evaluating the movements of the birds, including their response to extreme weather conditions and the adequacy of placement and duration of hunting seasons.

In Europe, woodcock hunting associations from different countries encourage their affiliates to collect data, which can be used to monitor the trend and breeding success of the species. However, until now the analysis of these data has mainly been done at the country level (Rodrigues et al. 2013, Christensen and Asferg 2016, Meunier et al. 2016). These hunting associations are joined in the *Féderation des Associations Nationales des Bécassiers du Palearctique Occidental* (FANBPO, Federation Western Palearctic Woodcock Associations), which facilitates their cooperation. Founded in 2003, FANBPO presently joins c. 4,000 French (*Club National des Bécassiers*, CNB), c.1,000 Spanish (*Club de Cazadores de Becada*, CCB), c. 1,000 Italians (*Club della Beccaccia*, CDB, and *Beccacciai d'Italia*, BDI), 300 Swiss (*Association Suisse des Bécassiers*, ASB), c. 100 Portuguese (*Associação Nacional de Cacadores de Galinholas*, ANCG), c. 250 Irish (The National Woodcock Association of Ireland, NWAOI), and c. 50 Welsh (Welsh Woodcock Club, WWC) woodcock hunters (Fig. 1).

In this study we use data collected by FANBPO members to: 1) describe autumn migration and winter phenology of Eurasian woodcock in southwestern Europe; 2) evaluate trends of wintering Eurasian woodcock populations; and 3) make inferences regarding variation in relative abundance and demographic parameters among hunting seasons. With these analyses, we aim to illustrate the importance of international cooperation for sustainable management of a migratory game species.

## Study Area

During the breeding season in continental Europe, Eurasian woodcock prefer a mosaic of woodland types and ages and utilize broad-leaved, mixed, and coniferous woodland (Cramp and Simmons 1983; Hirons 1987, 1988a; Hirons and Johnson 1987; Ferrand 1989). In winter, their habitat requirements are less specific, and include mainly woodlands and hedges during the day and fields and meadows at night (Cramp and Simmons 1983; Hirons and Bickford-Smith 1983; Wilson 1983; Gossmann et al. 1988; Duriez et al. 2005*a*,*b*).

We analyzed data collected by FANBPO members during woodcock hunting in Portugal, Spain, France, Italy, Switzerland, Ireland, and Wales. Banding studies and isotope analysis suggest that Eurasian woodcock migrating through or wintering in these countries come from different regions of the species breeding range and thus may belong to different populations. Accordingly, for analysis, we organized data by 3 major regions: 1) Swiss-Franco-Iberian, a region that includes the cantons of Romandie in Switzerland (close to France), France, Spain, and Portugal, and represents a wintering area for birds coming mostly from east-central Europe and the Baltic region (Gossmann et al. 2000; Bauthian et al. 2007; Guzmán et al. 2011; Hobson et al. 2013*a*,*b*; Arizaga et al. 2014). 2) The Swiss-Italian region, which includes the canton of Ticino, in Switzerland (close to Italy), and Italy; this is probably part of the wintering area of Eurasian woodcock that bred in central Europe and Belarus (Gossmann et al. 2000). 3) The British Isles, including Ireland and Wales, where a significant number of Scandinavian and northwestern Russia Eurasian woodcock tend to winter (Hoodless and Coulson 1994, Hoodless et al. 2013).

## Methods

### RELATIVE ABUNDANCE

*Data collection* Hunters collected data during woodcock hunting trips in hunting seasons from 2006–2007 to 2015–2016, in France (since 2006–2007), Spain (since 2006–2007), and Portugal (since 2009–2010). For each hunting trip, they recorded the date, location, duration, and number of different Eurasian woodcock seen. Hunters reported this information to each club's or association's scientific committee in pre-formatted forms, on paper or online.

Hunting seasons vary among these countries in start and end dates, the number of hunting days permitted, and the number of Eurasian woodcock that may be shot, although the hunting season usually spans from September or October to January or February (Appendix A). The hunting process used for Eurasian woodcock is usually the same: Eurasian woodcock are found by pointing dogs and shot by the hunter. We considered for analysis only data collected from hunting that occurred between September and February and that used pointing dogs.

*Analysis* To investigate variation in Eurasian woodcock relative abundance during and between hunting seasons, we used *mgcv* and *poptrend* R *packages* (Wood 2011, Knape 2016, R Core Team 2016) to fit generalized additive mixed models (GAMMs) with negative binomial errors and to visualize fits, respectively. All models included log of duration of each hunting trip (i.e., sampling effort) as an offset, and a 2-dimensional smoother for geographical coordinates of centroids of each region where hunting trips took place, to account for spatial auto-correlation (Zuur 2012). Because the precision of localities of each

**Table 1.** Summary of the generalized additive mixed models (GAMMs) for the variation in relative abundance of Eurasian woodcock (*Scolopax rusticola*) in southwestern Europe (France, Spain, and Portugal; hunting seasons 2006–2007 to 2015–2016) analyzing the species *Phenology*, between September and February, and *Trends*, between hunting seasons, for all data, migration period, and wintering period. Chi-square values, *P-values* and estimated degrees of freedom (EDF) are listed for each term included in the models. For each model the deviance explained (%) is presented.

| | | **Season** | **Decade** | **Day** | **Lat, Long** | **Deviance explained (%)** |
|---|---|---|---|---|---|---|
| *Phenology* | | 175.2,<br><0.001<br>(0.99) | 9524.3,<br><0.001<br>(14.12) | — | 47178.8,<br><0.001<br>(23.30) | 26.4 |
| *Trend* | All | 6.1,<br>0.042<br>(2.49) | — | 9660.8,<br><0.001<br>(8.90) | 47566.1,<br><0.001<br>(23.30) | 26.9 |
| | Migration | 2.7,<br>0.210<br>(1.27) | — | 9753.9,<br><0.001<br>(8.02) | 28263.0,<br><0.001<br>(23.28) | 27.7 |
| | Winter | 3.2,<br>0.160<br>(2.49) | — | 119.2,<br><0.001<br>(4.73) | 20535.2,<br><0.001<br>(23.11) | 26.9 |

hunting trip varied, we considered coordinates of centroids of 91 French departments (mean area ± SE: 5,925.0 ± 168.1 $km^2$), 40 Spanish provinces (10,114.5 ± 791.6 $km^2$), and 18 Portuguese districts (4,941.4 ± 499.0 $km^2$).

First, to describe autumn migration and wintering phenology of Eurasian woodcock in southwestern Europe, we modeled number of different Eurasian woodcock seen through the hunting season, according to "decade" (period of 10 days of each month), with hunting season as a covariate modelled as a smooth term with automatic selection of df (Knape 2016).

Second, we evaluated variation in relative abundance between hunting seasons by including region and day of hunting season as covariates, modelled as smooth terms with automatic selection of df. We built 3 models with 10 df with data from the: 1) entire hunting season (the first decade of September to the third decade of February); 2) migratory period (from the first decade of October to the second decade of December); 3) wintering period (from the third decade of December to the second decade of February).

The first day of the hunting season was always considered as 1 September and, therefore, for each hunting trip, the day of the hunting season was determined as the number of days since 1 September.

### DEMOGRAPHY

*Data collection* Sex and age, or age only, were determined for Eurasian woodcock shot in Switzerland (since 2008–2009), Italy (since 2010–2011), Ireland (since 2008–2009), Wales (since 2012–2013), France (since 2006–2007), Spain (since 2006–2007), and Portugal (since 2009–2010; see Tables 1 and 2). Eurasian woodcock are not sexually dimorphic so birds were sexed by gonad examination after dissection, primarily by hunters. Trained "wing readers" determined age class [juvenile (<1 year old) or adult (>1 year old)] by wing examination, according to Ferrand and Gossmann (2009*a*).

Additionally, we consider published data from Denmark, where Eurasian woodcock wings have been collected since the 1970s (Clausager 1974, Christensen 2017). This country is located upstream in a flyway that, probably, mostly concerns the British Isles and the Swiss-Franco-Iberian regions (Harradine 1983, 1988; Ferrand et al. 2008). Therefore, the annual Eurasian woodcock age ratio on the Danish hunting bag is considered to most closely correspond to breeding success of Eurasian woodcock in that region of Europe (Fadat 1988, 1995; Harradine 1983, 1988, Ferrand et al. 2008).

*Analysis* We organized data based on the major regions described previously. We investigated variation in the proportions of sex- and age-classes among hunting seasons based on chi-square tests and conducted statistical tests with $\alpha = 0.05$.

## Results

### RELATIVE ABUNDANCE

We analyzed a total of 356,837 reports of hunting trips from France, Spain, and Portugal, corresponding to a total of 537,024 contacts with Eurasian woodcocks and 1,187,292 hours of hunting.

*Phenology* The model describing variation in relative abundance of Eurasian woodcock by decade (10-day period) explained 26.4% of the deviance (Table 1). The deviance explained corresponds to the unadjusted variance explained by the models. Geographic location and season had a smoothing term significantly different from zero (Table 1), which indicates they have a significant contribution to the model. After a slight decrease during September, relative abundance increased during following decades, from the beginning of October until the first decade of December. From December to the end of February, abundance remained high but decreased slightly over time (non-significant; see Fig. 2).

**Table 2.** Variation among hunting seasons (2006–2007 to 2015–2016) in the sex ratio (females/male) of Eurasian woodcock (*Scolopax rusticola*) hunting bags in the Swiss-Franco-Iberian and Swiss-Italian regions. n: sample size; Chi-square test ($\chi^2$) results comparing frequencies of sexes between regions (all comparisons were significant at $P < 0.001$).

| | **Region** | | | | |
|---|---|---|---|---|---|
| | ***Swiss-Franco-Iberian*** **Switzerland[a], France, Spain, Portugal[b]** | | ***Swiss-Italian*** **Switzerland[c], Italy** | | |
| **Hunting season** | **Females:male** | ***n*** | **Females:male** | ***n*** | $\chi^2$ |
| 2006–2007 | 1.54 | 2,233 | | | |
| 2007–2008 | 1.54 | 2,543 | | | |
| 2008–2009 | 1.59 | 2,516 | | | |
| 2009–2010 | 1.60 | 2,727 | 0.94 | 322 | 20.70 |
| 2010–2011 | 1.52 | 1,929 | 1.06 | 411 | 11.07 |
| 2011–2012 | 1.53 | 2,187 | 1.02 | 617 | 20.14 |
| 2012–2013 | 1.57 | 2,335 | 1.19 | 1,244 | 15.36 |
| 2013–2014 | 1.52 | 2,370 | 1.11 | 1,695 | 23.37 |
| 2014–2015 | 1.43 | 2,088 | 1.07 | 2,235 | 21.94 |
| 2015–2016 | 1.45 | 1,950 | 1.12 | 2,202 | 16.47 |
| **Total** | | **22,878** | | **8,726** | |

[a] only cantons from Romandie; [b] since 2009–2010; [c] only Ticino

*Trend* The 3 GAMMs describing the variation in relative abundance of Eurasian woodcock between hunting seasons for the entire season, the migration period, and the wintering period described 26.9% , 27.7% and 26.9% of respective deviance (Table 1). Geographic location and day of the hunting season had a smoothing term significantly different from zero ($P < 0.001$) in all 3 models. There was no evidence of a significant trend in Eurasian woodcock relative abundance during the last 10 years in southwestern Europe (Fig. 3).

### DEMOGRAPHY

*Sex* For hunting seasons from 2006–2007 through 2015–2016, sex was determined for 31,604 Eurasian woodcock (Table 2; birds from Ireland and Wales were not sexed). During this period, the proportion of males and females in hunting bags did not vary significantly in the 2 regions considered: Swiss-Franco-Iberian ($\chi^2 = 6.555$, df = 9, $P = 0.683$) and Swiss-Italian ($\chi^2 = 5.706$, df = 6, $P = 0.457$). The proportion of females was significantly lower in the Swiss-Italian region for all hunting seasons (since 2011–2012).

*Age* For hunting seasons from 2006–2007 through 2015–2016, age was determined for 135,750 Eurasian woodcock (Table 3). During this period, the proportion of juveniles and adults in hunting bags varied significantly in all regions (Fig. 4): Swiss-Franco-Iberian ($\chi^2 = 794.718$, df = 9, $P < 0.001$); Swiss-Italian ($\chi^2 = 329.990$, df = 6, $P < 0.001$); British Isles ($\chi^2 = 194.755$, df = 7, $P < 0.001$). Geographic differences in age ratios were consistently observed across hunting seasons (Table 3; Fig. 4): the sample from the Swiss-Italian region always contained higher proportions of juveniles, whereas the British Isles always contained lower proportions. Despite the lack of statistical significance, proportions observed in the Swiss-Franco-Iberian region were strongly correlated with those observed in the Swiss-Italian region (r = 0.70, $P = 0.079$) and the British Isles (r = 0.68, $P = 0.062$).

Variation between hunting seasons in the age ratio of Eurasian woodcock shot in Denmark during the period under study is also represented in Fig. 4. Danish values were significantly correlated with those from the Swiss-Italian region (r = 0.82, $P = 0.024$), but not with those from the Swiss-Franco-Iberian region (r = 0.57, $P = 0.085$) or the British Isles (r = 0.10, $P = 0.806$).

## Dicussion

### RELATIVE ABUNDANCE

We used data collected during hunting activity to indirectly assess the relative abundance of the Eurasian woodcock population, namely the number of different Eurasian woodcock observed during a hunting trip—a number which, unlike the number of woodcock shot, is not influenced by the bag limit that exists in some countries included in our study. Though already possible to examine with other game bird species (e.g., Palmer et al. 2002; Cattadori et al. 2003), the type of relationship between Eurasian woodcock indexes of relative abundance and density is still to be demonstrated. Still, Ferrand et al. (2010) reported a strong correlation between the number of Eurasian woodcock observed per hunting trip and the number observed per hour during nocturnal banding sessions, which the authors considered strong evidence that the relative abundance estimated from hunting is a valid approach for evaluating autumn and winter abundance variation. In our study we accounted for harvesting effort (duration of hunting trip), which may be sufficient to remove some bias on the use of relative abundance to estimate genuine patterns of population change (Botsford et al. 1983, Berryman 1991, Berryman and Turchin 2001). We used data from a specific method of hunting Eurasian woodcock (with pointing dogs) and also accounted for the period within each hunting season, the hunting sea-

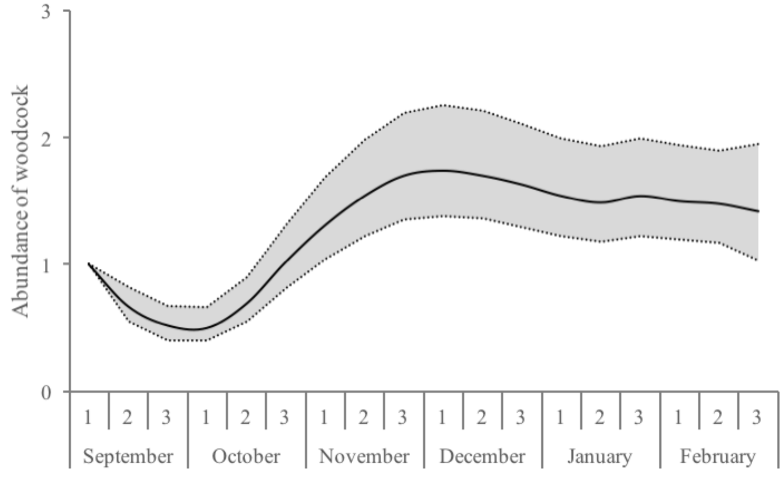

**Figure 2.** Variation in Eurasian woodcock (*Scolopax rusticola*) relative abundance by decade (period of 10 days) between September and February in southwestern Europe (France, Spain, and Portugal; hunting seasons 2006–2007 to 2015–2016). The solid line corresponds to the fitted relative abundance from a generalized additive mixed model (GAMM) with 18 df. The shaded area represents upper and lower 95% CI.

son, and the region. Cattadori et al. (2003, p. 440) note that "one of the strengths of harvesting records is that they often represent samples from a large area of suitable habitat, often over long time periods and with established harvesting traditions that provide good comparable data." We think that our sample presents these properties.

*Phenology* In the Franco-Iberian region, an area that includes France, Spain, and Portugal, relative abundance of Eurasian woodcock increased from September to the beginning of December, then remained high with only a slight decrease until the end of February. Eurasian woodcock are present year round in part of this region, namely in central, north-eastern, and mountainous areas of France (Ferrand et al. 2008) and in northern Spain (Onrubia 2003), but during autumn and winter they are present over a wider area, including Portugal and southern parts of Spain. Our results show that in southwestern Europe, most migratory Eurasian woodcock arrive before mid-December and do not leave these areas before the end of February.

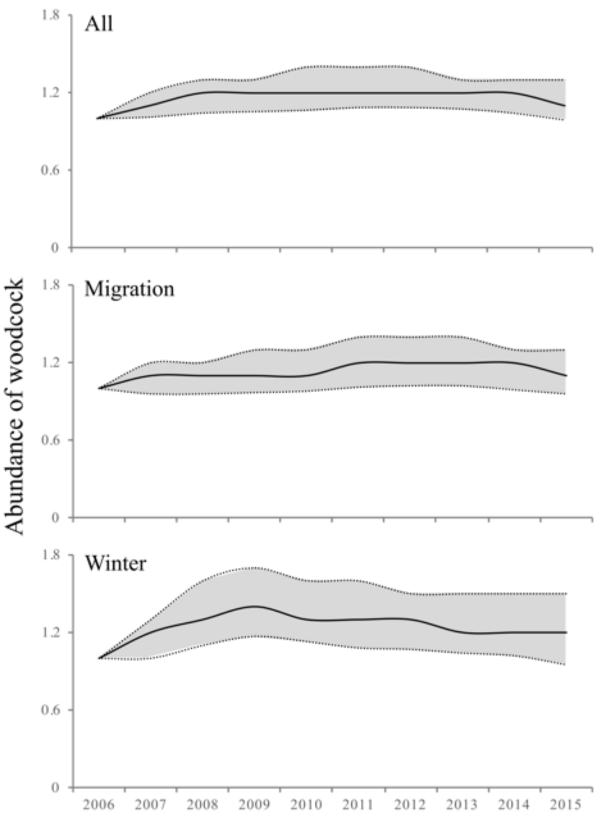

**Figure 3.** Variation between hunting seasons (2006–2007 to 2015–2016) in Eurasian woodcock (*Scolopax rusticola*) relative abundance in southwestern Europe (France, Spain, and Portugal). Solid lines correspond to the fitted relative abundance from a generalized additive mixed model (GAMM) with 10 df. The shaded area represents upper and lower 95% CI for all data (top), migration period (middle), and wintering period (bottom). Region and day of the season were included as smoothing functions.

For birds breeding in the most northern and eastern parts of Europe (Finland, Russia), autumn migration begins at the end of September or at the beginning of October (Iljinsky et al. 2000). General movement in Scandinavia occurs from October to November (Clausager 1974, Christensen and Asferg 2016). Thus, phenology observed in the Franco-Iberian region is in accordance with what would be expected, given its southwestern position in Europe.

The significant contributions of hunting season and region to our models of abundance are the result of differences in autumn migration and winter phenology between hunting seasons and regions. Several authors have already recorded differences in the timing of migration among years (e.g., Clausager 1974, Birtsas et al. 2013, Rodrigues et al. 2013). A 12-year study in Macedonia found that arrival date was related to atmospheric stability, with the onset of autumn migration postponed in warmer autumns (Birtsas et al. 2013).

The small proportion of the deviance explained by the model must be related to the low number of explanatory variables. Models may be improved with collection of additional variables related to each hunter and their dogs, or environmental variables in wintering and breeding areas that may influence habitat selection and migratory movements (Péron et al. 2011, Birtsas et al. 2013).

*Trend* According to our models describing variation in Eurasian woodcock relative abundance between hunting seasons, abundance during autumn migration and winter in the Franco-Iberian region has remained stable in the last 10 years. As with the phenology model discussed above, these models explained little deviance, and the inclusion of other variables could help improve the model. For instance, previous analysis of Eurasian woodcock hunting data from northern Spain indicated that relative abundance of Eurasian woodcock is related to weather conditions during the previous spring in breeding areas (Guzmán and Arroyo 2015).

A lack of trend was observed in France for the period 1990–1991 to 2002–2003 for several indices of autumn-winter abundance, including the number of Eurasian woodcock seen per 3.5 hours of hunting (Ferrand et al. 2006, 2008), and in northern Spain for the period 1991–1992 to 2011–2012, based upon the number of Eurasian woodcock observed per hour of hunting (Guzmán and Arroyo 2015). The latter study included partial data analyzed in the present paper. In the United Kingdom, the variation between hunting seasons in the number of Eurasian woodcock shot per 100 ha from 1961 to 2004 suggests a stable trend over the final 25 years (Aebischer and Harradine 2007). Conversely, in these regions some breeding populations declined during the last decenniums (Hewson and Noble 2009, Heward et al. 2015, Mollet 2015, Mulhauser and Zimmerman 2015). This difference is due to the fact that 2 groups of Eurasian woodcock occur in Western Europe: those that breed and winter there and others that only winter there and originate from western Russia, the Baltic States, Fennoscandia, and Central Europe (Bauthian et al. 2007; Guzmán et al. 2011; Hobson et al. 2013*a*,*b*; Hoodless et al. 2013; Arizaga et al. 2014). In France and Spain the latter represent ca. 90% of the Eurasian woodcock harvested (Hobson et al. 2013*a*,*b*), similar to values reported for the British Isles (Hoodless et al. 2013). Thus, by collecting data during autumn-winter (hunting season) in Western Europe, we are able to monitor not only the population that breeds there, but also a significant portion of the large population that breeds farther north and east. The meteorological conditions registered during the breeding season in the Baltic region are related to the winter relative abundance of Eurasian woodcock in northern Spain (Guzmán and Arroyo 2015), and winter relative abundance in France is strongly correlated with the proportion of chicks that have undergone complete molt at the end of summer in Russia (Ferrand and Gossmann 2009b). It is possible to use all this information to predict annual relative abundance during the hunting season in Western Europe, at least in the Franco-Iberian region (Ferrand and Gossmann 2009b, Guzmán and Arroyo 2015).

## DEMOGRAPHY

*Sex* The proportion of males and females in the Eurasian woodcock hunting bags remained stable in the Swiss-Franco-Iberian and Swiss-Italian regions during the period of our study, but the first region presented a higher proportion of females. This was previously recorded in hunting bag results published for France and Italy in the 1970s and 1980s (Spanò and Ghelini 1983, Fadat 1988).

The Eurasian woodcock hunting method most commonly used in both regions is the same—hunting with pointing dogs—and this could partially explain the tendency for hunting bags to contain more females than males, as females seem to seek more temperate and humid habitats, and hunters, knowing that they will find higher Eurasian woodcock numbers in such areas, visit them preferentially (Fadat 1988, 1995). Another factor that can contribute to higher proportions of females is the differential migration that seems to characterize Eurasian woodcock, i.e., females leave breeding areas earlier in autumn and arrive at breeding areas in spring later than males; females are therefore exposed to longer periods of hunting susceptibility during the non-breeding season compared to males (Clausager 1974; Fadat 1981, 1989; Fokin and Blokhin 2000; Ferrand et al. 2013). Additionally, Christensen et al. (2017) proposed that males may stay farther north in Europe than females during autumn and winter. The higher proportion of females in the Swiss-Franco-Iberian region could, eventually, be due to the region's great distance from the core breeding area of the majority of Eurasian woodcock that winter there.

*Age* The proportion of juveniles to adults varied over the period of our study and among the regions we considered. Although the proportion of juveniles is considered a practical measure of breeding success in waders (Minton 2003), the relationship is not direct. The proportion of juveniles among Eurasian woodcock shot during the hunting season can also be influenced by several other factors (Harradine 1983, 1988; Fadat, 1981, 1988, 1995). The breeding areas for most of the wintering Eurasian woodcock analyzed are very large and diverse (from Western Europe to western Siberia); both within and between seasons there is likely to be variation in production of fledged juveniles from one part of the range to another (Harradine 1983). Hunting pressure also has been demonstrated to influence age ratio (Fadat 1981, Duriez et al. 2005*a*, Péron et al. 2012). Adult Eurasian woodcock tend to occupy the best sites within wintering areas and are very faithful to them between winters, removal by hunting promotes more frequent replacement by juvenile Eurasian wood-

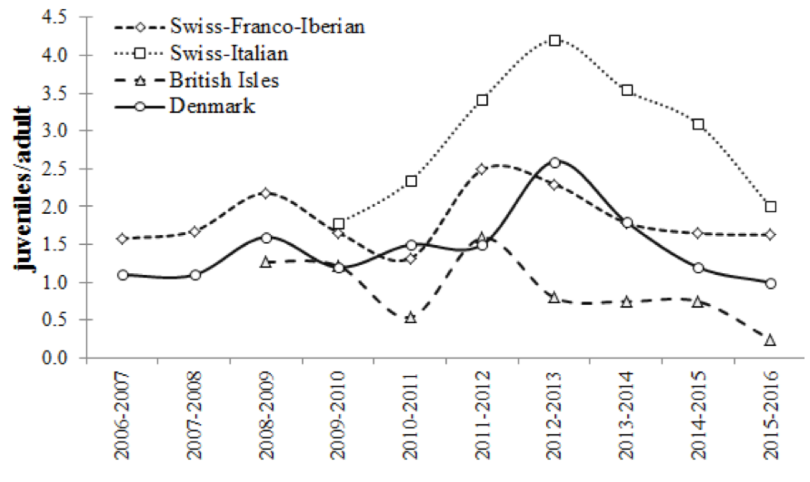

**Figure 4.** Variation in the age ratio (juveniles:adult) of Eurasian woodcock (*Scolopax rusticola*) shot between hunting seasons in the Swiss-Franco-Iberian and the Swiss-Italian regions, the British Isles, and Denmark (Christensen and Asfer, 2016), from 2006–2007 to 2015–2016.

cock, and higher hunting pressure can therefore lead to higher proportions of juvenile Eurasian woodcock. Also, distribution of juveniles may be influenced by weather conditions during autumn migration and movements in response to inclement-weather conditions that occur in some winters (Ferrand et al. 2008).

To overcome possible biases caused by these factors, Ferrand et al. (2008) proposed that the age ratio must be estimated for the maximum number of wintering areas possible. In the present study we analyzed the variation in the proportion of juveniles over most of southwestern Europe. Concerning hunting pressure, providing that it remains fairly constant from year to year within a country or region, there is no reason why it should obscure major variations between years in the proportion of juveniles in the population (Hirons 1988*b*).

Geographic differences in age ratios observed each season in hunting bags correspond, in general, to those described in previous works (Fadat 1988, 1995; Harradine 1983, 1988; Ferrand et al. 2008). The British Isles tend to present lower values. The hunting method (driven shooting is more prevalent) and the lower mortality estimated (Hoodless and Coulson 1994; Tavecchia et al. 2002; Péron et al. 2012) may partially explain differences between the British Isles and the Swiss-Franco-Iberian and the Swiss-Italian regions. However, we must take into account that our sample size for the British Isles, mainly since the 2009–2010 hunting season, is small. Additionally, Ireland and Wales only represent a part of the British Isles and age ratio seems to vary within this region (Harradine 1983, 1988).

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**Table 3.** Variation among hunting seasons (2006–2007 to 2015–2016) in the age ratio (juveniles/adult) of Eurasian woodcock (*Scolopax rusticola*) shot in each region studied. n: sample size; Chi-square test ($\chi^2$) results comparing frequencies of age classes among regions (all values correspond to $P < 0.001$).

| | **Region** | | | | | | |
|---|---|---|---|---|---|---|---|
| | ***Swiss-Franco-Iberian*** **Switzerland[a] + France[b] + Spain + Portugal[c]** | | ***Swiss-Italian*** **Switzerland[d] + Italy[e]** | | ***British Isles*** **Ireland + Wales** | | |
| **Hunting season** | **Juveniles:adult** | ***n*** | **Juveniles:adult** | ***n*** | **Juveniles:adult** | ***n*** | **$\chi^2$** |
| 2006–2007 | 1.58 | 9,970 | | | | | |
| 2007–2008 | 1.68 | 11,117 | | | | | |
| 2008–2009 | 2.18 | 10,998 | | | 1.27 | 1,407 | 88.52 |
| 2009–2010 | 1.66 | 11,690 | 1.78 | 1,000 | 1.22 | 1,218 | 27.55 |
| 2010–2011 | 1.32 | 9,662 | 2.34 | 1,018 | 0.54 | 692 | 207.11 |
| 2011–2012 | 2.49 | 10,660 | 3.42 | 2,143 | 1.59 | 556 | 64.22 |
| 2012–2013 | 2.30 | 10,567 | 4.20 | 3,679 | 0.80 | 998 | 520.78 |
| 2013–2014 | 1.79 | 11,496 | 3.54 | 3,967 | 0.75 | 339 | 350.35 |
| 2014–2015 | 1.65 | 11,232 | 3.09 | 4,688 | 0.75 | 493 | 376.39 |
| 2015–2016 | 1.63 | 11,390 | 2.00 | 4,651 | 0.25 | 119 | 125.74 |
| **Total** | | **108,782** | | **21,146** | | **5,822** | |

[a] only cantons from Romandie; [b] excluding Corsica; [c] since 2009–2010; *d* only Ticino; *e* excluding Sardinia and Sicilia

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**Appendix A.** Features of the 2015–2016 Eurasian woodcock hunting season by country member of FANBPO and respective regions (when justified), namely on the start and ending dates, the number of days per week hunting is allowed, the existence of a daily or seasonal bag limit (number of Eurasian woodcock allowed to be shot per hunter, daily or seasonally; also known as PMA — *Prélèvement Maximal Autorisé* or Maximum Authorized Harvesting). In the last decade these features remained relatively constant.

| | | | | | **Bag limit** | | |
|---|---|---|---|---|---|---|---|
| **Country** | **Region** | **Start** | **End** | **Days/ Week** | **daily** | **weekly** | **seasonally** |
| Ireland | | 01-11-2015 | 31-01-2016 | 7 | NO | | NO |
| Wales | | 01-10-2015 | 31-01-2016 | 6 | NO | | NO |
| France | | 14-09-2015 | 20-02-2016 | 2–7 | 1–4* | 1 - 6* | 30 |
| Switzerland | Romandie | 15-09-2015 | 14-12-2015 | 4–6 | 2 | | 12–20 |
| | Ticino | 16-10-2015 | 30-11-2015 | | | | 15 |
| Italy | Mainland | 21-09-2015 | 31-01-2016 | 3 | 2–3 | | 15–20 |
| | Sardinia and Sicily | 28-09-2015 | 31-01-2016 | 3 | 3 | | 20 |
| Spain | Mainland | 08-10-2015 | 15-02-2016 | 2–7 | 2–3 | | NO |
| | Balearic Islands | 05-10-2015 | 01-02-2016 | 2–4 | 1–4 | | NO |
| | Ceuta | 05-10-2015 | 21-12-2015 | 3 | | | |
| Portugal | Mainland | 01-11-2015 | 10-02-2016 | 2–4 | 3 | | NO |

* according to "départements" regulations


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## CHAPTER SIX

# Management Techniques

# Assessment of the American Woodcock Wing-Collection Survey

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**ABSTRACT:** The American Woodcock Wing-collection Survey (WCS) is a cooperative survey (U.S. Fish and Wildlife Service [FWS], State Wildlife Agencies, and U.S. woodcock hunters) that has been conducted annually since 1963 in the United States. The primary objective of the WCS is to provide an index to the reproductive success of American woodcock (*Scolopax minor*; hereafter, woodcock) because age and sex of harvested birds can be determined using feather characteristics. Based on recent harvest survey information, U.S. woodcock hunters harvest ≈ 300,000 woodcock per year, whereas hunters participating in the WCS contributed an average of 13,400 wings per year during the 2008–2012 seasons. Based on the sample size and harvest estimate, the WCS currently samples about 4.5% of the harvested woodcock every year, which is a much higher rate than sampled for waterfowl. For example, the Waterfowl Parts Collection Survey sampled ≈ 0.25% of the Mississippi Flyway waterfowl harvest in 2012. My objective was to assess if there were any differences in the proportion of wings by cohort (adult male, adult female, juvenile male, juvenile female) if wing collection was limited to a hunter's first 5 successful hunts, rather than all of their successful hunts as is currently done. I analyzed WCS data from the 2008–2012 woodcock seasons and used Pearson's Chi-Square Goodness of Fit test to assess if the proportion of wings for each cohort differed between the full data set and data from a hunter's first 5 successful hunts. Limiting data collection to the first 5 successful hunts resulted in a 5-year average (2008–2012) of 1,848 fewer envelopes and 4,202 fewer wings being submitted to the survey. Chi-square analysis indicated there was no difference in the proportion of wings by cohort between the full and partial data set. My results indicate that reducing the sample size of woodcock wings would not bias age ratio estimates and would result in considerable cost savings to the WCS. The FWS would realize cost savings through fewer envelopes having to be mailed and less staff time in processing wings when they are received.

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**KEY WORDS:** American woodcock, hunter harvest, sample size, wing-collection survey

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# Using Infrared Technology to Locate and Monitor American Woodcock Nests

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**ABSTRACT** Methods for locating American woodcock (*Scolopax minor*; hereafter woodcock) whether individuals, nests, or broods, have remained largely unchanged for more than 75 years, but use of current technology has the potential to increase efficiency and decrease observer-caused disturbance. Primary methods of searching for and locating woodcock have included the use of pointing dogs, and telemetry after capture using mist nets, nightlighting, or live traps. We tested the feasibility of using Forward Looking Infrared Radar (FLIR) cameras to locate individual woodcock, nests, and broods in the spring (24 March – 11 May) of 2015 as part of a research project to determine the timing of nest initiation along 3 American Woodcock Singing-Ground Survey (SGS) routes in southwestern Pennsylvania. By using FLIR to search potential woodcock nesting cover adjacent to SGS routes, we located a total of 28 nests and 4 broods, 2 of which were not linked to a previously known nest. We also located 180 individual woodcock. Searching took place over a total of 22 days, not all contiguous, for a total of 58.05 hours. Nest-searching efficiency using FLIR was 0.48 nests/hour compared to published reports of efficiency using historical search methods ranging from 0.03–0.4 nests/hour. The FLIR method is not only more efficient, but provides a non-intrusive approach to locating and monitoring nesting woodcock. In addition to nesting ecology, FLIR may have additional applications in woodcock research, including improving efficiency of capture methods and monitoring nocturnal behavior and habitat use. The technology also proved to be excellent at locating other birds and mammals, and therefore has many possible uses in wildlife research.

***Proceedings of the American Woodcock Symposium 11: 256–262***

**KEY WORDS:** American woodcock, display, Forward Looking Infrared Radar (FLIR), nest, nest search, nest monitoring, Pennsylvania, *Scolopax minor*

Infrared technology was used as early as the 1960s in the field of wildlife management (Galligan et al. 2003), although until fairly recently the primary use has been to survey large mammals from aircraft. Within the past decade or so, several studies have been conducted on the efficacy of using Forward Looking Infrared Radar (FLIR) to locate smaller-sized birds for capture (Mills et al. 2011, Chavarria et al. 2012), to monitor activity from a distance (Long and Locher 2011), or to search for nests (Galligan et al. 2003). Several important factors that can limit FLIR efficacy have been identified. Solar heating of inanimate objects on the ground (rocks, coarse woody debris, etc.) can create a thermal washout and diminish the contrast needed between a bird's body-heat signature and the cooler background (Boonstra et al. 1995, Garner et al. 1995, Galligan et al. 2003, Chavarria et al. 2012). Density of surrounding cover can block the view of the camera and mask the heat signature (Galligan et al. 2003, Long and Locher 2011, Chavarria et al. 2012). Topography was also found to be a limiting factor (Long and Locher 2011). Finally, the

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cost of FLIR units, although decreasing, is still high in comparison to other methods of locating birds.

There are many positive aspects of using FLIR, however. Not only can birds as small as passerines be located, but incubated eggs can also be located with the camera due to their heat signature (Galligan et al. 2003). When paired with other methods such as nightlighting or use of dogs in locating birds, FLIR increases location and/or capture rates (Galligan et al. 2003, Chavarria et al. 2012, Mills et al. 2011). In the case of clapper rail (*Rallus crepitans*) capture, Mills et al. (2011) found the use of FLIR, nightlighting, and airboat together produced a capture rate of 6.9 rails/hr, whereas trapping alone resulted in 0.019 rails/hr, and nightlighting using an aluminum boat produced 0.0 rails/hr. Probably the greatest positive application of FLIR is the non-intrusive ability to monitor birds and their nests (Galligan et al. 2003, Long and Locher 2011, Chavarria et al. 2012), which can prevent direct injury or mortality to birds (Ammann 1973, Chavarria et al. 2012) and decrease abandonment or predation on nesting birds and eggs or broods due to investigator disturbance (Gotmark 1992, Murphy and Thompson 1993). A study in Maine found that 28% of woodcock nests were negatively impacted by the researchers during the course of a study that did not use FLIR (McAuley et al. 1996).

We used FLIR as part of a larger pilot study to determine seasonal timing of peak display and peak nest initiation by woodcock within southwestern Pennsylvania (Keller 2016). We hypothesized that FLIR could be an especially efficient way to locate and monitor woodcock nests during both the egg-laying and incubation periods while also minimizing disturbance to nesting females.

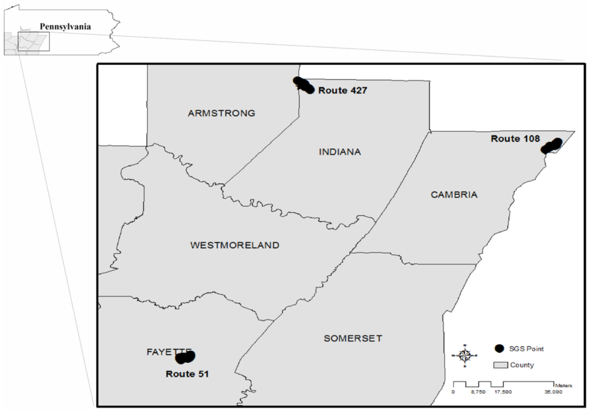

**Figure 1.** Map of southwestern Pennsylvania showing American woodcock singing-ground survey routes on which we evaluated FLIR efficiency for locating woodcock and their nests, with insert map of the state of Pennsylvania.

## Study Area

As part of the study of Keller (2016) we conducted singing-ground surveys (SGSs) at 3 routes selected within southwestern Pennsylvania during the period 24 March – 11 May 2015. These 3 survey routes represented 3 primary vegetation communities within southwestern Pennsylvania (Fig. 1). These included: 1) extensive, open grassland singing grounds surrounded by contiguous mature and early-successional forests (Route 108), 2) a conglomerate of agricultural and warm-season grass fields as singing grounds with a surrounding patchwork of fencerows and both early-successional and mature woodlots (Route 427), and 3) roads where trees were cut within 7.62 meters along either side to promote early-succession, bordered by adjacent small herbaceous openings (<4.04 hectares) and surrounded by contiguous forest in various stages of succession (Route 52). We characterized cover types within 0.32 kilometers (i.e. the approximate distance an observer can detect a singing male [Bergh, 2011]) of each survey route as mature forest, early-successional forest or shrub, and grassland. We surveyed each route during >14 evenings during the survey period.

## Methods

### NEST SEARCHING

After completion of an evening survey route, we returned to ≥1 singing ground along the route and systematically searched for nests in nesting habitat and locations where singing males were heard during the survey. We identified nesting habitat by evaluating known nesting habitat preferences using ArcMap GIS software and a variety of layers including aerial imagery, surface water, topographic, and existing forestry stands on game lands when available. Historic nesting habitat preferences within Pennsylvania were determined to be young, early-succession hardwood stands with high stem density and minimal invasive vegetation (Liscinsky 1972, Dessecker and McAuley 2001, Palmer 2008, Miller 2010). By identifying singing grounds during an SGS survey, marking singing males on a route map, and listening to singing males during moonlit nights, we attempted to search those areas with a high likelihood of supporting nests. We initiated searches within 2 hours post sunset, and search efforts lasted anywhere from 15 minutes to >5 hours. Individual observers conducted searches, except during 5.4 hours when an additional observer was being trained. Trainee hours were not counted towards the total search time used to estimate searching efficiency (i.e., number of woodcock nests located per hour; see below). Observers used FLIR cameras and moved slowly through possible nesting habitat. We searched areas opportunistically; and used neither grids nor transects. We searched for nests when conditions were optimal for avoiding background solar heating: cool, overcast, or wet weather and nighttime to early-morning periods. We documented all discovered nests and broods including location coordinates, number of eggs, number of young, and other pertinent information. If incubation stage could not be readily determined through egg observation we continued to periodically monitor a subset of the nests non-intrusively using FLIR until eggs hatched.

### EQUIPMENT

We used 2 different FLIR during nest searching: Recon M24 640x480 (hereafter Camera 1) and Sierra Pacific Innovations, IR 250D (hereafter Camera 2; the Pennsylvania Game Commission does not endorse these manufacturers). Camera 1 weighed 0.39 kg with batteries installed. This camera had 2 digital zoom levels (2x and 4x) beyond the normal, wide field of view, had adjustable focus and a self-adjusting brightness display, and had an overall size of 11.7 cm x 7.6 cm x 6.4 cm. This camera showed the gradient of heat in black and white, and had the ability to switch from heat showing in white or black. Camera 2 weighed 1.81 kg with batteries installed, had 1 digital zoom level (2x) and an adjustable focus, and its overall size was 25.4 cm x 10.2 cm x 14 cm. Camera 2 also had the ability to switch from heat showing in black or white. Both cameras had the ability to attach a recording device. We used each camera in various temperatures ranging from -1.7 to 25.6°. We also used both cameras in light to heavy fog, and light to heavy rain. We used Camera 1 during heavy snowfall.

### NEST SEARCHING EFFICIENCY RATE

We calculated search efficiency as the number of woodcock nests located per hour. We recorded the number of minutes spent nest searching at each location per night and the numbers of nests located. We then summed all minutes, converted to hours, and divided the total number of nests by the total number of hours spent searching. Although our primary focus was on locating nests, we also calculated search efficiency for all woodcock (total number of woodcock located divided by total number of hours spent searching) and investigated use of the FLIR for woodcock capture and other behavioral observations.

## Results

We used FLIR to search a total of 58.05 hours (3,483 minutes) over 22 days. We tallied days based on the day that the FLIR survey began, as many were overnight and extended into the following calendar day. Search days were not always consecutive. Most surveys were started within 1 hour of sunset, but this was not always the case depending on weather or travel conditions. We located 180 woodcock; 28 of these were nesting females and 4 were brooding females, 2 of which were associated with a previously located nest as they were found within meters of the nest soon after hatch. Search efficiency rate was 0.48 nests/hour and 3.1 birds/hour. Efficiency varied among routes and search areas. The route 108 search area had the highest nest search efficiency rate with 0.57 nests/hour and 3.44 birds/hour. Route 427 search area had an efficiency rate of 0.55 nests/hour and 3.09 birds/hour. Route 51 search area had the lowest efficiency rate of 0.10 nests/hour and 2.83 birds/hour.

With 4 exceptions that were approached only once to determine how closely we could approach nests without causing the female to leave, we approached nests no closer than 1 m when searching or during subsequent monitoring. We often monitored nests from up to 6 m away depending on vegetation density.

### EQUIPMENT COMPARISON

Initially, we used both cameras to search for woodcock and nests, and we tested cameras against each other for several characteristics. After the initial 2 surveys on route 427, we predominantly used Camera 1 for searching and used Camera 2 only for recording to document efficacy of FLIR in locating and monitoring woodcock. We found Camera 1 was more efficient at locating and quickly monitoring for presence or absence of incubating female woodcock. Camera 2 provided both a more detailed image of woodcock once located and video recording capabilities for documentation. The weight, eye relief, and narrow field of view limited the utility of Camera 2. Camera 2 did, however, have the ability to focus very clear images of heat signatures (Fig. 2) and provided images that enhanced our ability to identify species. Camera 1 did not provide as clear an image (Fig. 3), but with its wide field of view, compact size, and lightweight mobility, we found it to be more useful for locating woodcock heat signatures.

During the course of the project, we identified 10 different bird species, 11 species of mammals, 1 reptile, 1 insect, and 1 plant species (Table 1) with the use of FLIR.

**Figure 2.** Still frame of an American woodcock using the Sierra Pacific Communications IR 250D FLIR camera. This woodcock had just stood up from its nocturnal roost within an open forb stand and began walking forward.

## Discussion

### SEARCH METHODOLOGY

When using FLIR to search for woodcock, we found it was easiest to wear a headlamp, and while looking through the camera with 1 eye searching for heat signatures, to keep the other eye open for navigating through vegetation. This took practice, but in time a searcher was easily able to train each eye to focus on separate tasks. We also carried a rechargeable spotlight that could be used to assist in identifying animals we located via their heat signatures.

### LIMITATIONS

We confirmed that FLIR does not detect heat signatures of woodcock through solid vegetation (e.g., tree trunks, leaves) as found in previous research (Galligan et al. 2003, Long and Locher 2011, Chavarria et al. 2012); we did discover, however, that it works well through grasses, early-successional forest woody vegetation, etc. We also found that conifer trees radiate more heat than any other tree species, and conifer species with high needle density can impede detection of heat signatures associated with woodcock and other animals.

We also observed that thick fog impedes detection of heat signatures using FLIR. Rain, unless very heavy, did not negatively affect detection of woodcock using FLIR. In fact, searching using FLIR after or during rain was often very productive as vegetation, coarse woody debris, rocks, and other objects cool rapidly during rain. We also confirmed that as ambient temperature rises, detecting woodcock or other animals using FLIR can become more difficult because of additional heat signatures on the landscape (Boonstra et al. 1995, Garner et al. 1995, Galligan et al. 2003, Chavarria et al. 2012). When searching for woodcock during the beginning of the project (24 March), there were patches of snow still covering the ground and temperatures below freezing at night. Due to the temperature differential, woodcock and other animal heat signatures contrasted well with the cool background. During the latter part of the project (second week of May), daytime temperatures in excess of 30° warmed inanimate objects and also bare ground, which can often be found in habitat

**Figure 3.** Photograph of nesting American woodcock through the eye piece of the FLIR Recon M24 camera. Note both the white image of the bird and the brightness (heat signature) of the small conifer tree under which the woodcock placed her nest.

**Table 1.** Species located and identified using FLIR during research on American woodcock nest initiation in southwestern Pennsylvania, 24 March through 11 May 2015.

| Common Name | Scientific Name |
|---|---|
| ***Birds*** | |
| American robin | *Turdus migratorius* |
| American woodcock | *Scolopax minor* |
| Red-winged blackbird | *Agelaius phoeniceus* |
| Eastern towhee | *Pipilo erythrophthalmus* |
| Gray catbird | *Dumetella carolinensis* |
| Wild turkey | *Meleagris gallopavo* |
| Ruffed grouse | *Bonasa umbellus* |
| Northern cardinal | *Cardinalis cardinalis* |
| Field sparrow | *Spizella pusilla* |
| Song sparrow | *Melospiza melodia* |
| ***Mammals*** | |
| White-tailed deer | *Odocoileus virginianus* |
| Flying squirrel | *Glaucomys spp.* |
| North American porcupine | *Erethizon dorsatum* |
| Striped skunk | *Mephitis mephitis* |
| Virginia opossum | *Didelphis virginiana* |
| Eastern cottontail | *Sylvilagus floridanus* |
| Woodland jumping mouse | *Napaeozapus insignis* |
| Meadow jumping mouse | *Zapus hudsonius* |
| Meadow vole | *Microtus pennsylvanicus* |
| White-footed mouse | *Peromyscus leucopus* |
| Deer mouse | *Peromyscus maniculatus* |
| ***Reptiles*** | |
| Eastern box turtle | *Terrapene carolina carolina* |
| ***Plants*** | |
| Eastern skunk cabbage | *Symplocarpus foetidus* |
| ***Insects*** | |
| June bug | *Phyllophaga* spp. |

preferred by woodcock. When this occurred, search times increased and the shape and size of heat signatures became increasingly important to positively identify a woodcock or other animal.

The most significant limitation in our study was observer familiarity with the equipment and search image. When the observer understood the nuances of the camera, how auto adjustments operate, and particularly what a nesting woodcock heat signature looks like in comparison to a non-nesting woodcock, rock, similar-sized bird (e.g., ruffed grouse [*Bonasa umbellus*]), or rabbit (*Sylvilagus* spp.), successful use of the equipment increased dramatically.

### CONFIRMING NESTING

When we located a woodcock with FLIR, we used a spotlight to confirm species identification. We developed the ability to identify woodcock via their heat signatures through experience, but there were several cues that helped identify a nesting woodcock using FLIR. Nesting female woodcock would not move unless approached within centimeters, and sometimes not until touched. Nesting woodcock would not move any part of their body, including their head, as we approached nests. They held perfectly still, so watching the head closely when approaching provided important cues as to whether the bird was on a nest. When we approached a woodcock not on a nest within a meter it would generally move its head or shift position, sometimes standing, walking away, or flushing. Similar movement occurred both by woodcock we detected using FLIR and via nightlighting.

Nesting female woodcock also exhibited what we describe as a "melted" appearance in the FLIR. They appeared as if their bottom half had melted into the ground because of their shallow nest structure and flattened body covering the eggs or a brood. Male woodcock or females not nesting would often appear more rounded underneath, even when sitting on the ground.

Using a spotlight in conjunction with the FLIR provided confirmation that what the observer was seeing was indeed a woodcock. It also helped illuminate the surrounding habitat and provided a clear view of any behavior that helped determine whether the woodcock was nesting.

### ADVANTAGES

Compared to traditional methods of locating woodcock, and specifically nesting females, FLIR showed several definitive advantages. The primary traditional method for locating woodcock has been with pointing dogs. Several studies (Gregg and Hale 1977, Gregg 1984, Coon et al. 1982, Causey et al. 1987, Miller 2010) in which dogs were used to locate woodcock or nesting females reported varied success rates (Table 2). Using FLIR was more effective than the use of pointing dogs at locating nests and caused less nest disturbance than either pointing dogs or the combination of mist-netting and radio-telemetry (Ammann 1973, McAuley et al. 1996, Daly et al. 2013). We acknowledge

**Table 2.** Comparison of reported efficiency of various search methods in locating American woodcock nests.

| Author | Year Published | Location | Man hr | Dog hr | Years | Nest/ yr[a] | Nests/hr | Search method |
|---|---|---|---|---|---|---|---|---|
| Simon et al. | 1971 | PA | | 538 | 2 | 7.5 | 0.03[b] | Pointing Dog |
| Wenstram | 1974 | MN | | | 2 | 2.5 | | Multiple |
| Bourgeois | 1977 | MI | 92 | | 1 | 16 | 0.17 | Pointing Dog |
| Gregg and Hale | 1977 | WI | | | 2 | 13.5 | | Pointing Dog |
| Coon et al. | 1982 | PA | 84 | 312 | 3 | 11.4 | 0.4 (0.11b) | Pointing Dog |
| Gregg | 1984 | WI | 483 | | 4 | 14.7 | 0.12 | Pointing Dog |
| Causey et al. | 1987 | AL | | 1714.5 | 9 | 5 | 0.06[b] | Pointing Dog |
| Murphy and Thompson | 1993 | MO | | | 3 | 10 | | Pointing Dog |
| McAuley et al. | 1996 | ME | | | 3 | 29.7 | | Radiotelemetry |
| Miller | 2010 | PA | 103 | | 2 | 4 | 0.08 | Pointing Dog |
| Daly et a. | 2013 | MN | | | 2 | 26 | | Radiotelemetry |
| Keller | 2015[c] | PA | 58.05 | | 1 | 28 | 0.48 | FLIR |

[a] Nest/Year may not be comparable between study areas if a measure of effort was not provided.

[b] Based on dog hours.

[c] Year Published for Keller is the year research was conducted and not published.

that variations in woodcock population density could also affect differences in search efficiency between our research and other published research; however, although we lack density data to evaluate this possibility, our counts of singing males per stop on survey routes were similar to several of those reported from high-quality woodcock habitat in other studies (Miller 2010, Daly et al. 2013). We conclude, therefore, that using FLIR to locate woodcock nests is the primary factor accounting for the much higher search efficiency in our study.

Several studies have implicated observer disturbance as a contributing factor to nest failure during research or monitoring (Mendall and Aldous 1943, Ammann 1973, McAuley et al. 1996, Chavarria et al. 2012). Several potential reasons have been suggested for this decreased nest success, including humans and search dogs leaving a scent trail directly to the nest, woodcock being disturbed and abandoning nests, or eggs and chicks being stepped on by either a dog or a human (Ammann 1973). Using FLIR, we were able to locate, identify, and then monitor nests, all from a distance of 1–6 m depending upon vegetation structure in the vicinity of the nest. At no point during our study did we incidentally flush or injure an incubating female or disturb a nest, as has been recorded using other methods in previous research (Mendall and Aldous 1943, Ammann 1973, McAuley et al. 1996, Chavarria et al. 2012). We cannot definitively exclude the possibility that observer presence and/or the presence of human scent did not contribute to nest failure in the nests we located using FLIR. However, our methods minimized researcher-caused predation risk to nesting females by keeping human scent away from the immediate vicinity of the nest, and we did not disturb vegetation immediately surrounding the nest. There was no direct evidence of predation or nest failure that we attributed to the use of FLIR or human disturbance during searching or subsequent monitoring as was found with historical methods (Ammann 1973, Chavarria et al. 2012), nor did we note abandonment (Gotmark 1992, Murphy and Thompson 1993). In summary, we achieved our objective of evaluating using FLIR as an effective and efficient way to locate and monitor woodcock nests.

### OTHER POTENTIAL USES OF FLIR IN WOODCOCK RESEARCH

#### *Woodcock capture*

Spotlighting or nightlighting is a proven method for approaching and capturing woodcock (Sheldon 1967, Shuler et al. 1986). We tested the FLIR 1 night to locate woodcock for capture. Capture occurred on a rainy, moonless night; weather classified by Sheldon (1967) as being the optimal conditions to capture woodcock while nightlighting. We successfully approached 4 woodcock in open habitat to within 6 cm, and captured 1 easily with a net. This experience demonstrated that FLIR has the capability to be a useful tool for initially locating birds during nightlighting projects, and for relocating woodcock following a failed capture attempt.

#### *Nocturnal habitat use*

We found that, within old-field cover where mowing occurs only along borders or in single mower-width paths through the interior of fields, displaying males consistently selected these mowed areas versus non-mowed areas. When mown paths were curved and male woodcock could not see each other on the ground, males often would display in very close proximity to one another. Woodcock commonly used these mown areas for nocturnal roosting and could be found within these mowed paths in a variety of weather conditions. These observations may provide further evidence consistent with the predation risk hypothesis described by Masse (2014), which surmises that woodcock prefer nocturnal roosting in openings to avoid predation. Using FLIR provided an enhanced ability to observe behavior and habitat use of male woodcock, much of which is not well described.

#### *Nocturnal behavior*

Although not the primary purpose of our study, FLIR provided a means to observe woodcock nocturnal behavior. FLIR allowed observers to monitor woodcock with apparently little or no influence on their behavior after sunset and provided the opportunity to view both flight and woodcock behavior while they were on the ground. Using FLIR, we were able to observe male woodcock from close proximity during their courtship behavior both while they were on the ground and airborne. Having the ability to observe woodcock at night may facilitate better understanding of woodcock behavior during this period and of their interactions with each other and their environment in activities such as feeding, roosting, or predator avoidance.

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# Detecting Passage of Migrating Woodcock Using Nano Tag Technology

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**ABSTRACT:** Nano tags are regular VHF radio transmitters that broadcast on a single frequency that is encoded. Signals are picked up by towers and stored. Data can be stored at the tower for several months and then downloaded. After downloading, data are sent to Canada to be sorted and then sent to the individual researchers. Costs of the nano tags are the same as conventional VHF transmitter projects (about $210.00). The cost of the receiver is about $300. Currently there are about 564 receiving towers, mostly along the Atlantic coast, and 30 different projects, although the system can handle more studies. The data can be used to study movement patterns, migration timing, and speed, and also to give survival estimates. Birds do not need to be followed on the ground or from the air. Transmitters range in weight from 0.26 grams to 4.3 grams, and have a life expectancy of 10 to more than 11,000 days. We used the 4.6-gram transmitters with a life expectancy of 405 days.

In 2015 we deployed 24 transmitters at Moosehorn NWR during late September and October. We were interested in timing of migration and stopovers. Ten transmitters were detected in CT at 2 different towers. One bird was picked up by both towers, 2 were detected in RI, 1 at Plum Island on Long Island, NY, 3 at Cape May, NJ, and 2 at the Eastern Shores of VA NWR. Data from 2017 will be presented as well.

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**KEY WORDS:** American woodcock, Atlantic Coast, migration, nano tag

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# Determining Gender of Flushing American Woodcock (*Scolopax minor*)

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**ABSTRACT:** I investigated the possibility of determining gender of flushed American woodcock (*Scolopax minor*) by using flush and flight behavior occurring in the first 9–11 m of an initial flush. Correct gender predictions of flushing birds could provide an option for hunters to voluntarily modify their harvest. During 2013–2015, I harvested 130 woodcock and found that most females (>75% on initial flush) reached greater heights (>3m) than males in the first 9–11 m of the first flush. Such tower-flush behavior was not common for males, who instead flushed more horizontally than vertically, appeared smaller, and flew in a more twisting manner than females.

In 2017, I verified my gender assignment method and found that I could identify the higher, tower-flushing females >63% of the time before deciding to shoot. Using the tower-flushing behavior method, woodcock hunters have an option to reduce female harvest, possibly resulting in more breeding females returning to breed the following season. Four conditions and situations that could prompt hunters to exercise limited harvest of females include: (1) whenever one or two females have been bagged that day, (2) the hunt area is saturated with woodcock, (3) the hunt site will be hunted numerous times in a season, and (4) hunters wanting to improve their ability to recognize flushed females.

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**KEY WORDS:** American woodcock, gender assignment, hunter selection

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# Behavior of Incubating American Woodcock (*Scolopax minor*) in Maine

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**ABSTRACT:** During April – June 1987 and 1988, we remotely monitored 14 radio-marked female American Woodcock (*Scolopax minor*; hereafter woodcock) at 18 nest sites on Moosehorn National Wildlife Refuge in Maine, U.S.A., to determine patterns and constancy of nest incubation behavior. On average, females spent 93% of their time on the nest and 7% off the nest, leaving nests for an average of 104.2 minutes during a 24-hour period. Time off the nest each day did not vary by year, daily high temperature, or amount of daily precipitation. Our data suggest that renesting females spent more time off nest/day than females on first nests, and that second-year females made more diurnal recesses from the nest than after-second-year females. Most woodcock left the nest during crepuscular periods. Our results provide information about nest incubation constancy, and may be useful for informing woodcock research and habitat management.

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**KEY WORDS:** incubation constancy, nesting, Maine, renesting, recesses, *Scolopax minor*

The American Woodcock (*Scolopax minor*; hereafter woodcock) is a forest-dwelling shorebird and is probably one of the earliest ground-nesting species throughout its breeding distribution (Mendall and Aldous 1943, McAuley et al., 2013). In Maine, courtship begins in late March and nesting begins in early April, when temperatures can still drop below freezing and significant snowfall can occur (McAuley et al., 1990). Courtship and breeding in Maine last about 2.5 months (i.e., typically through mid-June; Mendall and Aldous 1943), with eggs hatching as late as 6 July (U.S. Geological Survey unpublished data). Nests usually are located in young, sparsely stocked upland hardwoods and mixed woodland cover types (McAuley et al., 2013). Gregg and Hale (1977) reported woodcock nests in stands of aspen (*Populus* spp.) and beaked hazel (*Corylus cornuta*) in Wisconsin. On actively managed sites (i.e., Moosehorn National Wildlife Refuge), woodcock select areas with low basal area and high stem density (McAuley et al., 1996).

Only the female woodcock, which is larger in body mass than the male, incubates eggs. Woodcock nests are little more than a shallow depression into which leaves and grass litter are incorporated (Mendall and Aldous 1943). The success of incubation depends on effective

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temporal organization of incubation effort that confronts unpredictable weather, snow, and low diurnal temperatures while balancing the female's need to feed (Norton 1972). Adult attentiveness is essential to maintain egg temperatures to prevent lethal chilling (Carey 1980); the energetic demands of incubation are thus particularly acute for single-sex incubators, such as woodcock, that must take recesses from the nest to feed. Although some Scolopacidae species share incubation between the sexes, single-sex incubating wading birds usually take short recesses. For example, pectoral sandpiper (*Calidris melantos*) take 8–15-minute recesses and white-rumped sandpiper (*C. fusciollis*) take 8–12-minute recesses off the nest alternating with longer periods of incubating eggs (Norton 1972, Wilkie 1981, Kondrat'ev 1982). Allocating time for foraging is necessary to obtain energy and still incubate efficiently (White and Kinney 1974, Vleck 1981). Pettingill (1936), Mendall and Aldous (1943), and Sheldon (1967) generally describe female woodcock leaving nests at dawn and dusk to feed; little else is reported about incubation behavior. Likewise, McAuley et al. (1993a) reported that females usually leave the nest at dawn and dusk to visit displaying males and to feed, but activities and behaviors during the rest of the day are unknown. Because of the lack of information about incubation behavior, we documented activity budgets of incubating female woodcock. As such, our main objective was to describe various aspects of woodcock incubation behavior, including incubation constancy, frequency of recesses, and recess duration.

## STUDY AREA

We marked woodcock at Moosehorn National Wildlife Refuge (NWR), which is comprised of 6,580 ha and located in eastern Maine, Washington County, near Calais on the United States-Canada border. Much of the refuge was clearcut and burned by a wildfire around the turn of the 20th century (Sepik et al., 1986). Many farms that were economically tied to the forestry industry were abandoned as timber supply declined in the early 1900s and became part of the refuge. By 1975, most of the refuge was covered by mature second-growth forest interspersed with natural and impounded water bodies, several meadows, and managed blueberry (*Vaccinium* spp.) fields. The forest was composed of pure stands of spruce (*Picea* spp.) and balsam fir (*Abies balsamea*) that were heavily damaged by spruce budworm (*Choristoneura fumiferana*) infestation (Dwyer et al.1988). Hardwood stands dominated by birch (*Betula* spp.), red maple (*Acer rubrum*), and aspen (*Populus* spp.) were common, but were gradually being replaced by conifers. Alder (*Alnus* spp.) stands were common along streams and in some abandoned fields. An active timber-cutting program to encourage woodcock habitat development was established in 1978 whereby 40–60 ha of mature timber were harvested annually (Sepik and Dwyer 1982).

## METHODS

### CAPTURE AND MONITORING FEMALE WOODCOCK

We used mist nets (Sheldon 1967) in the evening from 26 March to 30 May in 1987–1988 to capture female woodcock visiting display sites of males (McAuley et.al. 1993b). In addition, we used a trained dog (Ammann 1974, 1977; McAuley et al., 1993b) to capture some females with broods. We placed U.S. Fish and Wildlife Service aluminum leg bands on each woodcock, and determined age (SY, second-year. [1-yr-old]) and ASY, after-second-yr. [> 2 yr. old]) based on plumage characteristics (Martin 1964). We determined sex by measuring the combined width (at the widest part) of the outer 3 primaries (Greeley 1953) and length of the bill (Mendall and Aldous 1943).

We used cattle tag cement (Hudgins et al., 1985) to glue a VHF radio transmitter weighing 3–4 g (<3% of body mass) to the back of each woodcock. We positioned a single loop of Teflon-coated steel wire (Berkley®), embedded in the transmitter (Hudgins et al., 1985), around the breast and threaded the ends of the wires through a connector sleeve, crimped the sleeve, and trimmed excess wire (McAuley et al., 1993b).

We monitored females attending nests with a shielded coaxial cable from which we had removed a 3.8-cm section of coating to expose the inner wire that we then placed 30 cm above the nest. The cable extended to a hidden receiver (Licht et al., 1989) placed ~15 m from the nest, and we used a Rustrak (ISE, Inc.) recorder to monitor the presence, absence, and activity of birds within ~10 m of the nest (see Licht et al., 1989 for details). Rustrak recorders use tape to record whether telemetry signals are detected, and we changed the tape on the recorder daily. We used data recorded on the tapes to determine the amount of time that females were on and off the nest during different daily periods (crepuscular, diurnal, and nocturnal) and whether they were active near the nest or left the immediate vicinity (>10 m) when off the nest.

### STATISTICAL ANALYSIS

We calculated summary statistics for the variables we measured related to the time female woodcock were on and off the nest during 4 periods of a 24-hour day (crepuscular a.m., crepuscular p.m., diurnal, and nocturnal) and recorded the number of times they left the nest during the diurnal and nocturnal periods. We used weather-station data from Moosehorn NWR to evaluate the effects of daily high temperature, precipitation, and moon phase on the total time woodcock were off the nest per day. We also assessed differences by year (1987 vs 1988), age of females (second-year vs. after-second-year), and nest number (first nests vs. renests). We assumed that nests for females marked early in the breeding season (early April) were a first nest and we knew if they renested since they were marked.

We analyzed data using a nested ANOVA design with nest identification (FREQ) nested within AGE, to account for the repeated, daily observations of our marked sample of female woodcock. We conducted all analyses with SAS® software (SAS® Institute Inc., Cary, NC, USA).

## RESULTS

We monitored 14 (6 in 1987, 8 in 1988) radio-marked female woodcock at nest sites on Moosehorn NWR during April to June in 1987 and 1988. From our marked sample, we monitored 18 nests consisting of 12 initial nests and 6 renests. We collected nest time-budget data for 164 "nest days" (83 in 1987 and 81 in 1988) over the 2 breeding seasons.

On average, female woodcock spent 93% of the 24-hour day on the nest and 7% of the time off the nest (Fig. 1). Nesting female woodcock left their nests during 98% of the crepuscular periods we monitored, and remained on the nest for only 5 of 164 morning and 3 of 164 evening crepuscular periods, respectively.

Incubating female woodcock were off the nest an average of 104.2 min (95% CI = 95.1–113.2) per day (Table 1). We determined that, when off the nest, the female was active in the immediate vicinity (<10.1 m) of the nest 42% of the time and was farther away the remainder of the time. Female woodcock spent the most time off the nest during daylight hours ($\bar{x}$ = 58.2 min, 95% CI = 49.5–67.0; Table 1) and the least amount of time off the nest during the night ($\bar{x}$ = 6.1 min 95% CI = 2.6–9.5; Table 1). Time off the nest during morning ($\bar{x}$ = 18.1 min, 95% CI = 16.7–19.4) and evening ($\bar{x}$ = 21.8 min, 95% CI = 20.0–23.5) crepuscular periods was similar.

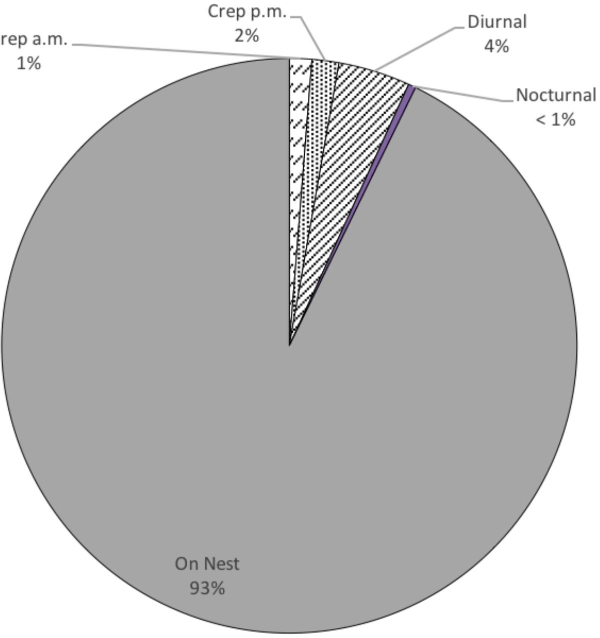

**Figure 1.** Average daily (24-hour) time budget (on nest vs. off nest) for incubating female America Woodcock (n=14) at Moosehorn NWR, Maine, U.S.A., during 1987–1988. Off nest time was divided into 4 daily periods: Crepuscular a.m. (Crep a.m.), Crepuscular p.m. (Crep p.m.), Diurnal, and Nocturnal.

We determined that the total time off the nest each day did not vary by year (*DF* = 1, 10, *F* = 0.44, *P* = 0.52), daily high temperature (*DF* = 1, 10, *F* = 0.06, *P* = 0.79), or amount of daily precipitation (*DF* = 1, 10, *F* = 0.41, *P* = 0.53). Moon phase had no effect on the number of recesses (*DF* = 3, 17, *F* = 1.72, *P* = 0.20) during nocturnal periods. There was some evidence that renesting female woodcock spent more time off the nest during diurnal periods than female woodcock tending initial nests (*DF* = 1, 2, *F* = 9.65, *P* = 0.090).

On average, incubating female woodcock made 2.24 (95% CI = 2.1– 2.7) recesses per day from the nest during diurnal periods (Table 2), whereas they rarely left nests at night (0.3 recesses per night, 95% CI = 0.1–0.4). Second-year incubating females took more frequent diurnal recesses ($\bar{x}$ = 3.1, 95% CI = 2.8–3.4) than after-second-year females ($\bar{x}$ = 1.9, 95% CI = 1.7–2.1; *DF* = 1, 9, *F* = 12.38, *P* = 0.006). Two woodcock left their nest 6 times in 1 day and 5 left 5 times. One female woodcock remained away from the nest for 415 minutes and 191 minutes during 2 different diurnal periods. The longest off-nest interval at night was 88 minutes for a single female.

## DISCUSSION

Our results represent the first data documenting the amount of time incubating female woodcock spend on and off the nest per day. Previously, Pettingill (1936), Mendall and Aldous (1943), and Sheldon (1967) generally described female woodcock leaving nests at dawn and dusk to feed; little else was reported about incubating behavior. Likewise, McAuley et al., (1993a) reported that females usually leave the nest at dawn and dusk to visit displaying males and to feed, but activities and behaviors during the rest of the day are unknown. Whereas females consistently left the nest during crepuscular periods as previously described, we also found they made frequent recesses during the diurnal period each day, and we were able to document the number and lengths of these recesses (Table 1).

Woodcock incubation patterns (93% incubation constancy, Fig. 1) were similar to those of other single-parent incubating birds. Incubation constancy has been reported as 95% for the female capercallie (*Tetrao urogallus*) (Lennerstedt 1966), 95% for white-tailed ptarmigan (*Lagopus leucurus*) (Giesen and Braun 1979), 93% for spruce grouse (*Canachites Canadensis*) (McCourt et al.1973), and 96% for ruffed grouse (*Bonasa umbellus*) (Maxson 1977). Some species, such as female white-tailed ptarmigan and blue

**Table 1.** Mean time (minutes) and 95% confidence intervals (CI) spent off the nest per day by period of the day for female American Woodcock at Moosehorn NWR, Maine U.S.A., 1987–1988.

| | **Crepuscular** | | | | | |
|---|---|---|---|---|---|---|
| **Year** | **a.m. (±95% CI)** | **p.m. (±95% CI)** | **Diurnal (±95% CI)** | **Nocturnal (±95% CI)** | **Total off nest (±95% CI)** | **Prop. off[c]** |
| 1987 (*n* = 6)[a] | 16.5 (15.2–17.8) | 20.7 (18.8–22.7) | 55.1 (49.8–60.4) | 6.3 (2.2–10.4) | 98.7 (92.2–105.2) | 0.07 |
| 1988 (*n* = 8)[b] | 19.7 (18.4–21.1) | 22.8 (21.3–24.4) | 61.4 (50.0–72.8) | 5.8 (3.1–8.5) | 109.8 (98.7–120.8) | 0.08 |
| Combined | 18.1 (16.7–19.4) | 21.8 (20.0–23.5) | 58.2 (49.5–67.0) | 6.1 (2.6–9.5) | 104.2 (95.1–113.2) | 0.07 |

[a] Six female woodcock were monitored for a total of 83 days in 1987.

[b] Eight female woodcock were monitored for a total of 81 days in 1988.

[c] Proportion was calculated by dividing the total time off the nest by 1,440 (minutes in a 24–hour day).

grouse (*Dendragapus obscurus*), are reluctant to leave their nests (they can often be touched on the nest when in the late stages of incubation) and have high levels of nest attendance (Giesen and Braun 1979, Zwickel and Bendell 2005). Although woodcock may desert a nest when disturbed early in the incubation period, as incubation progresses they are less likely to abandon the nest and can be handled without subsequent nest abandonment (McAuley et al., 2013).

During our study, females left their nests during 98% of crepuscular periods, whereas McAuley et al., (1993a) reported that in 82% of 302 movements radio-marked females at Moosehorn NWR left their nest during crepuscular periods. McAuley et al., (1993a) documented that, during these evening and morning recesses, 58% of females sought food, but 7% of females visited courting males before going to feed, 7% went to unidentified locations, and 28% did not leave their nest. During crepuscular recesses, we suspect that females were visiting males first and then feeding. This pattern differs from those of most other shorebirds, but the courtship pattern of male woodcock likely influences the nest recesses during crepuscular periods of the day.

Female woodcock left their nests for the longest periods during daylight hours ($\bar{x}$ = 58.2 min, Table 1) and averaged 2.4 recesses during that period. In contrast, a single *S. rusticola* (European Woodcock) took 4 recesses per day averaging 31.1 minutes/recess for 124 minutes off the nest during the day (Forges 1975). This is similar to 3 species of incubating sandpipers; dunlin (*Calidris alpine*) averaged 97.5 minutes, Baird's sandpiper (*C. bairidii*) averaged 96.5 minutes, and pectoral sandpiper (*C. melanotos*) averaged 85.0 minutes (Norton 1972). For the first 2 species, both sexes incubate, but for pectoral sandpiper only the females incubate.

High nest attentiveness may be an adaptive behavior to provide cover for exposed eggs in nests constructed with minimal nest material, thereby reducing detection of eggs by visual predators (Westmoreland and Best 1986). Furthermore, high nest attendance is probably necessary to maintain the proper thermal environment for developing embryos (Deeming 2002). Because woodcock have completely exposed eggs (i.e., they do not pluck down to cover the eggs), high constancy is required to maintain incubation temperature, especially because they nest early in the season when ambient temperatures can be below freezing. Female woodcock are at their lowest mass of the year when their broods hatch (179.7 g SD 9.2 [*n* = 69]; unpublished data), which is likely a consequence high nest attentiveness. Nesting and pre-nesting female woodcock from Moosehorn NWR weighed an average of 226.4 g (SD = 16.3 [*n* = 17], unpublished data). These values are similar to data from Minnesota, where female woodcock weighed an average of about 230 g pre-nesting and 180 g when with broods (Marshall 1982).

**Table 2.** Number of recesses from the nest for American Woodcock during diurnal and nocturnal periods at Moosehorn NWR, Maine, U.S.A., 1987–1988.

| **Year** | **Diurnal recesses (±95% CI)** | **Nocturnal recesses (±95% CI)** |
|---|---|---|
| 1987 (*n* = 6)[a] | 2.8 (2.5–3.1) | 0.2 (0.1–0.3) |
| 1988 (*n* = 8)[b] | 2.0 (1.8–2.3) | 0.3 (0.2–0.5) |
| Combined | 2.4 (2.1–2.7) | 0.3 (0.1–0.4) |

[a] Six female woodcock were monitored for a total of 83 days in 1987.

[b] Eight female woodcock were monitored for a total of 81 days in 1988.

We noted that second-year females were off the nest more times than after-second-year females, which may be a function of inexperience or being in poorer condition, although the difference only amounted to an average of 1 more time off the nest per day. We expected that moon phase would influence the amount of time female woodcock were off the nest at night because males display at night when the moon is visible, and as such, we expected females would visit males more often during this period.

However, we found no effect of moon phase on nest attentiveness.

Our study represents the first detailed information about woodcock incubation behavior. Future research should look at relationships between nest success and incubation behavior while considering landscape variables. Better understanding of these relationships may improve management of woodcock habitat, perhaps by encouraging the provision of high-quality feeding cover near nesting cover. Such juxtaposition of nesting and feeding cover may result in females making fewer or shorter recesses to feed, thereby decreasing exposure risk to predation or allowing incubation that is more constant.

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