The Proceedings of the Tenth American Woodcock Symposium

2006

Editors: Alan Stewart and Valerie Frawley, Michigan Department of Natural Resources and Environment
Proceedings published by a generous donation from the Hal and Jean Glassen Memorial Foundation

Allen Press, Inc., Lawrence, KS

10th American Woodcock Symposium

Roscommon, Michigan, USA

Every few years, the scientific woodcock community hosts a symposium to highlight recent research on the American woodcock. The Tenth American Woodcock Symposium hosted in Roscommon, Michigan, provided an opportunity to present and discuss results from research projects completed throughout the woodcock's range in recent years.

The symposium brought together researchers, land managers, biologists, hunters, and woodcock enthusiasts to discuss and report current information on the ecology and management of the species, share ideas on the future of woodcock research and management efforts, and talk about "hot topics" in the woodcock world.

Previous woodcock symposia have effectively fostered communication of woodcock research and have proved to be the foundation for successful woodcock management internationally. Symposia have been held across the range of the species; in Minnesota (1966), Louisiana (1968, 1997), Maine (1969), Michigan (1971, 2006), Georgia (1974), New Brunswick (1977), Pennsylvania (1980), and Indiana (1990).

With each symposium, the quality of data, sophistication of statistical analysis, and originality of methods have taken a giant step forward. The Proceedings of the Tenth American Woodcock Symposium consists of peer-reviewed papers on a variety of topics associated with biology, ecology, behavior, conservation, and management of woodcock. These proceedings contain current research results that contribute toward a greater understanding of woodcock.

The Michigan Department of Natural Resources and Environment sincerely thank the many partners that contributed to the success of the symposium. It is through such collaboration that resource managers, Legislators, conservation organizations, and interested individuals can make a difference and leave a legacy for the future.

Photography provided by:

Timothy Flanigan • Cover Image, 11
Bob Gwizdz (DNRE) • 2
David Kenyon (DNRE) • 1, 3, 6, 8, 9, 10
Randy Strouse • 5, 7
U.S. Fish and Wildlife Service • 4

Tenth American Woodcock Symposium

Proceedings of the
Tenth American Woodcock Symposium

Roscommon, Michigan
3-6 October 2006

Edited by

C. ALAN STEWART AND VALERIE R. FRAWLEY
Michigan Department of Natural Resources and Environment
Wildlife Division
Lansing, Michigan

Associate Editors

DAVID E. ANDERSEN, United States Geological Survey Minnesota Cooperative Fish and Wildlife Research Unit, University of Minnesota, *St. Paul, Minnesota*

JOHN G. BRUGGINK, Department of Biology, Northern Michigan University, *Marquette, Michigan*

THOMAS R. COOPER, United States Fish and Wildlife Service, Division of Migratory Bird Management, *Ft. Snelling, Minnesota*

DANIEL R. DESSECKER, Ruffed Grouse Society, *Rice Lake, Wisconsin*

DAVID G. KREMENTZ, Arkansas Cooperative Fish & Wildlife Research Unit, University of Arkansas, *Fayetteville, Arkansas*

SARAH L. MAYHEW, Michigan Department of Natural Resources and Environment, Wildlife Division, *Lansing, Michigan*

MICHAEL W. OLINDE, Louisiana Department of Wildlife and Fisheries Office of Wildlife, *Baton Rouge, Louisiana*

GARY J. ROLOFF, Department of Fisheries and Wildlife, Michigan State University, *East Lansing, Michigan*

Published by Michigan Department of Natural Resources and Environment

Published in 2010 by
Michigan Department of Natural Resources and Environment
Stevens T. Mason Building
P.O. Box 30444
Lansing, MI 48909-7944

Printed by
Allen Press, Inc. 810 East Tenth Lawrence, KS 66044

Printed in the United States of America
10 9 8 7 6 5 4 3 2 1

First edition

Illustrations by Ed Sutton

Library of Congress Cataloging-in-Publication Data

American Woodcock Symposium (Tenth : 2006 : Roscommon, Mich.)
Proceedings of the Tenth American Woodcock Symposium, Roscommon, Michigan 3-6 October 2006 / edited by C. Alan Stewart and Valerie R. Frawley ; associate editors, David Andersen ... [et al.].
p. cm.
1. Woodcock, American--Ecology--Congresses. 2. Upland game bird management--Congresses. I. Stewart, C. Alan, 1952- II. Frawley, Valerie R., 1974- III. Title.
QL696.C48A525 2006
598.3'3--dc22
2010054268

Proceedings available from:

The Ruffed Grouse Society
451 McCormick RoadCoraopolis, Pennsylvania 15108
www.ruffedgrousesociety.org
412-262-4044
1-888-JOIN-RGS

10th American Woodcock Symposium

October 3 - 6, 2006 Roscommon, Michigan, USA

Sponsors

Hal & Jean Glassen Memorial Foundation (Premium Sponsor)

Advanced Tex

Atlantic Flyway Council

Avery Inc.

Cabela's

Cherry Central

First Place Sports

Jim and Joanne Foote

Fowl Pursuit – Shawn Stahl

Gander Mountain

George Harris' Wildlife Collection

George Lynch- Lynch Mob Goose Calls

Gunnerman Press

Tom Huggler

Hunters Creek Club

Frank Jezioro

Frito-Lay Company

Kim's County Kitchen, Lasalle, MI

Latini-Gatto Creative Design

Mars, Incorporated

Michigan Department of Natural Resources and Environment

Michigan History Magazine

Michigan Outdoor News

Michigan United Conservation Clubs

Mississippi Flyway Council

National Wild Turkey Federation

The Pointing Dog Journal

The Wildlife Society, MI Chapter

River Wild Winery

Ruffed Grouse Society

Ed Sutton

US Fish and Wildlife Service

US Forest Service

Waterfowl USA-Southwestern Lake Erie Chapter

Woodcock Limited

Wolverine Power Cooperative

Tenth American Woodcock Symposium Acknowledgments

Program Committee Members and Manuscript Reviewers

David E. Andersen
John G. Bruggink
Daniel R. Dessecker
Valerie R. Frawley
James R. Kelley, Jr.
David G. Krementz
Daniel G. McAuley
Michael W. Olinde
C. Alan Stewart

Additional Manuscript Reviewers

Roger D. Applegate
Todd W. Arnold
Mark E. Banker
Dean E. Beyer, Jr.
Albert Bourgeois
Henry Campa III
Michael J. Chamberlain
Karen T. Cleveland
Thomas R. Cooper
Amy L. Derosier
Michael L. Donovan
Thomas D. Drummer
James E. Dubovsky
Olivier Duriez
Amy Clark Eagle
Dwayne R. Etter
Yves Ferrand
Brian J. Frawley
Kurt J. Haroldson
Frederick G. Kimmel
Micheal A. Larson
David R. Luukkonen
Sarah L. Mayhew
Faye M. McNew
Kelly F. Millenbah
Richard A. Morschek
Andrew J. Nuhfer
David L. Otis
Clint V. Otto
Paul I. Padding
William F. Porter
Harold H. Prince
Rebecca D. Rau
Carol A. Reed
Gary J. Roloff
Thomas H. Roberts
Brent A. Rudolph
David P. Scott
Kim T. Scribner
Marshall L. Strong
Barry C. Wilson
Scott R. Winterstein
Petra B. Wood
Guthrie S. Zimmerman

Additional Program Committee Members

Mark R. Buchinger
Carrie L. DeVault
Keith J. Fisher
Arnold L. Karr
Jennifer L. Kleitch
R. Scott Lutz
Shari K. McCarthy
John A. Niewoonder
Joseph D. Robison
Michael T. Ryan
Lou Ann Shaw
Alice L. Stimpson
Ralph A. McMullan Center Staff

Preface

The woodcock—a diminutive species with large eyes and mystical ways—has captured the imagination and admiration of people for centuries. Folklore suggests that woodcock were harbingers of spring and marked a time for rejuvenation. Early bird observers recorded their fascination with watching woodcock sky-dance across the crimson afterglow of sunset. Throughout history, many people have worked to unravel the unknowns associated with this bird. President Theodore Roosevelt and naturalist John James Audubon each had woodcock study skins in their collection of ornithological specimens. Aldous, Pettingill, Mendell, Liscinsky, Sheldon, Ammann and others spent their careers developing the foundation of our woodcock knowledge. Contemporary scientists expanded on this knowledge through the enhancement of technology and understanding. Today, the secretive and unique behavior of this bird continues to attract the interest of many followers.

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 Tenth American Woodcock Symposium was the first symposium held this century. The symposium highlighted conservation strategies, habitat management, and population dynamics.

Past Woodcock Symposia

1st	1966	Minnesota
2nd	1968	Louisiana
3rd	1969	Maine
4th	1971	Michigan
5th	1974	Georgia
6th	1977	New Brunswick
7th	1980	Pennsylvania
8th	1990	Indiana
9th	1997	Louisiana
10th	2006	Michigan

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. Scientists, policy makers, and other woodcock supporters from 23 states and 4 countries attended the Michigan conference. This meeting was designed to stimulate thought, expand ideas, and increase our knowledge about woodcock management and ecology. The proceedings and included collection (CD) of all previous symposia document a segment of our current level of collaborative knowledge and shared concepts about woodcock.

Many people helped make the symposium and these peer-reviewed proceedings possible, including a host of professional colleagues and friends whose names are contained within. The ability of authors to develop concepts and present their ideas was the core of the meeting. Keith Charters, Michigan Natural Resources Commission Chair and woodcock advocate, launched the meeting with a welcome and comments from a boot-worn, woods-walker’s perspective. The associate editors did the “heavy lifting” with authors, referees, and co-editors. Their expertise added significant value to the proceedings. During the review process, referees provided constructive critiques. Art Sutton provided artwork. Tim Flanigan, Bob Gwizdz, Dave Kenyon, and Randy Strouse provided photos for the cover. Jennifer Kleitch designed the symposium logo, and Jennifer Olson helped produce the symposia CD. Charlie Jarvis designed the dust jacket and CD. He also did the layout and design for each manuscript. He was immediately able to comprehend our goals and apply his creative skills during the final stages of production. Carol Reed focused her keen eyes throughout the editing stage and improved the quality of this document. The meeting and the proceedings could not have been accomplished without the support of our sponsors, particularly the Hal and Jean Glassen Memorial Foundation. Thank you to each of you for contributing to this scientific endeavor.

Words cannot express the gratitude I have for co-editor Valerie Frawley. Her organizational skills, attention to detail, follow-through and positive demeanor are all traits that any editor would find valuable. I am particularly indebted to her for providing these skills on this symposium and on the many projects that we have tackled together.

Val and I are indebted to our families (Brian, Seth, and Shawn; Pat, Chris, and Tom) for their support throughout the publication process. We also acknowledge our supervisors, Mike Bailey, Doug Reeves, Russ Mason, and our co-workers for their encouragement and backing as we progressed from hosting the meeting to finalizing the proceedings.

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.

Forty years ago, biologists warned that woodcock population declines would occur if early successional forest habitats were not maintained within the bird’s range. Many bureaucrats, hunters, landowners, and conservationists refused to listen. Others listened but failed to take action. Today, some may have forgotten or are unaware of this past prophecy. Symposia help to record the history of our predictions, activities, and vision. Significant responsibilities rest on our shoulders. To be successful, we must act now to ensure that woodcock have a positive future.

C. Alan Stewart, Editor
(See biographical sketch on page 167.)

Symposium Welcome

It is an honor to welcome you to Michigan. Although I'm geographically challenged, let me say, as an airline attendant might, "If you're not supposed to be at Roscommon for the Tenth Woodcock Symposium, then you reached the wrong destination and you should check with the nearest service representative…", or you might want to stay because these are usually very interesting meetings.

This is a historic event—the Tenth Symposium. Some would say that our dedication to this bird is like a marriage and this gathering marks a fortieth anniversary, or as you'll hear later from Andy, perhaps it's really a golden anniversary. During most of my 27-year career in Louisiana, I have worked with woodcock. It's a bird that gets in your blood—whether it is your bird dog's first point, the first bird you band, the five-hundredth bird you band or your first confirmed radio telemetry signal from a migrating bird. We all have woodcock experiences that we cherish. This great game bird, with its famous upside brain, has been migrating south for winter and north in the spring for millennia. It has me migrating in the opposite direction—coming north for the winter—well, at least this feels pretty much like winter where I'm from.

I'm not a biblical scholar by any means—a prime example being I didn't know that The Byrds' song about "a time for every season" was from the Bible until my late adulthood. This time of year is certainly a time to reflect on the beauty of the nature's stunning fall colors. It is also a period when all of us remember our fellow biologists who have done so much for this bird, but are no longer with us. This symposium is dedicated to Jim Foote, Michigan DNR biologist and famous wildlife artist. Two others that were special to me were Greg Sepik and another Michigan DNR biologist, Bob Odom, who attended numerous woodcock wingbees, often at his own expense. I'm sure everyone knows others…

Maybe Bob Dylan wasn't singing about woodcock symposia when he sang "the times they are a changing," or maybe he was. Woodcock symposia, which have been held every 5 or so years, have certainly contributed greatly to our understanding of the bird. We see changes, not only in the focus of work being conducted throughout the symposia and presentations, but also in long-held truths. Early symposia focused on basic biology, migration, and management using what now might be considered rudimentary techniques. None-the-less, there is still no substitute for many of them. Conversely, the technological and statistical advances have opened entire new avenues to re-evaluate lessons learned as well as explore voids in our current knowledge. Thomas Huxley, a noted nineteenth century British biologist and educator, challenged us to be open to change and to continually reassess our understanding with any number of quotable quotes. Woodcock symposia provide that avenue.

Looking at the audience I see some familiar faces as well as some new ones. Like woodcock, woodcock biologists may be considered an indicator species, although luckily we don't have to eat our weight a day in earthworms. A poll of the states represented here today versus 20 or even 30 years ago likely mirrors woodcock population indices. While some no longer participate, hopefully things have leveled off and an upswing is in the future. Certainly the time is right.

Al, Jennifer, Valerie, and the Michigan Department of Natural Resources staff have worked diligently to make the symposium possible. The RAM Conference Center, which has been the site of a recent woodcock wingbee, is a remarkable venue for the symposium. It provides an atmosphere that encourages the interaction among participants—fledgling and fully fledged—thereby optimizing the educational experience. The innovative approach of passing the torch by creating electronic copies of past symposia is another example of how we are able to use technology to affect change by building on the past.

Michael Olinde,
Louisiana Department of Wildlife and Fisheries

(See biographical sketch on page 225.)

Director's Symposium Welcome

Wow, doesn't Michigan have a lot to offer?! Thank you, Al, for that warm introduction and virtual tour. It is a pleasure for me to welcome you to the Great Lakes State.

The Michigan DNR is proud to host this symposium, and honored that Michigan now ranks as one of just two states to have hosted this prestigious group more than once.

Here in Michigan, the quality of life our citizens enjoy is directly related to our abundant natural resources. Michigan residents love the outdoors and value the recreation opportunities our state has to offer. In fact, studies clearly show that what sets Michigan apart, especially when a business wants to relocate, is our outdoor recreational opportunities, which are so vital to Michigan.

Michigan ranks third in the nation in the number of licensed hunters – contributing well over one billion dollars each year to our economy.

In Michigan, ruffed grouse and woodcock are popular forest game birds that are pursued by over 120,000 hunters who spend a million days afield annually.

Recently, Michigan pushed through a rigorous effort to have our state forests become certified under national and international standards. I am happy to report to you that Michigan met the requirements of two internationally recognized forest certification programs, meaning that we are established as practicing sustainable forest management now and for the future.

But, what does that mean for woodcock? Sustainable forest management takes into account the big picture… timber needs, habitat requirements, wildlife concerns and human dimensions. Sustainable forest management also takes into account matters such as the use of chemicals to manage our landscape. The DNR is committed to ensuring that such practices are proven suitable and appropriate.

In our state's Wildlife Conservation Plan, we have listed woodcock as a species of special concern – not because it is endangered, but rather because we choose to highlight the needs of woodcock and the suite of species that use young forests.

Yes, we are working hard, but we cannot do it alone. That is why the DNR is working closely with corporate and private landowners to assist in making our landscape all that it can be for important wildlife species, such as woodcock. We also link closely to the USDA Forest Service in our collective efforts to assure habitat protection and enhancement. And, we have had good success working with our land conservancy partners to assure that new acquisitions have conservation easements placed upon them to keep them open forever to recreation, such as hunting and fishing. By looking at the big picture, we can help to ensure the future of this little, but highly important, bird.

In my many years serving on the Mississippi Flyway Council, I have been immersed in the numerous issues surrounding migratory bird management. While habitat is certainly our primary focus for migratory birds, we must also be cognitive of environmental issues, especially as they relate to how soil contaminants can potentially affect woodcock.

We all understand the restraints that are often imposed upon us when it comes to management. There are those who want to actively manage our forests and those who wish that we leave the landscape untouched.

This agency, as with all others, is being pushed from multiple sides. Working with our stakeholders and partners, we will continue to strive to achieve goals that meet the natural, scientific requirements for our state's landscape and those creatures that depend on it.

I am an avid bird hunter and have had my share of misses and successes hunting woodcock. While I have harvested only a few of the 1.1 million woodcock taken each year in this country, I can assure you these birds are on my radar—for hunting and for management. Michigan biologists have a long tradition of being actively involved in woodcock management. We plan to continue that involvement.

In closing, I want to thank the Michigan DNR staff and others who worked so diligently in organizing and preparing this event. My thanks to each of you who came from various parts of the world to champion the plight of the woodcock. It is crucial that we work together to conduct research and exchange information at meetings like this.

Once again, it is our pleasure to host you in Michigan. I expect great things to come from this conference, and I know the future of this unique bird to thrive generation after generation is in good hands. Thank you for the work that you do.

Rebecca Humphries, Director,
Michigan Department of Natural Resources and Environment

Dedicated to the Memory of James (Jim) Edward Foote

1925–2004

(Photo Tom Carney, Tailfeather Communications, LLC)

After a woodcock hunt near his cabin in Atlanta, Michigan, Jim Foote relaxes with his setter Libby (right) and her son Paddy.

A modest, unassuming wildlife biologist with the Michigan Department of Natural Resources for 27 years, Jim E. Foote was always attracted to the ways of upland game birds and waterfowl. He had a soft spot in his heart for peenting woodcock, English setters and October fall colors. As a biologist in northern Michigan, he worked on public and private lands to prove that habitat could be manipulated to maintain young forests needed by woodcock and ruffed grouse to thrive.

A self-trained artist, Jim used his drawing and painting skills to highlight grouse and woodcock at a national level. An ardent supporter of conservation organizations, he created the first Ruffed Grouse Society conservation stamp and donated numerous art to the Society. In honor of Jim's commitment to upland forest game birds, the Ruffed Grouse Society established the "Jim Foote" chapter in Michigan and developed an award for wildlife artists in Jim's name.

As a nationally-renowned wildlife artist, his works of art are highly collectable and his finely detailed woodcock prints evoke an admiration for this unique bird.

Contents

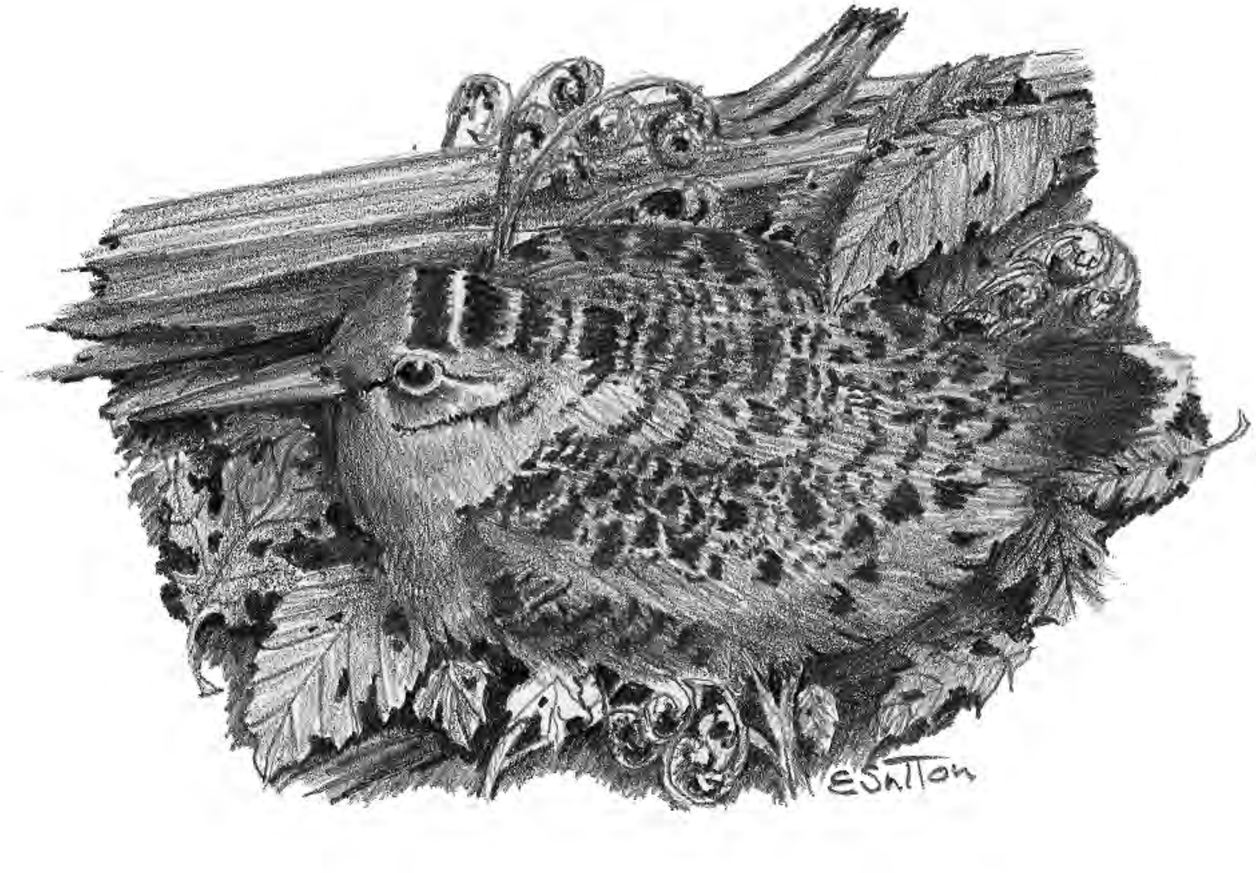
CHAPTER I: CONSERVATION STRATEGIES

CHAPTER II: HABITAT ECOLOGY

CHAPTER III: POPULATION DYNAMICS

Chapter I

Conservation Strategies



IMPROVING WOODCOCK MANAGEMENT BY IMPLEMENTING LESSONS FROM OTHER MIGRATORY GAME BIRDS

10th American Woodcock Symposium
Roscommon, Michigan, USA

JOHN H. SCHULZ [1], Missouri Department of Conservation, Resource Science Center,
Columbia, MO 65201, USA

DAVID R. LUUKKONEN, Michigan Department of Natural Resources, Rose Lake Research Center,
East Lansing, MI 48823, USA

RALPH O. MORGENWECK, U.S. Fish and Wildlife Service, U.S. Geological Survey Regional Director's Office,
Denver, CO 80225, USA

Abstract: Traditionally, American woodcock (*Scolopax minor*) management has involved a mix of harvest and habitat management. Foresters, wildlife biologists, policy makers, and stakeholder groups have historically embraced a habitat paradigm as the primary mechanism affecting woodcock abundance. Recent experiences with mourning doves, waterfowl, and the North American Bird Conservation Initiative (NABCI) may provide concepts leading to a new strategic and heuristic vision. We believe applying lessons from these initiatives will help garner sufficient financial and human resources to expand and support two important objectives: 1) an integrated system of woodcock population and habitat management that uses effective strategic planning, and 2) adaptive resource management that is supported by effective monitoring and evaluation of management efforts. The success of future management depends on expanding traditional partnerships to include non-traditional partners who do not have a vested interest in the annual harvestable surplus of woodcock but rather embrace the benefits of early successional forest management to a wide variety of other migratory birds.

Proceedings of the American Woodcock Symposium 10: 1–11

Key words: American woodcock, habitat paradigm, Joint Venture, research planning, *Scolopax minor.*

During the 1930s–1950s, small game populations were likely at all-time high levels and small game hunters were witnessing the zenith of their favorite pastime (Cokinos 2000, Weddell 2002). Unknown to small game hunters at the time, a series of linked events and occurrences at multiple geospatial scales had synergistically brought about a range of conditions favorable to small game populations and their corresponding habitats (Ryan 1986, Askins 2000, Belanger and Kinnane 2002).

Land that had been scarred earlier by aggressive agricultural and timber extraction activities had begun to slowly heal and change (Askins 2000). Clear-cut forests began to regenerate as young forest cover and worn out farmland reverted to old field and brushlands. As time passed and succession moved forward plant communities slowly and subtly changed. *R*-selected small game bird populations began to positively respond to these changing landscapes by showing seemingly "cause and effect" relationships to the practitioners of an emerging science called wildlife management.

By applying a few intuitive and simple concepts gleaned from these new sciences (Leopold 1933, Trippensee 1948, Allen 1954), it was believed that the existing condition could be perpetuated almost indefinitely with proper and sufficient habitat management. The new wildlife management texts of the time laid the foundation for this pervasive upland habitat paradigm; i.e., problems associated with the lack of small game are rectified primarily through the proper quantity and quality of habitat management activities. Due to these initial successes, the paradigm of habitat management became well entrenched not only in professional wildlife management, but also in the hunting public as evidenced today by numerous non-governmental organizations devoted to the promotion of habitat management for a specific species or suite of species (e.g., Ducks Unlimited, Pheasants Forever, Ruffed Grouse Society, Quail Unlimited, and Woodcock Limited).

---

[1] E-mail: John.H.Schulz@mdc.mo.gov

Decades later, however, we continue witnessing long-term declines in almost all small game populations for which we have population trend information (e.g., roadside surveys), and American woodcock, although different from other small game species, are no exception as demonstrated by declines in the Singing Ground Survey (SGS; Kelley and Rau 2006). Modern research publications for woodcock often cite these long-term declines in woodcock population trends, habitat, and harvest. Surprisingly, however, each research publication usually concludes with a confirmatory statement supporting the existing habitat paradigm. We believe that a different approach and new heuristic is necessary to identify information needs for decision making and to implement management that will eventually benefit the woodcock resource. Our objective, therefore, was to design a broad strategic framework that sets woodcock research priorities based upon the ultimate recognition of critical management uncertainties, financial limitations, adaptive resource management, and linked information needs and questions.

THE HABITAT PARADIGM

Traditionally, American woodcock management involved a mixture of harvest and habitat management (Straw et al. 1994, McAuley et al. 2000). This is an example of "scientific management" which tried to rise above politics and rely upon science as the foundation for decisions and policies made (Brunner et al. 2005). However, biologists and managers explicitly recognized the complex and often subtle interrelationships among population and habitat management decisions and stakeholder wants and needs. Despite this recognition among biologists, there continues to be a professionally perpetuated disjunction in the actual development and implementation of woodcock population and habitat policies and decisions, because those complex and subtle interrelationships are not specifically incorporated in our decisions. In other words, stakeholders perceive that management decisions related to habitat and harvest are independent of each other. As briefly mentioned earlier, part of the explanation for the disjunction and one of the unchallenged tenets of wildlife conservation is the habitat paradigm (Schulz et al. 2003). In addition, we have not used what C.S. Holling calls "science of the integration of the parts" which is "fundamentally concerned with integrative modes of inquiry and multiple sources of evidence" (as reported by Brunner et. al. 2005). We believe this means that the necessary effort to develop a strategic outlook for woodcock management must incorporate rigorous science with an integrative function that includes the interests of stakeholders and their ability to accomplish management actions on the ground. One very important aspect of this integrative function is the ability to learn from management efforts and to change direction if the necessary results are not realized.

Simply stated, the habitat paradigm suggests that *r*-selected small game population densities (in this case woodcock) are driven by habitat quality and quantity, and that harvest has limited impact given suitable habitat quantity and quality (Leopold 1931, Warner 1988), especially within the context of decreasing hunting effort as hunting trips are unsuccessful, also known as the theory of diminishing returns (Allen 1954). Implied within the habitat paradigm are linkages which are believed to bring about a chain reaction and cascade of positive or negative outcomes. A positive example for woodcock goes something like this: a new early-successional forest habitat management initiative leads to increased public and private landowner awareness of woodcock habitat requirements, which in turn leads to forest habitat quality and quantity increases, which in turn leads to increases in the distribution and density of woodcock populations, which in turn leads to larger woodcock harvests, which in turn leads to more successful hunters killing more birds per trip, which in turn leads to an overall increase in hunter numbers, which in turn leads to more satisfied hunters, which in turn leads to larger woodcock harvests and more hunting licenses sold, which eventually leads to a utopian world where hunters, biologists, administrators, and nongovernmental organizations are simultaneously all happy and satiated. The antithesis, of course, is a series of negative presumed outcomes associated with cascading declines in woodcock habitat, woodcock populations, hunters, license revenue, and stakeholder satisfaction.

Specifically for woodcock hunters, the quality or number of hunting opportunities are a product of the annual habitat quality and resulting nesting season. If prospects for the upcoming hunting season appear less than promising, a range of plausible causative factors are easily attributed to the habitat paradigm. Foresters, wildlife biologists, policy makers, and stakeholder groups embraced the habitat paradigm for several decades as the primary mechanism affecting woodcock abundance. A fundamental assumption of applying the habitat paradigm to woodcock is that the creation of early successional forest on both public and private forest landscapes will result in increased woodcock abundance as monitored through SGS population trends, and indirectly through harvest data from the Migratory Bird Harvest Information Program (HIP; Ver Steeg and Elden 2002). Thus, as abundance and/or harvest appears to decline (as suggested by SGS and harvest trends), the habitat paradigm informs stakeholders that more woodcock habitat is needed, and habitat management will result in greater

$$PP_1 \rightarrow TT_1 \rightarrow EE_1 \rightarrow PP_2 \ldots$$

$$PP_x \rightarrow TT_x \rightarrow EE_x \rightarrow PP_{x+1}$$

Figure 1. Growth of reliable knowledge can be simplistically depicted by the identification of a priority resource problem (PP_1) which leads to the development of a tentative theory (TT_1) about the causes of the problem, which is followed by a rigorous process of error elimination (EE_1) or hypothesis testing, which in turn influences the refinement and refocusing of the priority problem; this is an ongoing incremental process (PP_{x+1}) in developing reliable knowledge (Popper 1979, Miller 1985). In other words, multiple and replicated research projects are necessary to build reliable knowledge.

woodcock abundance, larger harvests, increased participation in woodcock hunting leading to more satisfied hunters and reduced inter-stakeholder conflict.

It is critical to remember that the previous discussion is not an argument against increased support of critically important habitat programs (USFWS 2004, Rich et al. 2004, Schroeder et al. 2004). The discussion, however, should help frame our thinking about the over-simplification and over-application of simple solutions to relatively complex and broad habitat and harvest management problems. Thus, an adaptive resource management approach (Walters 2001, Linkov et al. 2006) encourages the integration of woodcock management, research, and stakeholder wants and needs. One very important aspect of this integrative function is the ability to learn from management efforts and to change direction if the necessary results are not realized. However, embracing a new approach or paradigm is not easy for most of us. In business and government, change management expertise is being used more and more to help these organizations and their workforce adapt to this ever-changing world. Such expertise might be useful in the context of adapting to a new paradigm. Hiatt and Creasey (2003) point out that resistance to change can be managed and perhaps avoided given strong leadership and commitment to assisting people as they make difficult changes.

THE ULTIMATE CHALLENGE VERSUS PROXIMATE DETAILS

Another common belief ingrained in our profession is that most of our current wildlife management knowledge is based upon sound scientific principles which were generated through the rigorous application of the scientific method. An extension of this belief is that most of what we need to know to address a particular management uncertainty is already summarized in a book (e.g., Baskett et al. 1993, Tacha and Braun 1994, Braun 2005), or the answer is likely buried in some obscure unpublished P–R federal aid final report somewhere (e.g., Schulz 1994, Schulz 1999); to solve the problem at hand we simply need to find the existing information and apply it to our management problems.

$$\begin{tikzcd} & & & & SR_1 \\ PP_1 \arrow[r] & TT_1 \arrow[r] & EE_1 \arrow[r] \arrow[urr, bend left] & PP_2 \ldots & \\ PP_x \arrow[r] & TT_x \arrow[r] & EE_x \arrow[r] \arrow[drr, bend right] & PP_{x+1} & \\ & & & & SR_{x+1} \end{tikzcd}$$

Figure 2. Is the knowledge building process a methodical endeavor where we attempt to refine an existing “*fact*,” or is it a revolutionary activity that aims to prove existing hypotheses incorrect? Spurious results (SR_{x+1}), or results that don’t make sense, occur sometimes. Usually, we tend to ignore them until they begin to confound our interpretation of the results (Kuhn 1996).

Wildlife professionals hold an institutionalized belief that the purpose of new research is to refine existing knowledge or fill in knowledge gaps, not as a mechanism to challenge the veracity of existing paradigms, theories, or hypotheses (Chalmers 1999). In other words, reliable scientific knowledge increases through a process where scientists actively test hypotheses through rigorous experimentation (Figure 1; Popper 1979, Miller 1985). However, wildlife managers at times implement a particular well-established management action and obtain a spurious result (Figure 2); e.g., more critical habitat was established for woodcock and local populations became more depressed. Over time, these spurious results can no longer be ignored, and a completely new paradigm emerges (Figure 3); i.e., a paradigm shift occurs where a new management hypothesis is posited that accommodates the spurious results (Kuhn 1996).

When presented with mounting spurious results, the wildlife profession (and many other disciplines for that matter), often ignore the need for a paradigm shift and look further into the details of the old paradigm. Mathematical equations are developed that provide the veneer of scientific credibility which avoids the real difficult work of building a new hypothesis that challenges conventional thought. We believe that the quality of a woodcock research and management program, and its resulting knowledge, could be improved by substantive long-range strategic planning, driven by management questions and critical information needs (i.e., what goal or destination do we ultimately want to achieve?), more biometric involvement in the study

$$\begin{tikzcd}
PP_x \arrow[r] & TT_x \arrow[r] & EE_x \arrow[r] \arrow[rrd, bend right=10] & PP_{x+1} & \\
 & & & & SR_{x+1} \arrow[dlll, bend right=10] \\
 & PP_y \arrow[r] & TT_y \arrow[r] & EE_y \arrow[r] & PP_{y+1}
\end{tikzcd}$$

Figure 3. Revolutionary science and scientific revolutions: over time, the spurious results pile up and can not be ignored any longer, and an individual scientist proposes an entirely new and revolutionary theory (Kuhn 1996).

design phase (e.g., larger and more meaningful sample sizes resulting in more meaningful data), and more communication among stakeholders resulting in the necessary broad-based support and financial commitment. Identifying long-term questions that result in a reduction in the uncertainty of wildlife management outcomes will provide the foundation for designing and conducting priority research. Identifying the ultimate woodcock management question and conducting the highest priority study to address the long-term nagging woodcock management problem is much more important than first worrying about sample size, or study site location.

Before attempting to develop a list of needed woodcock research projects or avenues for funding sources, we must first establish a continuum of issues and details ranging from ultimate factors transcending down to proximate details. In other words, this is an effort for getting everything on the table so we can sort and categorize issues and topics and set priorities within a larger strategic framework that involves stakeholders. The following questions provide a partial framework to begin the process of establishing ultimate priorities upon which proximate details (e.g., monitoring systems, research needs, and habitat objectives) can be developed (Figure 4):

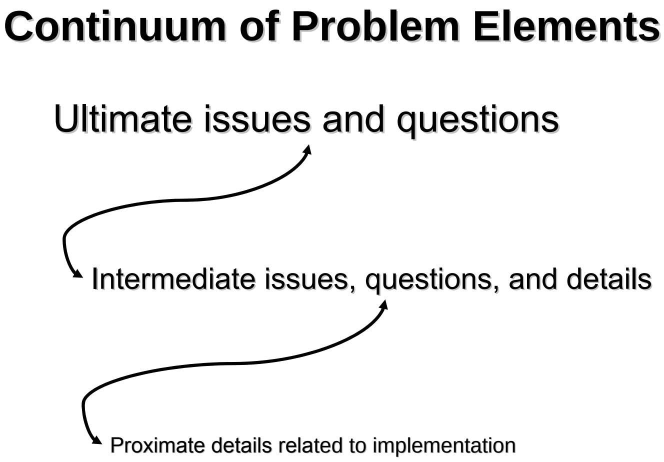


Figure 4. In a generalized problem-solving process, the ultimate issues must be explicitly identified and agreed upon by all stakeholders before making decisions about intermediate and/or proximate details. Without an understanding of the “umbrella” effect of the explicitly defined ultimate issues, much energy will be wasted on attempting to reach agreement on proximate details with each stakeholder having different or undefined ultimate issues.

- What measurable or intangible products do we want from the woodcock resource?
- Do we want more woodcock habitat? For what purpose?
- Do we want larger woodcock populations? For what purpose?
- Do we want more spatially expanded woodcock populations? Why?
- Do we want to have larger harvests? Why?
- Do we want more woodcock hunters? Why?
- Do we want more happy and satisfied woodcock hunters?
- Do we want to use the principles of adaptive resource management (Morrison et al. 2001, Walters 2001, Linkov et al. 2006) to better integrate the science of woodcock management with stakeholder interests and make learning a premium outcome of our management activities? Or do we explicitly want to take a risk-averse approach and purposely avoid any potential conflict?
- Can we develop an effective coalition of interested parties to accomplish the long-term vision for woodcock populations and habitat?
- Is there a need for change-management expertise to assist the woodcock scientist, land manager, wildlife policy maker, and stakeholder to more fully integrate science and stakeholder interests?
- To what degree does land management for woodcock benefit (or deter) other species?

During this phase of the discussion process, the temptation must be avoided to craft an all-inclusive goal statement that simultaneously optimizes habitat, populations, harvest, hunter numbers, and hunter satisfaction. In other words, the ultimate goal should focus on an explicitly described future condition, upon which one or more hypotheses can be developed to improve woodcock populations, as compared to a laundry list of every conceivable issue that could be explored in hopes of something having a positive outcome by chance alone. Once the ultimate future destination is explicitly described and agreed upon by all the stakeholders, a planning process can begin that takes the seemingly insurmountable long-term goal and decompose it into manageable tasks informed by an adaptive resource management approach.

The previous questions lead to the ultimate long-term objectives that 1) focus on learning about vital rates associated with woodcock populations at regional and management region levels for use in population modeling exercises, and 2) attempt to reduce management uncertainty about how harvest affects changes in populations in an adaptive learning context. This is only an example of a thought process to help frame the conceptual ideas, and should not necessarily be perceived as a codified recommendation.

PLANS, PLANNING, AND MEASURABLE PROGRESS

One of the greatest obstacles in this process is identifying one or two critically important woodcock management questions that will eventually form the basis for long-term adaptive resource management (Walters 2001) and a coordinated and linked research effort (Phenicie and Lyons 1973) that will reduce management uncertainty and build reliable knowledge (Romesburg 1981). Our example in the previous paragraph explicitly describes two important information needs that will direct our combined adaptive resource management and linked-research endeavor: gathering regional and management region-wide information on vital rates for woodcock to be used in future population modeling, and implementing an adaptive resource management approach when harvest regulations need to be changed. In other words, we need to learn about woodcock population dynamics and how changes in hunting regulations and habitat conditions may (or may not) affect population abundance.

Using a step-down approach (Phenicie and Lyons 1973) with our example long-term goal, we decompose the ultimate goal into distinct and manageable tasks. The research plan is, therefore, conceptually deconstructed from the ultimate goal down towards the proximate details that can be described as manageable research tasks or projects. Conceptually, the research plan is constructed from the top to the bottom, and implemented from the bottom to the top. The initial process of breaking the goal into manageable tasks may involve only a few steps. However, as initial research is accomplished, the plan will evolve as the new information is incorporated. In other words, more research uncovers more layers of uncertainty in our understanding of the system processes and their interrelated roles (Sarewitz 2006). We may learn that we need to conduct research in areas we had not previously considered, or that our foundational knowledge may have been incomplete at the outset.

Given an initial woodcock research strategy (Appendix A), how do we garner the support and funding to implement the plan?

AVAILABLE TEMPLATES

Several existing and emerging initiatives involving a wide variety of birds provide valuable insights into the development of a strategic plan linking current habitat theory, population dynamics, partnerships, and stakeholder interests. Recent experiences with mourning doves (Anonymous 2005), waterfowl (NAWMP Plan Committee 1998, NAWMP Plan Committee 2004), other migratory birds (USFWS 2004), and Partners in Flight and the North American Bird Conservation Initiative (NABCI; Rich et al. 2004) may provide insights into to a new strategic and heuristic vision. We believe several concepts borrowed from these initiatives will help garner financial and human resources to expand and support an integrated system of woodcock population and habitat management. The ultimate success of future woodcock management depends on expanding traditional partnerships to include non-traditional partners who do not have a vested interest in the annual harvestable surplus of woodcock, but who embrace the benefits of early successional forest management for a wide variety of other migratory birds.

The Mourning Dove National Strategic Harvest Management Plan (National Dove Plan; Anonymous 2005) provides suggestions for developing a strategic vision for woodcock harvest management. The National Dove Plan provides a long-term vision for improving mourning dove management by 1) developing predictive harvest strategies by promoting coordinated management across management units to insure uniformity and equitable conservation across the species range, 2) recognizing the demographic differences among management units, and 3) acknowledging the need to improve the existing knowledge base used for making harvest management decisions. The plan uses these general concepts as the basis for reducing uncertainty in the harvest management decision-making process. The outline of the National Dove Plan provides a useful template to address similar issues related to American woodcock as shown in the following paraphrased elements:

- Where are we currently with our woodcock management; i.e., what is the status quo? (Where are we?)
- Where do we envision the future of woodcock harvest and habitat management? (Where do we want to be?)
- How will we get to this desired future condition for woodcock? (How will we get there?)
- How will we know if we achieved our ultimate goal for the woodcock resource? (Did we make it?)

The answers to these four basic questions as well as the questions posed earlier (in “The ultimate challenge versus proximate details”) will provide the basis for meaningful dialog aimed at developing a strategic vision for improving the overall status of the woodcock resource. A clear and explicit strategic vision is critical for describing the desired future condition, but the vision is of little value unless it is accompanied by an implementation strategy and set of processes to put the vision into practice.

The USFWS recently completed a strategic plan for migratory bird management with American woodcock identified as a “bird of management concern” and a “game bird below desired condition” (USFWS 2004). The broad vision embraced by this plan includes a renewed commitment to a scientific foundation for migratory bird management, including adaptive resource management. The plan also reinforces the concept that wildlife management and research should consider the intersection of three spheres: populations, habitats, and people (Giles 1978). Similar to the National Dove Plan (Anonymous 2005), the strategic plan for migratory bird management (USFWS 2004) provides a broad vision for improving woodcock management; our focus is on specific examples drawn from other sources where woodcock strategic planning may be enhanced by experiences with other migratory game bird groups or species.

Lessons from emerging waterfowl management activities provide one example of a pathway that might be considered for woodcock. Current mallard harvest management is considered by many an example of successful application of adaptive resource management (Walters 2001, U.S. Fish and Wildlife Service 2002, Linkov et al. 2006). Although we believe that an adaptive approach to woodcock management is desirable, Adaptive Harvest Management (AHM) for mallards (Williams and Johnson 1995) has been very data-driven and resource-intensive. It has been said that mallard management was pre-adapted for AHM (Nichols 2000), and an important component of pre-adaptation was a long-term investment in surveys and research. While it may be tempting to replicate AHM for woodcock as implemented for mallards, strategic planning for woodcock population research and management should recognize that adaptive resource management works most efficiently, and learning occurs most rapidly, in management scenarios with the greatest uncertainty. Therefore, large and voluminous long-term data sets are not a prerequisite of embracing concepts of adaptive resource management. Key elements of adaptive resource management that woodcock managers can emulate include careful planning, development of explicit management and learning objectives, development of a suite of explicit competing models, and investment in monitoring systems that provide feedback at appropriate scales to address the most pressing and nagging sources of uncertainty. A premium should be placed on making use of existing data sources to reduce uncertainties while recognizing that expanded or new monitoring systems will likely be needed. This should include evaluating the veracity of existing population surveys to determine if measures of vital rates (e.g., abundance, recruitment, survival, and harvest rate) are reliable at the appropriate scale of management (i.e., the management region). For example, banding programs and parts-collection surveys have been an essential component of waterfowl harvest management, and it is likely that existing woodcock banding (Krementz et al. 2003) and hunter-killed wing collection efforts are inadequate to address woodcock harvest management at the management unit scale.

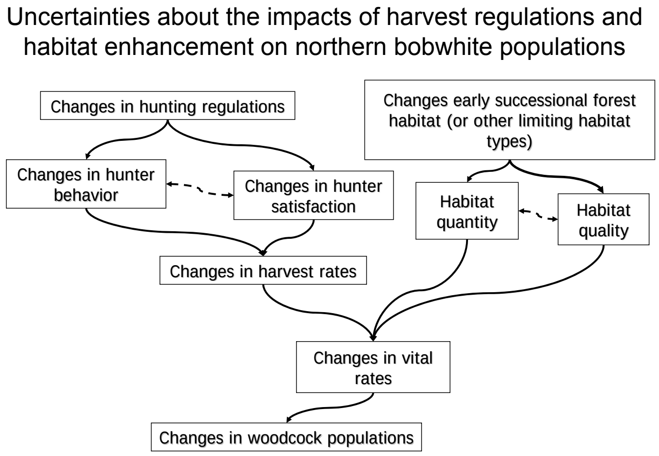


Figure 5. There are numerous uncertainties in our understanding of how changes in woodcock hunting regulations and changes in woodcock habitats ultimately affect woodcock populations. For example, reductions in daily bag and season length may affect hunter behavior in such a fashion that harvest rates remain unaffected. Likewise, habitat programs may affect the quantity or quality of forest management, but those changes may have no measurable impact on population vital rates. Also, monitoring efforts must not only be focused on the explicitly stated resource objective; monitoring activities must be designed to accommodate the numerous and linked uncertainties.

An important recent lesson from waterfowl management is the need to integrate the relationship between harvest and habitat management. Although waterfowl management has traditionally considered the three elements mentioned earlier (i.e., populations, habitat, and people), it is only recently that there has been an attempt to unify population and habitat management (Runge et al. 2004). There has been a disconnect between adaptive harvest management for mallards and habitat management as envisioned in the North American Waterfowl Management Plan (U.S. Department of Interior and Environment Canada 1986). This type of disconnect might be avoided for woodcock if habitat and population managers agree on the objectives for woodcock research and management early in planning. This process should include explicit recognition of the nature of management uncertainties about the effects of hunting and habitat limitation on woodcock populations (Figure 5).

Joint-venture partnerships have been the primary tool for implementing waterfowl habitat management under the North American Waterfowl Management Plan, and adopting an all-bird approach by many joint ventures ensures at least some consideration of woodcock habitat requirements. For example, woodcock are included in the Upper Mississippi and Great Lakes Joint Venture list of focal species (Soulliere 2005). The joint-venture planning approach apportions continental bird population objectives among relevant joint-venture areas, and habitat modeling is used to quantify habitat needs and inventory existing habitat. Implementation programs are designed to eliminate habitat and population deficits or maintain minimal habitat thresholds. Key assumptions of this approach for woodcock are that habitat is limiting or capable of becoming so, and that improvements or declines in habitat impact woodcock demographics. Although there is evidence that local woodcock breeding abundance has responded positively to experimental large-scale habitat manipulation (e.g., Bennett et al. 1982), the role of habitat limitation in regulating woodcock populations at regional or management unit scales remains uncertain. A separate Woodcock Task Force has been working parallel to joint-venture efforts on habitat planning, although the explicit relationship between these groups has not been articulated. A strategic planning approach that incorporates appropriately focused research could reduce uncertainties about the role of habitat limitation by developing appropriate metrics and monitoring systems to assess the impact of management on woodcock demographics. Specifically, relationships between vital rates and population growth rates (λ) are critical to understanding and managing populations (Hoekman et al. 2002). An understanding of these relationships could help inform decisions related to allocation of financial resources devoted to breeding verses wintering habitat.

The discussion of how to integrate human dimensions science into migratory game bird management systems is still in its infancy. The recent national waterfowl hunter survey (National Flyway Council and Wildlife Management Institute 2006) was an attempt to gather representative input from U.S. duck hunters on a variety of issues relating primarily to hunting regulations. One important result of this and other state-specific surveys was the realization that state and federal wildlife biologists' perceptions about duck hunter opinions are sometimes formed by a minority of vocal hunters or hunting groups. Waterfowl managers and researchers continue to struggle with how (or if) human dimensions information can be used in population or habitat management. A focus of this discussion has been the relationship between hunter satisfaction and hunting regulations. Perhaps a lesson for woodcock management is the value of developing and maintaining good communications among stakeholders early in the planning process (i.e., prior to formulating goals and objectives). There are long-established partnerships with federal and state agencies and private groups via flyway councils and joint-venture partnerships that stand as an example of cooperative management that has benefited from formal venues for communication among professionals. Strategic planning for woodcock should take advantage of existing partnerships and perhaps direct efforts at creating new partnerships, particularly where resources to implement a strategic plan can be expanded through cooperation. Another human dimensions arena for woodcock (and other species utilizing similar early successional forest habitats) is to better understand public tolerance to timber harvest and to develop an effective educational message about the value of managing forested habitats for the multiple migratory and resident wildlife species that use these habitats.

THE FUTURE AND BEYOND

A review of systems analysis shows that we often devote 99 percent of our attention and energy to details and processes that have little likelihood of affecting the system we are attempting to change, while we neglect to recognize the importance of paradigm shifts and open-mindedness to affect meaningful change (Meadows 1999). In this paper we have attempted to avoid this trap. We describe a conceptual process for identifying the critical content that will form the foundational ideas for processes of collecting information, implementing management programs, and monitoring the effectiveness of the entire process. This is difficult work and requires continuous and open dialog among all stakeholders. Given the limited available resources that are competing with other societal needs (e.g., war, famine, energy shortages), we cannot continue the status quo and hope something good emerges once in a while. A thoughtful and deliberate problem-solving approach, driven by a clear and explicit objective with corresponding linked information gathering activities, will have a greater likelihood of improving the status of American woodcock.

ACKNOWLEDGMENTS

Funding and support for this study were provided by the Missouri Department of Conservation's Resource Science Center, the Michigan Department of Natural Resources, and the U.S. Fish and Wildlife Service's Office of the Science Advisor with special thanks to D. Ashe and P. Schmidt. We also acknowledge helpful reviews of earlier drafts of this manuscript from S. L. Sheriff and J. G. Dillard.

LITERATURE CITED

Allen, D. L. 1954. Our wildlife legacy. Funk and Wagnall, New York, New York, USA.

Anonymous. 2005. Mourning dove national strategic harvest management plan. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Askins, R. A. 2000. Restoring North America's birds: lessons from landscape ecology. Yale University, New Haven, Connecticut, USA.

Baskett, T. S., M. W. Sayre, R. E. Tomlinson, and R. E. Mirarchi, editors. 1993. Ecology and management of the mourning dove. Stackpole, Harrisburg, Pennsylvania, USA.

Belanger, D. O., and A. Kinnane. 2002. Managing American wildlife: a history of the International Association of Fish and Wildlife Agencies. Montrose, Rockville, Maryland, USA.

Bennett, C. L, Jr., D. L. Rabe, and H. H. Prince. 1982. Response of several game species, with emphasis on woodcock, to extensive habitat manipulations. Pages 97–105 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Department of the Interior, Fish and Wildlife Service Wildlife Research Report 14, Washington, D.C., USA.

Braun, C. E. 2005. Techniques for wildlife investigations and management. Sixth edition. The Wildlife Society, Bethesda, Maryland, USA.

Brunner, R. D., T. A. Steelman, L. Coe-Juell, C. M. Cromley, C. M. Edwards, and D. W. Tucker.2005. Adaptive Governance. Columbia University, New York, New York, USA.

Chalmers, A. F. 1999. What is this thing called science? Third edition. Hackett, Indianapolis, Indiana, USA. Cokinos, C. 2000. Hope is the thing with feathers: a personal chronicle of vanished birds. Jeremy P. Tarcher/Putnam, New York, New York, USA.

Giles, R. H., Jr. 1978. Wildlife management. W. H. Freeman, San Francisco, California, USA.

Hiatt, J. M., and T. J. Creasey. 2003. Change management. Prosci Learning Center. Loveland, Colorado, USA.

Hoekman, S. T., L. S. Mills, D. W. Mills, D. W. Howerter, J. H. Devries, and I. J. Ball. 2002. Sensitivity analyses of the life cycle of midcontinent mallards. Journal of Wildlife Management 66: 883–900.

Kelley, J. R., Jr., and R. D. Rau. 2006. American woodcock population status, 2006. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Krementz, D. G., J. E. Hines, and D. R. Luukkonen. 2003. Survival and recovery rates of American woodcock banded in Michigan. Journal of Wildlife Management 67: 398–407.

Kuhn, T. S. 1996. The structure of scientific revolutions. Third edition. University of Chicago, Chicago, Illinois, USA.

Leopold, A. 1931. Report on a survey of the north central states. Sporting Arms and Ammunition Manufacturer's Institute, Democrat Printing, Madison, Wisconsin, USA.

Leopold, A. 1933. Game management. University of Wisconsin, Madison, Wisconsin, USA.

Linkov, I., F. K. Satterstrom, G. A. Kiker, T. S. Bridges, S. L. Benjamin, and D. A. Belluck. 2006. From optimization to adaptation: shifting paradigms in environmental management and their application to remedial decisions. Integrated Environmental Assessment and Management 2: 92–98.

McAuley, D. G., J. G. Bruggink, and G. F. Sepik, editors. 2000. Proceedings of the Ninth American woodcock symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRDITR – 2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Meadows, D. 1999. Leverage points: places to intervene in a system. The Sustainability Institute, Hartland, Vermont, USA.

Miller, D. W., editor. 1985. Popper selections. Princeton University, Princeton, New Jersey, USA.

Morrison, M. L, W. M. Block, M. D. Strickland, and W. L. Kendall. 2001. Wildlife study design. Springer-Verlag, New York, New York, USA.

Nichols, J. D. 2000. Evolution of harvest for North American waterfowl: Selective pressures and preadaptations for adaptive harvest management. Transactions of the North American Wildlife and Natural Resources Conference 65: 65–77.

National Flyway Council and Wildlife Management Institute. 2006. National duck hunter survey 2005: national report. Wildlife Management Institute, Washington, D.C., USA.

North American Waterfowl Management Plan, Plan Committee. 1998. North American waterfowl management plan—1998 update: expanding the vision. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambente y Recursos Naturales.

North American Waterfowl Management Plan, Plan Committee. 2004. North American waterfowl management plan 2004. Strategic guidance: strengthening the biological foundation. Canadian Wildlife Service, U.S. Fish and Wildlife Service, Secretaria de Medio Ambente y Recursos Naturales.

Phenicie, C. K, and J. R. Lyons. 1973. Tactical planning in fish and wildlife management and research. U.S. Department of Interior, Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Resource Publication 123, Washington, D.C., USA.

Popper, K. R.1979. Objective knowledge: an evolutionary approach. Revised edition. Clarendon, New York, New York, USA.

Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest,E. H. Dunn, W. C. Hunter, E. E. Inigo-Elia, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. Partners in flight North American landbird conservation plan. Cornell Laboratory of Ornithology, Ithaca, New York, USA.

Romesburg, H. C. 1981. Wildlife science: gaining reliable knowledge. Journal of Wildlife Management 45: 293–313.

Runge, M. C., F. A. Johnson, M. G. Anderson, M. Koneff, E. T. Reed, and S. Mott. 2004. The need for coherence between waterfowl harvest and habitat management. Wildlife Society Bulletin 34: 1231–1237.

Ryan, M. R. 1986. Nongame management in grassland and agricultural ecosystems. Pages 117– 136 *in* J. B. Hale, L. B. Best, and R. L. Clawson, editors. Management of nongame wildlife in the Midwest: a developing art. Proceedings of the symposium of the 47th Midwest Fish and Wildlife Conference. Northcentral Section of The Wildlife Society, 17 December 1985, Grand Rapids, Michigan, USA.

Sarewitz, D. 2006. Liberating science from politics. American Scientist 94: 104–106.

Schroeder, M. A., R. K. Baydack, S. A. Harmon, C. A. Hagen, D. M. Davis, S. K. Sherrod, S. DeMaso, R. W. Hoffman, T. Z. Riley, J. B. Haufler, and R. R. Manes et al, editors. 2004. The North American grouse management plan: a prospectus. North American Grouse Partnership, Williamsport, Maryland, USA.

Schulz, J. H. 1994. Evaluation of field techniques used to estimate mourning dove age and sex by plumage characteristics with selected experienced personnel. Missouri Department of Conservation, Federal Aid in Wildlife Restoration Project W-R-13-R-48, Job 1, Final Report, Missouri Department of Conservation, Columbia, USA.

Schulz, J. H. 1999. Physiological and pathological effects of internal and external radiotransmitters on mourning doves. Missouri Department of Conservation, Federal Aid in Wildlife Restoration Project W-R-13-R-53, Final Report, Missouri Department of Conservation, Columbia, USA.

Schulz, J. H., J. J. Millspaugh, D. T. Zekor, and B. E. Washburn. 2003. Enhancing sport-hunting opportunities for urbanites. Wildlife Society Bulletin 31: 565–573.

Soulliere, G. J. 2005. Role of the Upper Mississippi River and Great Lakes Joint Venture and synopsis of bird conservation initiatives. UpperMississippi River and Great Lakes Joint Venture Technical Office, East Lansing, Michigan, USA.

Straw, J. A. Jr., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

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

Trippensee, R. E. 1948. Wildlife management: upland-game and general principles. McGraw-Hill, New York, New York, USA.

U.S. Department of the Interior and Environment Canada. 1986. The North American Waterfowl Management Plan. U.S. Department of the Interior, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 2002. Adaptive harvest management: 2002 duck hunting season. U.S. Department of Interior, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 2004. A blueprint for the future of migratory birds: migratory bird program strategic plan 2004–2014. U.S. Fish and Wildlife Service, Washington D.C., USA.

Ver Steeg, J. M., and R. C. Elden, compilers. 2002. Harvest Information Program: evaluation and recommendations. International Association of Fish and Wildlife Agencies, Migratory Shore and Upland Game Bird Working Group, Ad Hoc Committee on HIP, Washington, D.C., USA.

Walters, C. J. 2001. Adaptive management of renewable resources. Blackburn, Caldwell, New Jersey, USA.

Warner, R. E. 1988. Habitat management: how well do we recognize the pheasant facts of life? Pages 129–146 *in* D. L. Hallett, W. R. Edwards, and G. V. Burger, editors. Pheasants: symptoms of wildlife problems on agricultural lands. North Central Section of The Wildlife Society, 8 December 1987, Bloomington, Indiana, USA.

Weddell, B. J. 2002. Conserving living natural resourcesb in the context of a changing world. CambridgeUniversity, Cambridge, United Kingdom.

Williams, B. K., and F. A. Johnson. 1995. Adaptive management and the regulation of waterfowl harvests. Wildlife Society Bulletin 23: 430–436.

APPENDIX A.

An example American woodcock question-driven research plan shows how difficult management questions can be reduced into smaller and smaller manageable research tasks. The plan is constructed from top to bottom, and implemented from bottom to top. The lower steps, once accomplished, provide the foundation of reliable knowledge that can help justify further expenditures on more expensive research endeavors (e.g., improved research methodology or new equipment development).

American woodcock research plan – an example

Management question – How do changes in harvest mortality and habitat quantity and/or quality affect woodcock vital rates which ultimately affect woodcock abundance?

Ultimate research goal – The ability to predict woodcock population response to changes in harvest regulations under a wide variety of environmental conditions, as well as to changes in early successional forest habitat at a wide range of temporal and spatial scales.

I. Conduct a series of complex experiments at multiple locations in both breeding and wintering areas testing hypotheses related to differences in vital rates given different habitat treatments (e.g., scales and patterns of forest harvest management) and different levels of harvest management (e.g., combinations of daily bag or season length).

A. Develop an understanding of synergistic relationships between habitat and harvest management and the impact of those relationships on vital rates.

1. Habitat issues

a) Determine relative importance of breeding versus wintering habitats, and which may be limiting population growth.

b) Determine how to measure the relative importance of different seasonal habitat types, and which population characteristics would be most diagnostic.

c) Determine relationships among habitat quantity and quality and population growth rates at local, regional, and management region scales (i.e., can we measure actual population benefits from habitat improvements, and do we have the tools to make those measurements? – see section II below).

2. Harvest management issues

a) Develop and conduct experiments to determine if (or what) relationships exist between changes in harvest regulations and changes in harvest rates, and develop an understanding of what level of harvest ultimately impacts annual survival.

b) Establish harvest regulation packages (e.g., daily bag, season length, or several permutations of combined bag and season length) that provide meaningful options that will advance our understanding of harvest impacts while simultaneously providing realistic options that are acceptable to hunters and other stakeholders.

c) Conduct expanded operational woodcock banding programs.

d) Evaluate existing operational woodcock banding programs and make recommendations for improvement so that vital rates can be estimated with greater precision for use in later experiments.

II. Evaluate the existing field techniques and population monitoring tools, and determine if existing tools need to be developed.

A. Reevaluate the efficacy of assumptions related to existing field techniques (e.g., evaluate capture stress related to banding and resulting impacts on survival, accuracy of SGS and parts collection surveys).

John H. Schulz is a Resource Scientist for the Missouri Department of Conservation, and an active member of The Wildlife Society at the state, section, and national levels. His primary interests include management and research of migratory game birds, integrated and interdisciplinary watershed management, the philosophy of science, and the interface of science, policy, and politics.

Ralph Morgenweck is the Senior Science Advisor in the U.S. Fish and Wildlife Service. He is involved in a variety of issues including climate change, information quality, peer review, and the impacts of the Deepwater Horizon oil spill in the Gulf. His special interest is in migratory shore and upland game birds.

David R. Luukkonen is a Wildlife Research Specialist with the Michigan Department of Natural Resources; he is also an adjunct faculty member of the Department of Fisheries and Wildlife at Michigan State University. His primary interest is research to improve management decisions for migratory and resident game birds.

10th American Woodcock Symposium
Roscommon, Michigan, USA

DEVELOPMENT OF HABITAT GOALS FOR THE AMERICAN WOODCOCK CONSERVATION PLAN AND RECOMMENDATIONS FOR IMPLEMENTATION

THOMAS R. COOPER[1] **and JAMES R. KELLEY, JR.,** U.S. Fish and Wildlife Service, Division of Migratory Bird Management, *BHW Federal Building, 1 Federal Dr., Fort Snelling, MN 55111, USA*

SCOT J. WILLIAMSON, Wildlife Management Institute,
69 Clinton Ave., St. Johnsbury, VT 05819, USA

MARK BANKER, Ruffed Grouse Society, PA,
451 McCormick Rd., Coraopolis, PA 15108, USA

DANIEL R. DESSECKER, Ruffed Grouse Society,
P.O. Box 2, Rice Lake, WI 54868, USA

DAVID G. KREMENTZ, Arkansas Cooperative Fish & Wildlife Research Unit, Department of Biological Sciences, University of Arkansas, *Fayetteville, AR 72701, USA*

DANIEL G. McAULEY, U.S. Geological Survey, Patuxent Wildlife Research Center,
5768 South Annex A, Orono, ME 04469-5768, USA

WILLIAM L. PALMER[2]**,** Pennsylvania Game Commission,
333 Sinking Creek Rd., Spring Mills, PA 16875, USA

TIMOTHY J. POST, New York Department of Environmental Conservation, Bureau of Wildlife,
625 Broadway, Albany, NY 12816, USA

Abstract: American woodcock populations have experienced long-term population declines. In response to the declines, The U.S. Fish and Wildlife Service developed national American woodcock (*Scolopax minor*) management plans in 1985 and 1990. Both plans outlined general objectives and strategies for woodcock population and habitat management; however, they lacked quantifiable population and habitat goals, or overall objectives to guide woodcock management. In 2002, the Association of Fish and Wildlife Agencies charged the Woodcock Task Force (Task Force) to develop a more comprehensive conservation plan. The Task Force used data from the American Woodcock Singing-ground Survey and the U.S. Forest Service's Forest Inventory and Analysis Program to estimate woodcock densities during two time periods: 1970–1975 and 2000–2004. Differences between the two time periods were used to estimate woodcock population deficits for each Bird Conservation Region (BCR) throughout the species' core breeding range. The Task Force calculated population and habitat goals for each BCR by estimating the amount of habitat that needs to be created to return woodcock densities to levels observed during 1970–1975. We conclude with some recommendations for implementing the American Woodcock Conservation Plan.

Proceedings of the American Woodcock Symposium 10: 13–25

Key words: American woodcock, Bird Conservation Region, early successional habitat, population goals, *Scolopax minor*.

---

[1] E-mail: tom_cooper@fws.gov

[2] Retired

American woodcock populations, as measured by the American Woodcock Singing-ground Survey (SGS), have shown long-term declines (1968–2006) in both the Eastern (–1.9 %/year) and Central (–1.8 %/year) management regions (Kelley and Rau 2006). Data from the Wing-collection Survey (Figure 1) have shown similar long-term declines in woodcock recruitment in both management regions (Kelley and Rau 2006). Biologists believe that loss of early successional forest habitat (ESH) is largely responsible for the population declines (U.S. Fish and Wildlife Service 1990, Straw et al. 1994, Dessecker and McAuley 2001, Kelley et al. 2008). Data from the U.S. Forest Service's Forest Inventory and Analysis (FIA, U.S. Forest Service 2010) program indicate that ESH has declined throughout much of the eastern United States primarily from forest succession and deforestation (Table 1). Increased forest age is thought to have resulted from negative societal attitudes about active forest management, suppression of natural fire regimes, and an increase in the number of landowners owning small forest tracts that are more difficult to manage (U.S. Fish and Wildlife Service 1990, Straw et al. 1994, Dessecker and McAuley 2001, Kelly et al. 2008). Deforestation is primarily attributed to conversion of woodlands to urban, rural, or agricultural land uses. In addition to woodcock, other birds relying on early successional forest habitat have experienced long-term population declines (Hunter et al. 2001). Data from the North American Breeding Bird Survey (1966–2007) indicate a greater proportion of birds using early successional habitat have experienced declines when compared to species requiring mature forest habitat (Figure 2, Sauer et al. 2007).

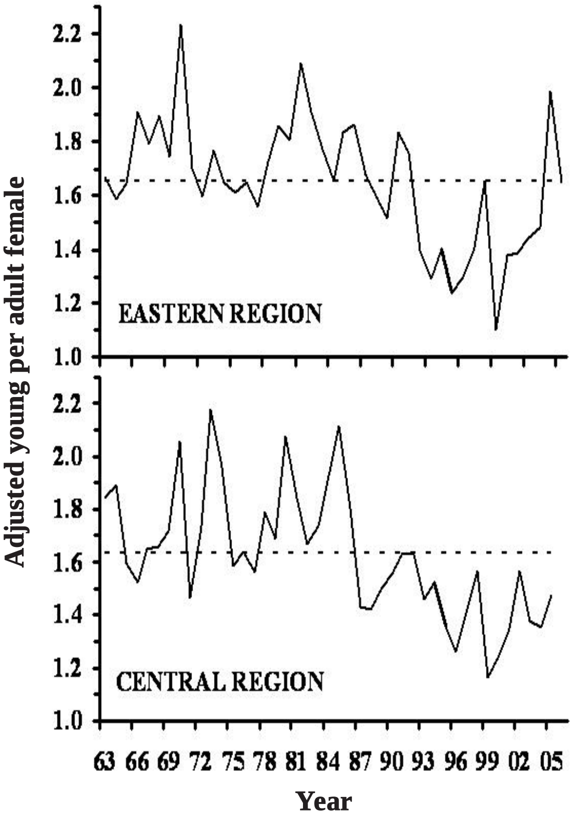


Figure 1. Weighted annual indices of recruitment from the Woodcock Wing-collection Survey (U.S.), 1963–2005 (Kelley and Rau 2006). The dashed line represents the 1963–2004 average.

Table 1. Acres of early successional habitat for selected Bird Conservation Regions within the American woodcock breeding range during the early 1970s (historic) and early 2000s (current) as measured by the U.S. Forest Service Forest Inventory and Analysis Program.

Bird Conservation Region	Historic (acres)	Current (acres)
12	12,737,650	14,299,021
13	5,589,400	3,935,700
14	13,338,200	11,478,590
22	1,805,191	1,176,683
23	3,108,190	2,328,328
28	10,534,817	8,843,850
30	2,884,855	752,400
Total	49,998,303	42,814,572

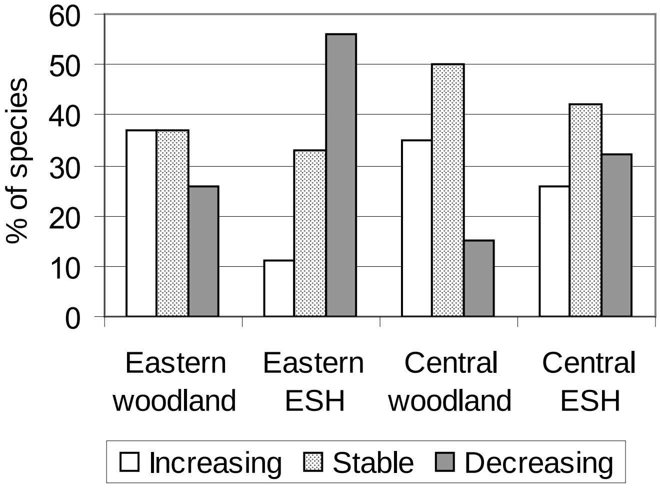


Figure 2. Breeding bird population trends for species breeding in woodland and early successional habitat (ESH) in the eastern and central United States based on data from the North American Breeding Bird Survey, 1966–2007 (Sauer et al. 2007).

In response to declining populations, the U.S. Fish and Wildlife Service completed woodcock conservation plans in 1985 and 1990 (U.S. Fish and Wildlife Service 1990). Both plans outlined general objectives and strategies for woodcock population and habitat management. Although some specific action items were identified in the plans including acquisition of key habitat in Cape May, New Jersey, and Canaan Valley, West Virginia, both plans lacked quantifiable population and habitat goals, or specific objectives to guide woodcock management. In 2002, the Woodcock Task Force (Task Force) was created by the Migratory Shore and Upland Game Bird Working Group through the Association of Fish and Wildlife Agencies and is composed of biologists from federal, state, provincial, and private conservation organizations. The Task Force was responsible for documenting habitat change over the past 3 decades and developing habitat management recommendations needed to halt, and ultimately reverse, population declines. The Task Force's findings and recommendations are contained in the American Woodcock Conservation Plan (woodcock plan).

The overall goal of the woodcock plan is to halt the decline of woodcock populations and to ultimately return populations to the densities that occurred in the early 1970s (Kelley et al. 2008). The Task Force selected the early 1970s because they believed that returning populations to early 1970s levels was a realistic goal. Further, population data, through the SGS, were available for this time period, which allowed the Task Force to develop explicit population and habitat goals. Specific goals of the woodcock plan are to 1) halt woodcock population declines by 2012 as measured by SGSs; 2) achieve positive population growth by 2022 as measured by SGSs; 3) halt decline of ESH by 2012 as measured by the FIA; and 4) increase ESH by 2022 as measured by the FIA. The Task Force recognized that significant acreage of former woodcock habitat has been converted to other land uses (e.g., agriculture or development) that make it unavailable to new management efforts. Therefore, the Task Force did not develop goals that aimed for a return to absolute population sizes observed during the early 1970s. Rather, they adopted a framework for returning woodcock densities to those that occurred in the early 1970s.

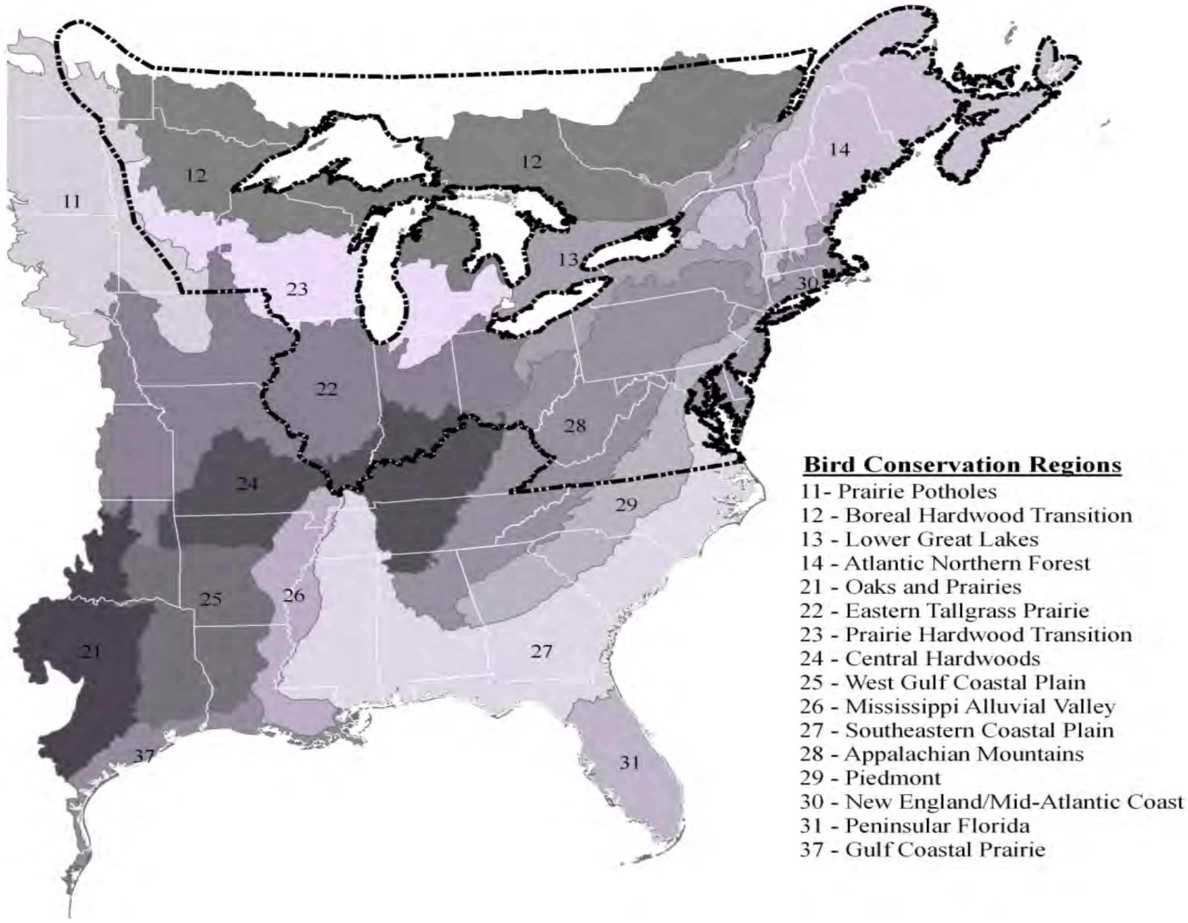


Figure 3. Bird Conservation Regions (BCRs) within the American woodcock range of North America. Habitat goals were only calculated for BCRs or portions of BCRs that are within the American Woodcock Singing-ground Survey area, which is depicted by the dashed line.

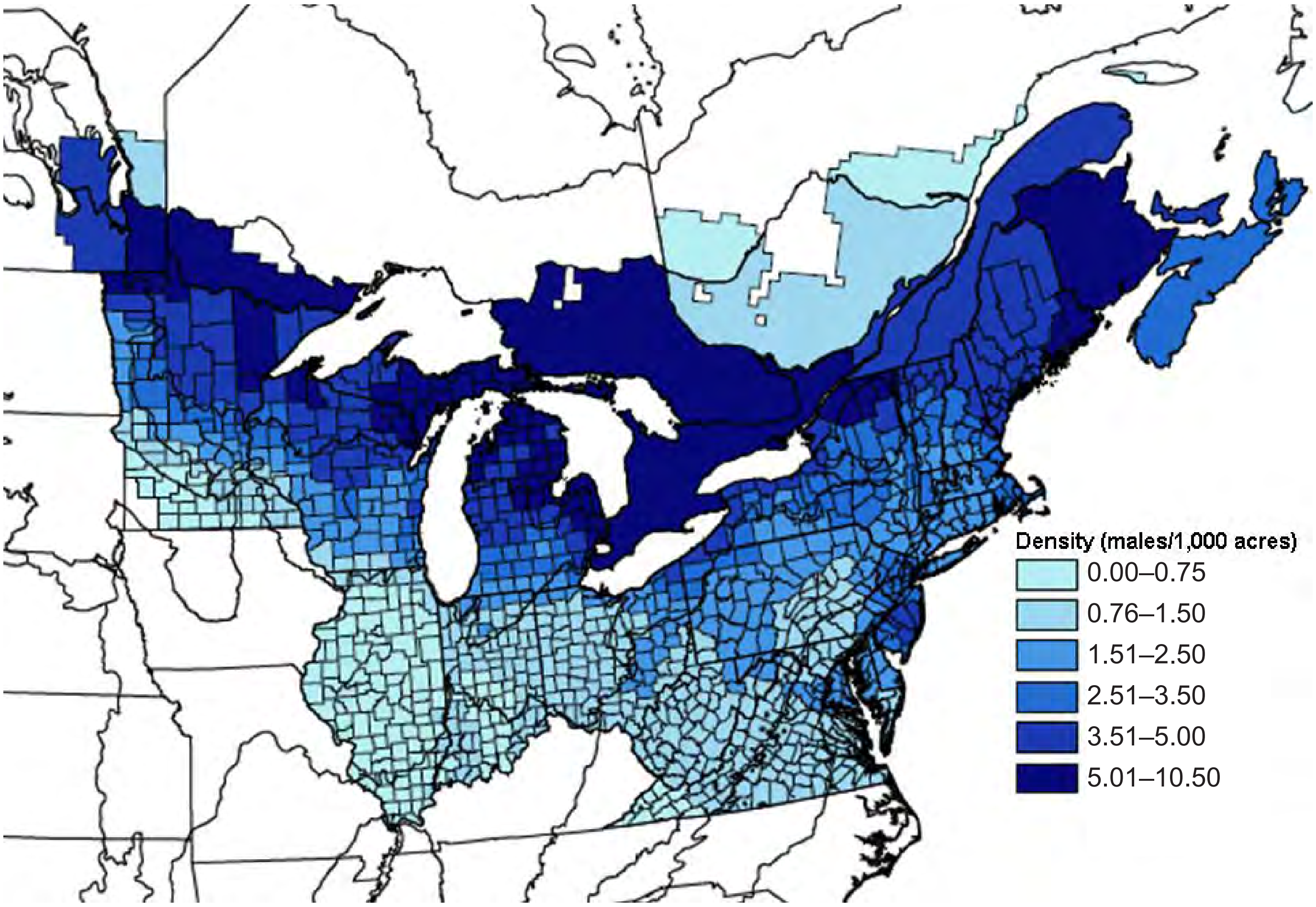


Figure 4. Historic (1970–75) woodcock density estimates (singing males/1,000 acres) at the county level for the United States and the province level for Canada.

Our objective for this paper is to present the methods used by the Task Force to develop population and habitat goals for the woodcock plan. We conclude with some recommendations on how to implement the woodcock plan in cooperation with partners engaged with forest management in North America.

METHODS

The Task Force used a deficit approach to derive population and habitat goals that were specific for Bird Conservation Regions (BCRs) throughout the species breeding range (Figure 3). Bird Conservation Regions are areas that encompass landscapes having similar bird communities, habitats, and conservation issues (North American Bird Conservation Initiative 2000). We could only develop explicit population and habitat goals for BCRs or portions of BCRs covered by the American Woodcock Singing-ground Survey (BCRs 11, 12, 13, 14, 22, 23, 24, 27, 28, 29, and 30). We did not calculate goals for BCR 26 since a small portion of the BCR occurs within the area surveyed by the SGS.

We used data from the SGS to estimate average populations of singing male woodcock during 1970 to 1975 (historic population) and from 2000 to 2004 (current population) for each BCR covered by the SGS. The SGS is an annual survey where singing male woodcock are counted along approximately 1,500 routes distributed throughout the core of the woodcock breeding range (Sauer and Bortner 1991, Kelley and Rau 2006). We converted the average number of singing males per route to singing males per acre based on the assumption that a 250-meter radius around each survey point was sampled. Based on these data, density contours were developed for the entire area surveyed by the SGS. In the United States, we assigned individual counties a density category based on the density contour within which the majority of the county's land area fell. In Canada, density categories were assigned only at the provincial level (Figures 4 and 5). We calculated the total number of singing males in each county or province by multiplying the density estimate for each county or province by the total land area (not simply acres of woodcock habitat) in the county or province. We did this because the SGS routes are randomly distributed across the landscape and can include habitat not used by woodcock.

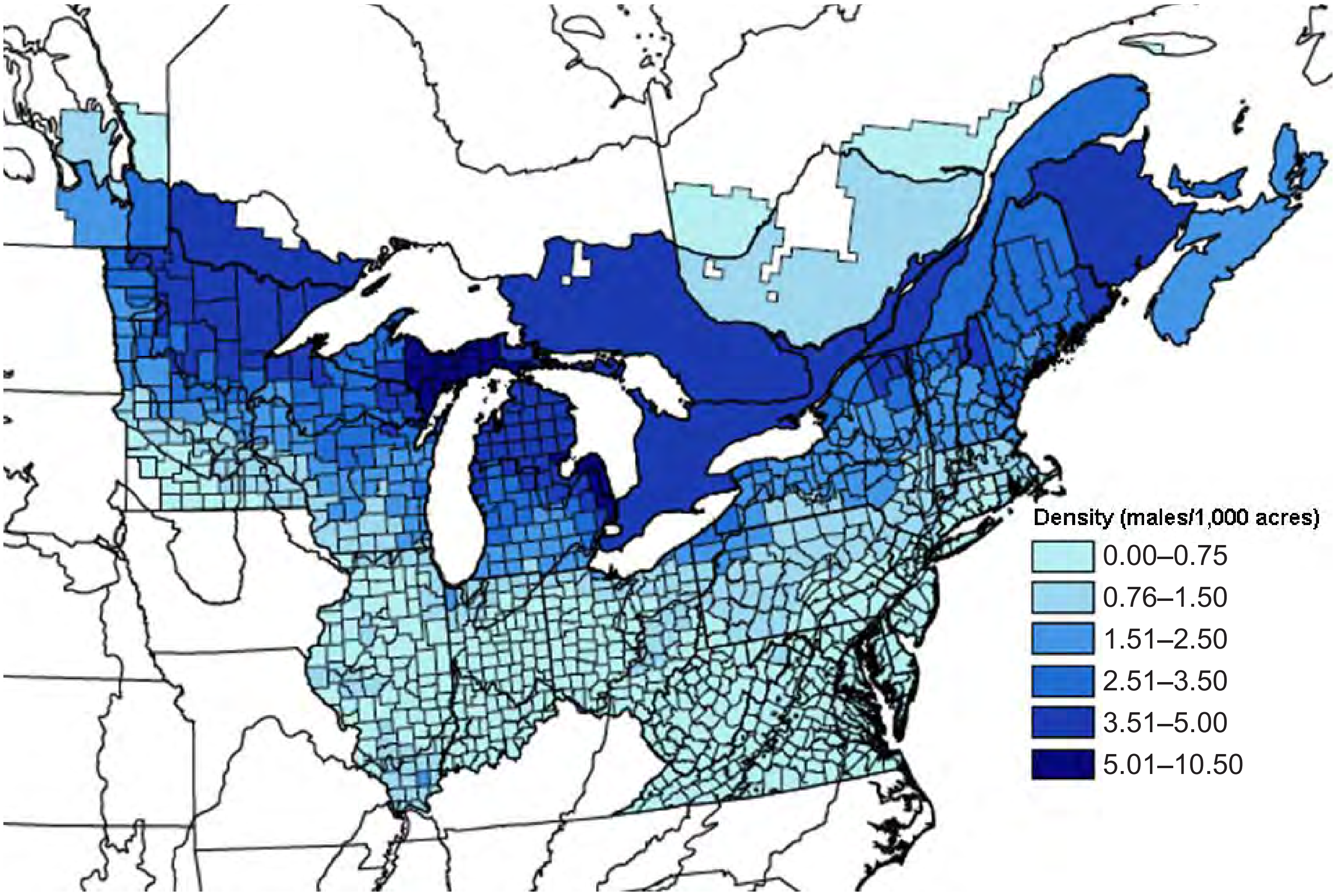


Figure 5. Current (2000–04) woodcock density estimates (singing males/1,000 acres) at the county level for the United States and the province level for Canada.

We estimated the population for each BCR by summing population estimates from individual counties or provinces found within the BCR. The effective density of singing males in each time period was determined by dividing the number of singing males by the total acres of manageable forest found in the BCR during that time period. We defined manageable forest as all timberland identified through the FIA. The woodcock density deficit was calculated by subtracting the current effective density from the historical effective density. The population deficit is the number of singing males that need to be added to a given BCR to achieve the effective density observed during 1970 to 1975. The population deficit was calculated by multiplying the density deficit by the current number of manageable acres within each BCR.

We used population deficits to determine breeding habitat goals for each BCR. Habitat goals are the additional acres of woodcock habitat in a given BCR that must be created to increase the effective density of singing males to equal densities present during 1970 to 1975. We identified woodcock habitat as being small diameter (seedling or sapling) and non-stocked forest inventory categories (Cushwa et al. 1977, Gutzwiller et al. 1982). First, we developed a habitat multiplier to determine how many acres of new habitat would be needed to add one singing male to the BCR. For each BCR, we calculated a habitat multiplier by dividing the acreage of early successional habitat (small-diameter and nonstocked forest) for the 1970 to 1975 period by the number of singing males found in the BCR during the same period. We believed that calculating the habitat multiplier this way was a reasonable estimate for the amount of additional habitat required to add one male woodcock to the population. Acreage goals were calculated for each BCR by multiplying the population deficit by the habitat multiplier specific to that BCR. An example of how habitat goals were calculated is presented in Table 2.

RESULTS

We estimated that about 986,000 singing male woodcock need to be added to the population to return densities to levels experienced in the early 1970s. Based

Table 2. An example of new acreage habitat goal calculations for Bird Conservation Region 12 in Michigan.

	Historic	Goal calculation	Current
Population estimate (males) [a]	407,260		304,934
Manageable forest (acres) [b]	14,928,400		14,472,184
Effective density (males/acre) [c]	0.027		0.021
Density deficit (males/acre) [d]		0.006	
Population deficit (males) [e]		89,880	
Habitat multiplier (acres) [f]		10	
Habitat goal (acres) [g]		898,800	

[a] Estimated woodcock singing male population for the early 1970s (historic) and early 2000s (current) calculated using the methodology presented in the methods section.

[b] Total acreage of forest in the BCR 12 portion of Michigan as estimated from the U.S. Forest Service FIA program.

[c] Calculated by dividing the estimated population by the forest acreage for each time period.

[d] Difference between the historic and current effective densities.

[e] Calculated by multiplying the density deficit by the current acreage of forest.

[f] Acres of habitat required to add one singing male to the population. Acreage was calculated by dividing the historic population estimate by the amount of early successional habitat from the early 1970s that occurred in each state by BCR region.

[g] Calculated by multiplying the population deficit by the habitat multiplier.

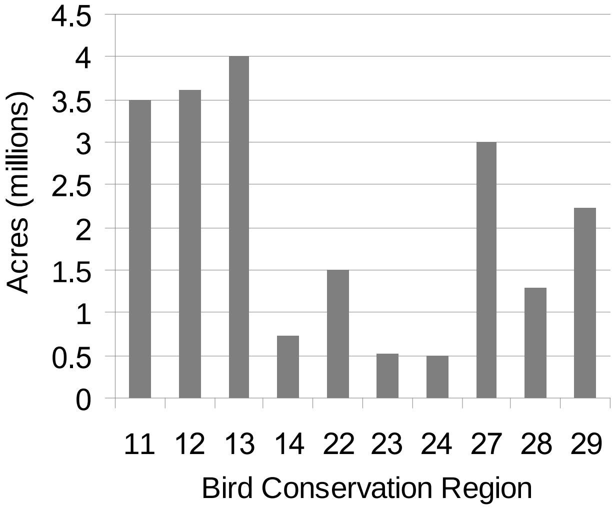


Figure 6. Additional acres of early successional habitat required in each Bird Conservation Region in order to return American woodcock population densities to early-1970s levels.

on our methodology, approximately 20.8 million acres (8.6 million hectares) of new woodcock habitat must be created throughout the core breeding range to eliminate the deficit. New habitat goals range from 3,999 acres in BCR 11 to just over 4 million acres in BCR 14 (Figure 6). Specific population deficits and habitat goals for each BCR by state or province region are listed in Table 3.

DISCUSSION

Although the amount of overall forest habitat has increased in many BCRs (Table 3), early successional habitat continues to be lost throughout much of the woodcock breeding range. The ESH acreage goals listed in Table 3 are in addition to the amount of ESH that currently occurs on the landscape. At minimum, cooperators should work to maintain the current acreage of ESH on the landscape in order to maintain current population levels.

The American Woodcock Management Plan is intended to be used as a tool for planning purposes. We acknowledge that the habitat goals presented in the woodcock plan are ambitious; however, the habitat goals presented represent less than 20% of the total forest acreage in all of the BCRs except BCR 30 (Table 4). Partners should view the goals as a starting point for working with forest managers and private landowners throughout the woodcock breeding range. Future efforts should focus on stepping down the habitat goals to the local scale (i.e., county scale) to further assist cooperators working directly with local habitat managers and private landowners.

We recognize it may not be realistic to achieve the habitat goals for all BCRs, particularly regions with high urban and agricultural land uses. Further, acreage goals for certain regions of the initiative may not be feasible because more ESH exists now than in the early 1970s (i.e., BCR 12; Table 1) or because large-scale forestry plans call for reducing the amount of ESH on the landscape. In such cases, cooperator efforts can be adjusted to address other factors that may be limiting woodcock population growth such as improving brood survival, placing habitat in the most productive locations (e.g., areas with moist soil), or addressing non-breeding season habitat concerns. Although not covered in this paper, the woodcock plan contains estimates of available forest habitat and habitat management recommendations for migratory and wintering BCRs not covered by the SGS. Partners can use this information to guide management actions in non-breeding season habitats.

Table 3. Population deficit and habitat goals for each state or province by Bird Conservation Region (BCR). See Table 2 for an example of how goals were calculated for each region.

BCR	State or province	Historic population[a]	Current population[a]	Historic manageable forest (acres)[b]	Current manageable forest (acres)[b]	Historic effective density[c]	Current effective density[c]	Density difference[d]	Population deficit[e]	Habitat multiplier[f]	Habitat goal (acres)[g]
11	Minnesota	41,773	33,337	629,900	519,679	0.066	0.064	0.002	1,126	3.55	3,999
	BCR Total	41,773	33,337	629,900	519,679				1,126		3,999
12	Michigan	407,260	304,934	14,928,400	14,472,184	0.027	0.021	0.006	89,880	10.00	898,800
	Minnesota	182,669	156,067	8,581,900	11,882,889	0.021	0.013	0.008	96,865	10.00	968,648
	Wisconsin	108,141	79,712	7,569,200	8,027,509	0.014	0.010	0.004	34,977	10.00	349,769
	Sub-total U.S.	698,070	540,713	31,079,500	34,382,582				221,722		2,217,217
	Manitoba	63,064	21,609	na	na	na	na	na	na	na	na
	Ontario	491,666	381,358	13,251,000	13,688,400	0.037	0.028	0.009	126,537	10.00	1,265,370
	Quebec	58,347	58,276	29,513,700	29,548,300	0.002	0.002	0.000	139	10.00	1,390
	Sub-total CA	613,077	461,243	42,764,700	43,236,700				126,676		1,266,760
	BCR Total	1,311,147	1,001,956	73,844,200	77,619,282				348,398		3,483,977
13	New York	97,888	62,239	5,674,700	6,611,200	0.017	0.009	0.008	51,804	30.88	1,599,693
	Ohio	25,413	13,276	1,268,700	1,570,700	0.020	0.008	0.012	18,186	17.80	323,716
	Pennsylvania	12,831	7,882	919,200	761,200	0.014	0.010	0.004	2,743	29.25	80,247
	Vermont	6,344	4,363	481,500	461,000	0.013	0.009	0.004	1,711	15.64	26,759
	Sub-total U.S.	142,476	87,760	8,344,100	9,404,100				74,444		2,030,415
	Ontario	193,746	149,638	12,274,100	12,568,800	0.016	0.012	0.004	48,760	27.70	1,350,647
	Quebec	46,318	46,184	1,403,700	1,619,800	0.033	0.029	0.004	7,265	27.70	201,231
	Sub-total CA	240,064	195,822	13,677,800	14,188,600				56,024		1,551,878
	BCR Total	382,540	283,582	22,021,900	23,592,700				130,469		3,582,293
14	Connecticut	2,349	896	399100	410488	0.006	0.002	0.004	1,520	36.53	55,527
	Maine	168,170	108,952	16,395,400	16,701,511	0.010	0.007	0.004	62,358	30.67	1,912,514
	Massachusetts	4,445	2,393	757,800	748,328	0.006	0.003	0.003	1,996	37.49	74,827
	N. Hampshire	29,505	21,970	4,194,700	4,188,680	0.007	0.005	0.002	7,493	35.90	268,986
	New York	43,741	28,230	3,356,100	3,240,178	0.013	0.009	0.004	14,000	34.39	481,465
	Vermont	27,906	20,582	3,948,400	4,143,397	0.007	0.005	0.002	8,702	45.29	394,122
	Sub-total U.S.	276,116	183,023	29,051,500	29,432,582				96,069		3,187,441
	N. Brunswick	181,679	142,681	14,684,600	15,104,300	0.012	0.009	0.003	44,191	11.89	525,426
	Nova Scotia	67,372	52,373	9,696,700	9,571,500	0.007	0.005	0.001	14,129	12.68	179,157
	Prince Ed. Is.	10,973	6,799	666,100	601,200	0.016	0.011	0.005	3,105	11.31	35,116

Table 3. Continued.

BCR	State or province	Historic population[a]	Current population[a]	Historic manageable forest (acres)[b]	Current manageable forest (acres)[b]	Historic effective density[c]	Current effective density[c]	Density difference[d]	Population deficit[e]	Habitat multiplier[f]	Habitat goal (acres)[g]
	Quebec	101,344	99,329	8,475,900	8,775,400	0.012	0.011	0.001	5,596	14.10	78,904
	Sub-total CA	361,368	301,182	33,523,300	34,052,400				67,021		818,603
	BCR Total	637,484	484,205	62,574,800	63,484,982				163,090		4,006,044
22	Illinois	18,495	32,302	2,661,700	2,931,096	0.007	0.011	–0.004	no deficit	none	maintain
	Indiana	19,273	9,998	822,900	1,033,421	0.023	0.010	0.014	14,206	18.84	267,633
	Michigan	4,037	2,978	90,700	108,676	0.045	0.027	0.017	1,859	18.84	35,025
	Minnesota	3,536	3,074	128,600	139,228	0.027	0.022	0.005	754	18.84	14,210
	Ohio	26,166	14,409	1,225,600	1,663,775	0.021	0.009	0.013	21,112	18.84	397,747
	BCR Total	71,507	62,761	4,929,500	5,876,196				37,931		714,615
23	Illinois	599	481	59,700	92,691	0.010	0.005	0.005	449	11.59	5,204
	Indiana	8,012	4,502	248,400	341,071	0.032	0.013	0.019	6,499	11.59	75,324
	Michigan	134,278	99,832	3,490,950	4,107,026	0.038	0.024	0.014	58,143	11.59	673,879
	Minnesota	48,226	42,781	1,946,500	2,218,032	0.025	0.019	0.005	12,172	11.59	141,078
	Wisconsin	114,890	84,519	6,346,200	7,604,561	0.018	0.011	0.007	53,152	11.59	616,032
	BCR Total	306,005	232,115	12,091,750	14,363,381				130,416		1,511,517
24	Illinois	3,697	6,971	2,454,200	1,064,802	0.002	0.007	–0.005	no deficit	none	maintain
	Indiana	11,715	4,716	2,824,500	3,076,225	0.004	0.002	0.003	8,043	63.30	509,126
	Ohio	443	211	927,600	94,965	0.000	0.002	–0.002	no deficit	none	maintain
	BCR Total	15,855	11,898	6,206,300	4,235,992				8,043		509,126
26	Illinois	121	292	na	na	na	na	na	na		maintain
	BCR Total	121	292								
27	Virginia	8,189	2,186	2,750,784	2,533,138	0.003	0.001	0.002	5,355	92.80	496,951
	BCR Total	8,189	2,186	2,750,784	2,533,138				5,355		496,951
28	Maryland	2,518	1,099	587,916	464,777	0.004	0.002	0.002	892	34.00	30,315
	New Jersey	5,048	1,176	460,871	431,375	0.011	0.003	0.008	3,549	34.00	120,663
	New York	38,704	22,817	5,438,042	5,698,943	0.007	0.004	0.003	17,744	34.00	603,293
	Ohio	17,540	8,741	4,261,413	4,554,410	0.004	0.002	0.002	10,005	34.00	340,169
	Pennsylvania	71,497	42,030	14,510,890	14,702,990	0.005	0.003	0.002	30,414	34.00	1,034,059
	Virginia	13,068	4,284	5,478,689	5,697,355	0.002	0.001	0.002	9,306	34.00	316,389
	West Virginia	31,120	13,898	11,900,346	11,538,419	0.003	0.001	0.001	16,276	34.00	553,368

Table 3. Continued.

BCR	State or province	Historic population[a]	Current population[a]	Historic manageable forest (acres)[b]	Current manageable forest (acres)[b]	Historic effective density[c]	Current effective density[c]	Density difference[d]	Population deficit[e]	Habitat multiplier[f]	Habitat goal (acres)[g]
	BCR Total	179,495	94,045	42,638,167	43,088,269				88,185		2,998,256
29	Maryland	4,158	1,308	674,000	473,400	0.006	0.003	0.003	1,612	47.00	75,764
	New Jersey	5,243	909	227,100	280,900	0.023	0.003	0.020	5,576	47.00	262,072
	Pennsylvania	8,111	2,439	572,100	580,800	0.014	0.004	0.010	5,795	47.00	272,365
	Virginia	20,188	5,499	7,277,700	7,105,500	0.003	0.001	0.002	14,211	47.00	667,917
	BCR Total	37,700	10,155	8,750,900	8,440,600				27,194		1,278,118
30	Connecticut	10,261	3,388	1,406,500	1,269,500	0.007295	0.003	0.005	5,874	48.20	283,096
	Delaware	5,199	1,377	384,500	375,500	0.013521	0.004	0.010	3,700	48.20	178,350
	Maine	6,006	3,906	498,900	487,000	0.012038	0.008	0.004	1,957	48.20	94,312
	Maryland	13,427	3,738	1,615,400	1,351,800	0.008312	0.003	0.006	7,498	48.20	361,393
	Massachusetts	6,006	3,906	2,039,900	1,822,800	0.002944	0.002	0.001	1,461	48.20	70,409
	N. Hampshire	4,321	3,090	497,300	443,100	0.008689	0.007	0.002	760	48.20	36,634
	New Jersey	20,651	2,983	1,161,000	1,134,900	0.017787	0.003	0.015	17,204	48.20	829,199
	New York	7,908	2,707	226,700	174,300	0.034883	0.016	0.019	3,373	48.20	162,580
	Rhode Island	3,765	1,302	395,300	339,700	0.009524	0.004	0.006	1,933	48.20	93,189
	Virginia	3,979	1,079	284,252	256,300	0.013998	0.004	0.010	2,509	48.20	120,917
	BCR Total	81,523	27,476	8,509,752	7,654,900				46,268		2,230,080
	Total	3,073,339	2,244,008	244,947,953	251,409,119				986,475		20,814,976

[a] Estimated woodcock singing male population for the early 1970s (historic) and early 2000s (current) calculated using the methodology presented in the methods section.

[b] Total acreage of forest in each state by BCR region as estimated from the U.S. Force Service FIA program.

[c] Calculated by dividing the estimated population by the forest acreage for each time period.

[d] Difference between the historic and current effective densities.

[e] Calculated by multiplying the density deficit by current acreage of forest.

[f] Acres of habitat required to add one singing male to the population. Acreage was calculated by dividing the historic population estimate by the amount of early successional habitat from the early 1970s that occurred in each state by BCR region.

[g] Calculated by multiplying the population deficit by the habitat multiplier.

Table 4. Bird Conservation Region (BCR) habitat goals in relation to the total amount of forest on the landscape within each BCR.

BCR	Total forest (acres)	Habitat goal (acres)	% of total forest
11	519,679	3,999	0.77
12	77,619,282	3,483,977	4.49
13	23,592,700	3,582,293	15.18
14	63,484,982	4,006,044	6.31
22	5,876,196	714,615	12.16
23	14,363,381	1,511,517	10.52
24	4,235,992	509,126	12.02
27	2,533,138	496,951	19.62
28	43,088,269	2,998,256	6.96
29	8,440,600	1,278,118	15.14
30	7,654,900	2,230,080	29.13

Habitat creation that results from implementation of the woodcock plan should benefit other species that depend on young forest habitat such as ruffed grouse (*Bonasa umbellus*) and golden-winged warblers (*Vermivora chrysoptera*). As such, the habitat goals from the woodcock plan should be integrated with plans for other species as conservation plans are completed and made available for species requiring ESH. Cooperators can modify or adjust woodcock goals based on the habitat needs identified for other ESH-dependent species.

PLAN IMPLEMENTATION

One mechanism for implementing the woodcock habitat goals is through North American Habitat Joint Venture (JV) partnerships. Joint Ventures are regional partnerships that strive to deliver science-based bird conservation through cooperation between federal, state, local, and non-governmental partners (Association of Joint Venture Management Boards 2007). The key JVs within the woodcock range of the United States include the Upper Mississippi River and Great Lakes Region JV, Atlantic Coast JV, Prairie Pothole JV, Central Hardwoods JV, Lower Mississippi Valley JV, and the Gulf Coast JV. Future planning efforts should focus on integrating the woodcock habitat goals with other all-bird planning efforts being coordinated by the JVs. Effective communication through all-bird planning will enable managers to implement ESH projects in locations that will have minimal effect on species requiring different habitat types.

Potential partners for implementing the conservation plan include 1) forest products industry; 2) state and provincial natural resource agencies; 3) federal natural resource agencies; 4) counties and land trusts managing public forest land; 5) private conservation organizations (i.e., Ruffed Grouse Society); 6) private landowners; and 7) private forest management consultants. These cooperators, with input from other interested parties, should use the best available science to develop a set of best management practices (BMPs) for guiding "on the ground" habitat management. BMPs should be applied on demonstration areas distributed throughout the woodcock breeding range. Local population response to BMPs can be monitored at the demonstration areas, which will allow the efficacy of BMPs to be evaluated and modified using an adaptive approach. Demonstration areas will also serve as key outreach tools for educating private landowners and public land managers about habitat needs for ESH wildlife.

(Editors' note: Since the symposium, 3 regional woodcock initiatives have been created through the leadership of the Wildlife Management Institute. The initiatives are the Northern Forest Woodcock Initiative (BCR 14), the Appalachian Mountains Woodcock Initiative (BCR 28), and the Upper Great Lakes Woodcock and Young Forest Initiative (BCR 12 and 23). Each initiative has developed a set of Best Management Practices (BMPs) to guide management and has begun setting up a network of demonstration areas where BMPs are used to guide management decisions. In addition, partners in each initiative have developed a set of spatially explicit habitat suitability models to help guide implementation within each BCR. For more information about each of the initiatives, see www.timberdoodle.org).

ACKNOWLEDGMENTS

We thank J. R. Sauer (U.S. Geological Survey) for conducting analyses of Singing-ground Survey data and providing helpful comments during plan development. J. E. Fallon (U.S. Geological Survey) provided valuable GIS support. Personnel from the U.S. Forest Service provided assistance in interpretation of Forest Inventory Data. We thank the Wildlife Management Institute for providing partial funding for plan development and publication. Members of the Migratory Shore and Upland Game Bird Working Group of the Association of Fish and Wildlife Agencies provided helpful comments on early drafts of the plan. Finally, we thank the anonymous reviewers for providing helpful comments to improve the manuscript.

LITERATURE CITED

Association of Joint Venture Management Boards. 2007. U.S. Migratory Bird Joint Ventures: Partnerships in Action—Delivering Bird Conservation (fact sheet).

Dessecker, D. R., and D. G. McAuley. 2001. Importance of early successional habitat to ruffed grouse and American woodcock. Wildlife Society Bulletin 29: 456–465.

Cushwa, C. T., J. E. Barnard, and R. B. Barnes. 1977. Trends in woodcock habitat in the United States. Pages 31–38 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Gutzwiller, K. J., C. H. Strauss, K. R. Kinsley, J. S. Wakeley, and G. L. Storm. 1982. Relationships between land use and woodcock habitat in Pennsylvania, with guidelines for rangewide research. Pages 86–96 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14, Washington D.C., USA.

Hunter, W. C., D. A. Buehler, R. A. Canterbury, J. L. Confer, and P. B. Hamel. 2001. Conservation of disturbance-dependent birds in eastern North America. Wildlife Society Bulletin 29: 440–455.

Kelley, J. R., Jr., and R. D. Rau. 2006. American woodcock population status, 2006. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

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. Compiled by the Woodcock Task Force, Migratory Shore and Upland Game Bird Working Group, Association of Fish and Wildlife Agencies. Wildlife Management Institute, Washington, D.C., USA. <http://www.timberdoodle.org>.

North American Bird Conservation Initiative. 2000. Bird Conservation Region descriptions: A supplement to the North American Bird Conservation Initiative Bird Conservation Regions Map. <http://library.fws.gov/Bird_Publications/na_birdconservation_regdescrip00.pdf>.

Sauer, J. R., and J. B. Bortner. 1991. Population trends from the American woodcock singing-ground survey, 1970–88. Journal of Wildlife Management 55: 300–312.

Sauer, J. R., J. E. Hines, and J. Fallon. 2007. The North American breeding bird survey, results and analysis 1966–2006. Version 10.13.2007. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA

Straw, J. A., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–116 *in* T. C. Tacha and C. E. Braun, editors. Migratory Shore and Upland Game Bird Management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 1990. American woodcock management plan. U.S. Fish and Wildlife Service, Washington, D.C., USA.

U.S. Forest Service. 2010. Forest Inventory and Analysis National Program. <http://fia.fs.fed.us/> Accessed 3 March 2010.

Thomas R. Cooper (*left*) has been a biologist with the U.S. Fish and Wildlife Service, Division of Migratory Bird Management from 2006 to present. Since 2007, he has served as the Eastern Webless Migratory Game Bird Specialist for the Division. He was co-editor of the American Woodcock Conservation Plan and serves as the co-chair of the Woodcock Task Force under the direction of the Association of Fish and Wildlife Agencies' Migratory Shore and Upland Game Bird Working Group. Prior to working for the U.S. Fish and Wildlife Service, he worked as a habitat restoration biologist for the Minnesota Waterfowl Association. He received a B.S. in Biology (1993) from Bloomsburg University of Pennsylvania and an M.S. (1997) and Ph.D. (2005) in Wildlife and Fisheries Sciences from South Dakota State University.

James R. Kelley, Jr. (*right*) has been a biologist with the U.S. Fish and Wildlife Service, Division of Migratory Bird Management from 1991 to present. During 1991–2000 he served as a staff biologist focusing on waterfowl population dynamics and assessment. He served as the Eastern Webless Migratory Game Bird Specialist for the Division from 2000–2007. During this period he coordinated and was co-editor of the American Woodcock Conservation Plan. In 2007, he assumed duties as the Mississippi Flyway Representative where he serves as a liaison between the Service and the 14 state agencies within the Flyway. He received a B.S. in Wildlife Management from the University of Maine (1983) and an M.S. in Fisheries and Wildlife from the University of Missouri (1986).

Scot Williamson is Vice President of the Wildlife Management Institute, an organization of professional wildlife biologists chartered in 1911 to advance sound, science-based wildlife conservation. Scot has been with WMI since 1994 and has assisted Northeastern resource agencies and conservation groups on a number of wildlife and land management initiatives, including the Northeast Regional Conservation Needs Grant program, the Northeast Wildlife Damage Cooperative, and the Northern Forest Woodcock Initiative–the 2008 recipient of the Secretary of Interior's Cooperative Conservation Award. The WMI publication, "Feeding Wildlife, Just Say No!" was authored by Scot and received the Wildlife Society Conservation Education Award in 2003. Prior to WMI, Scot was Big Game Director for Texas Parks and Wildlife Department and White-tailed Deer Project Leader for NH Fish and Game. Scot received a MS in Wildlife Science from the University of Vermont and a Bachelor of Science in Forestry from the Pennsylvania State University.

Daniel R. Dessecker is the Director of Conservation Policy for the Ruffed Grouse Society. As such, he is responsible for the administration and development of the Society's conservation policy initiatives in North America. Dan received a B.S. in Wildlife Management (1981) from the University of Wisconsin–Stevens Point and a M.S. in Wildlife Management (1984) from the Pennsylvania State University. His professional interests include the historical and current roles of disturbance in forest ecology and he has published extensively on this and related topics. Dan is past-president of the Wisconsin Chapter of The Wildlife Society and served as Chair of the American Wildlife Conservation Partners in 2003. AWCP is a consortium of 44 national wildlife conservation organizations that work to affect wildlife and natural resource policy at the federal level. He was appointed in 2006 by then Secretary of the U.S. Department of the Interior, Gale Norton, to serve on the newly established Sporting Conservation Council. The 12-member Council was charged with providing guidance to the Secretaries of Agriculture and the Interior on issues related to wildlife conservation and hunting.

David Krementz received a B.S. in Wildlife Management and Conservation, a M.S. in Zoology and Physiology from University of Wyoming in 1977 and 1980, respectively, and a Ph.D. in Zoology from University of Western Ontario in 1984. After completing his doctorate, he served as a wildlife biologist for the U.S. Fish and Wildlife Service and then the U.S. Geological Survey at the Patuxent Wildlife Research Center from 1986–1999 where he studied waterfowl, woodcock and songbird population biology and habitat use. Currently, David is the Unit Leader of the USGS Arkansas Cooperative Fish and Wildlife Research Unit which he has held since 1999. David is a Past-President of the Arkansas State Chapter of the Wildlife Society.

William (Bill) L. Palmer is a retired Pennsylvania Game Commission Research Biologist. Bill received his M.S. from the Pennsylvania State University. His focus with the wildlife agency was habitat management/population relationships and he worked primarily with white-tailed deer, ruffed grouse, woodcock and mourning doves.

Dan McAuley is the Station Leader and Research Wildlife Biologist with the U.S. Geological Survey's Patuxent Wildlife Research Center, Orono, Maine field station. He has worked for Patuxent since 1978. Primary responsibility is to conduct field research on migratory bird issues identified by the U.S. Fish and Wildlife Service and other Department of Interior agencies. He has worked on American woodcock population ecology and conservation for the past 30 years, addressing issues related to population dynamics; ecology; spring, summer, and fall survival and habitat use; habitat change along woodcock Singing-ground Surveys routes; and the effects of hunting pressure on American survival of woodcock in Maine, New Hampshire, Vermont, and Pennsylvania. He is the Assessment and Research Coordinator for the American Woodcock Initiative and has helped to develop Best Management Practices for woodcock for the 4 regional woodcock initiatives. Current research includes studies on adaptive habitat management and habitat use of American woodcock in the Northeast, survival of American woodcock during fall migration using radio telemetry, as well as studies on survival and recruitment of common eiders using mark-recapture methods and band recovery analyses, and evaluating use of fixed-wing aircraft to survey red-necked phalaropes in the Bay of Fundy.

10th American Woodcock Symposium
Roscommon, Michigan, USA

THE NORTHERN FOREST WOODCOCK HABITAT INITIATIVE

SCOT J. WILLIAMSON[1], Wildlife Management Institute,
4426 VT Route 215 N, Cabot, VT 05647, USA

DANIEL G. MCAULEY, U. S. Geological Survey, Patuxent Wildlife Research Center-Orono,
5768 S. Annex A, Orono, ME 04469-5768, USA

GARY DONOVAN, International Paper Company,
PO Box 146, Holden, ME 04429, USA

Abstract: The most recent compilation of research and management needs for American woodcock (Straw et al. 1994) contains the recommendation to create regional habitat demonstration areas. To address the issue of loss of habitats important for woodcock and other high priority species, the Wildlife Management Institute has assembled the largest public/private coalition ever created to proactively address habitat improvement for woodcock. Twenty-five partners, ranging from private landowners to federal agencies, have signed on to an initiative designed to link improvements on public lands with widespread management gains on private lands. Major partners within the initiative include private forest landowners, the U.S. Fish and Wildlife Service, the U. S. Geological Survey, the Natural Resource Conservation Service, International Paper Company, state fish and wildlife agencies, and hunting and conservation NGO's. The Northern Forest Woodcock Habitat Initiative will provide technical assistance, labor and funding to create demonstration areas on state and federal lands that exemplify best management practices (BMPs) for American woodcock; monitor woodcock populations and habitat use before, during and after implementation of BMPs; and use demonstration areas as case histories within coordinated outreach efforts to inform and motivate private landowners. The initiative will also make available to private landowners technical assistance, labor and machinery to improve American woodcock habitat on their land. The Initiative has begun implementation in Bird Conservation Region 14, including New England and the Adirondacks of New York.

Proceedings of the American Woodcock Symposium 10: 27–28

Key words: American woodcock, Demonstration Areas, habitat management, Northern Forest Bird Conservation Region, population monitoring, population recovery, Best Management Practices.

Editors' Note: See www.timberdoodle.org for additional information about the Woodcock Habitat Initiative.

LITERATURE CITED

Straw, J. A., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–116 *in* T. C. Tacha and C. E. Braun, editors. Migratory Shore and Upland Game Bird Management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

---

[1] E-mail: wmisw@together.net

Scot Williamson is Vice President of the Wildlife Management Institute, an organization of professional wildlife biologists chartered in 1911 to advance sound, science-based wildlife conservation. Scot has been with WMI since 1994 and has assisted Northeastern resource agencies and conservation groups on a number of wildlife and land management initiatives, including the Northeast Regional Conservation Needs Grant program, the Northeast Wildlife Damage Cooperative, and the Northern Forest Woodcock Initiative—the 2008 recipient of the Secretary of Interior's Cooperative Conservation Award. The WMI publication, "Feeding Wildlife, Just Say No!" was authored by Scot and received the Wildlife Society Conservation Education Award in 2003. Prior to WMI, Scot was Big Game Director for Texas Parks and Wildlife Department and White-tailed Deer Project Leader for NH Fish and Game. Scot received a MS in Wildlife Science from the University of Vermont and a Bachelor of Science in Forestry from the Pennsylvania State University.

Not Pictured

Gary Donovan is a Certified Wildlife Biologist with 41 years of professional experience. In 1995, he retired from the Maine Department of Inland Fisheries and Wildlife where he held a variety of field and supervisory positions including the position of Wildlife Division Director for the last eight years of his 26+ year career with the agency. He then worked in the forest industry until 2006 as Manager of Wildlife Programs for International Paper's (IP) Lake States and Northeast Regions providing leadership and oversight for the conservation of non-timber resources and management of public-uses on IP's northern forest ownership. Gary is currently under contract with the Wildlife Management Institute as Habitat Management Coordinator for the Northern Forest and Appalachian Mountain Woodcock Initiatives.

Dan McAuley is the Station Leader and Research Wildlife Biologist with the U.S. Geological Survey's Patuxent Wildlife Research Center, Orono, Maine field station. He has worked for Patuxent since 1978. Primary responsibility is to conduct field research on migratory bird issues identified by the U.S. Fish and Wildlife Service and other Department of Interior agencies. He has worked on American woodcock population ecology and conservation for the past 30 years, addressing issues related to population dynamics; ecology; spring, summer, and fall survival and habitat use; habitat change along woodcock Singing-ground Surveys routes; and the effects of hunting pressure on American survival of woodcock in Maine, New Hampshire, Vermont, and Pennsylvania. He is the Assessment and Research Coordinator for the American Woodcock Initiative and has helped to develop Best Management Practices for woodcock for the 4 regional woodcock initiatives. Current research includes studies on adaptive habitat management and habitat use of American woodcock in the Northeast, survival of American woodcock during fall migration using radio telemetry, as well as studies on survival and recruitment of common eiders using mark-recapture methods and band recovery analyses, and evaluating use of fixed-wing aircraft to survey red-necked phalaropes in the Bay of Fundy.

ESTIMATING WOODCOCK HUNTER ACTIVITY AND HARVEST IN THE UNITED STATES

PAUL I. PADDING[1], U.S. Fish and Wildlife Service, Division of Migratory Bird Management,
10815 Loblolly Pine Drive, Laurel, MD 20708, USA

MARY T. MOORE, U.S. Fish and Wildlife Service, Division of Migratory Bird Management,
206 Concord Drive, Watkinsville, GA 30677, USA

KENNETH D. RICHKUS, U.S. Fish and Wildlife Service, Division of Migratory Bird Management,
10815 Loblolly Pine Drive, Laurel, MD 20708, USA

ELWOOD M. MARTIN, U.S. Fish and Wildlife Service, Division of Migratory Bird Management,
10815 Loblolly Pine Drive, Laurel, MD 20708, USA

Abstract: From 1964–2001, the U.S. Fish and Wildlife Service (USFWS) conducted annual surveys that estimated American woodcock (*Scolopax minor*) harvest in the United States. Because those surveys were based on samples of federal duck stamp purchasers, estimates represented only the harvest of woodcock by waterfowl hunters. To remedy this problem, state wildlife agencies and the USFWS established the cooperative state-federal migratory bird Harvest Information Program (HIP). HIP requires state wildlife agencies to annually collect the name and address of every licensed migratory bird hunter in their state as well as answers to a series of screening questions. For the HIP woodcock harvest survey, about 15,000 hunters are sent diary forms to record the date, state, county, and bag of each woodcock hunt. Although 1999–2001 HIP estimates of active woodcock hunters and woodcock harvest were about double the estimates obtained from the previous survey system, comparisons suggest that the 1964–2001 survey results provided reliable indices that reflected trends accurately. HIP harvest estimates at the management unit level had 95% confidence intervals that were about 25% of the point estimates.

Proceedings of the American Woodcock Symposium 10: 29–35

Key words: American woodcock, harvest, Harvest Information Program, harvest surveys, hunting activity, *Scolopax minor.*

The U.S. Fish and Wildlife Service (USFWS) has conducted a national migratory bird harvest survey annually since 1952. The survey initially was established only to estimate annual waterfowl hunting activity and harvest, but it was expanded in 1964 to include other migratory game birds, including American woodcock (Martin 1979). The original survey's sample frame consisted of all people who purchased the Federal Migratory Bird Hunting and Conservation Stamp, commonly known as the federal duck stamp. Only waterfowl hunters 16 years of age and older must purchase the stamp; thus, woodcock hunters who did not hunt waterfowl were excluded from the sample frame each year. Woodcock harvest estimates derived from the federal duck stamp-based national harvest survey only represent indices of woodcock harvest in the United States (Martin 1979).

This deficiency was recognized soon after the survey's inception (Tautin et al. 1989) and migratory game bird researchers and managers repeatedly called for establishing a new national survey with a sample frame that included all migratory game bird hunters (e.g., Owen et al. 1977, Tautin et al. 1989). Their recommendations resulted in several attempts to establish a federal permit system similar to Canada's, where hunters of any migratory game bird species must possess a Canada Migratory Game Bird Permit that is administered by the federal government (Cooch et al. 1978). None of those attempts, which included several bills introduced to the U.S. Congress (Tautin et al. 1989), were successful. The problem was rectified in 1992 when the national migra-

---

[1] E-mail: paul_padding@fws.gov

tory bird Harvest Information Program (HIP) was established by the USFWS and state wildlife agencies (Elden et al. 2002).

The HIP is a cooperative, state-federal program that requires all licensed migratory bird hunters to register annually with each state in which they hunt migratory game birds. Hunters who are exempt from state licensing requirements may also be exempt from the HIP registration requirement. Sheriff et al. (2002) reported that 41 states do not require certain groups of hunters to possess a state hunting license; 32 of those states extend the exemption to include the HIP requirement. The most common license exemptions are for junior hunters, senior hunters, and landowners hunting on their own property. Of these, we believe that seniors are most likely to be woodcock hunters. Only 11 states exempt seniors from the HIP requirement (Sheriff et al. 2002), therefore we believe that the HIP excludes few woodcock hunters.

Every state wildlife agency is responsible for annually obtaining the name and address of each licensed migratory bird hunter in the state and forwarding that information to the USFWS. This provides the USFWS with a nearly complete sample frame for national migratory game bird harvest surveys, including one that specifically targets woodcock hunters. It is used to estimate the number of active U.S. woodcock hunters, how many days they hunt, and how many woodcock they harvest each year. All states in the continental United States have participated in this program since 1998, and the surveys have been conducted nationwide since 1999.

Our objectives for this paper were to summarize woodcock hunting activity and harvest estimates derived from the federal duck stamp-based survey from 1964–2001 and from the HIP woodcock survey from 1999–2005, compare the results of the 2 survey systems during the 3 years during which we conducted both surveys (1999–2001), and evaluate the potential of duck stamp-based estimates as indices of long-term trends.

METHODS

Federal Duck Stamp-based Survey

The U.S. Postal Service provided the USFWS an annual report of how many federal duck stamps were sold the previous year at each of about 16,000 post offices that sold the stamps. The USFWS stratified the post offices by state and post office size, and randomly selected 3,000–4,000 of them for the sample each year. At the selected post offices, postal clerks were asked to give a postage-paid name and address form (post card) to each person who bought a federal duck stamp, and ask the purchaser to fill out the form and mail it to the USFWS (Martin and Carney 1977). Thus, each sampled post office was a cluster sample of federal duck stamp purchasers (Geissler 1990).

Duck stamp purchasers who completed and mailed the name and address forms constituted the harvest survey's sample of hunters. At the end of the waterfowl hunting season, each hunter in the sample was sent a self-administered mail questionnaire that asked about his or her hunting activity for the season. About a month after that mailing, a second request and survey was sent to those hunters who had not responded. Martin and Carney (1977) detailed the survey methods, and Geissler (1990) described the data analysis methods.

Beginning in 1964, the survey included a question that asked whether the person hunted woodcock and, if so, how many woodcock that person bagged. Hunters' answers provided estimates of the proportion of active woodcock hunters among duck stamp purchasers in each state and the mean number of woodcock harvested by those hunters. The parameters were estimated without adjustments for response and nonresponse bias (Martin 1979). State-specific estimates of active woodcock hunters and their harvest were calculated by expanding the proportions and means using federal duck stamp sales for the state. Regional estimates were obtained by summing the appropriate state-specific totals. We used locally weighted regression (lowess) curves (Cleveland and Devlin 1988) to examine long-term trends in hunter activity, harvest, and hunter success. Lowess lines fit a pattern to the majority of the estimates and help identify points that deviate from the pattern. Lowess analysis (PROC LOESS) allows great flexibility because no assumptions about the parametric form of the regression model are needed (SAS Institute Inc. 1999).

HIP Woodcock Harvest Survey

The HIP woodcock survey sample frame consisted of hunters who identified themselves as potential migratory bird hunters when they purchased state hunting licenses. People who hunted migratory birds in more than 1 state had to comply with the HIP requirement in each state in which they hunted. Thus, the HIP sample frame was specific to each state. Each year, the states began sending the USFWS the sample frame data in August and continued sending data from new license sales twice per month until the end of the last migratory bird hunting season.

The states also were required to ask migratory bird hunters a series of questions about the species they hunted and their hunting success the previous year; we used this information as a predictor of current-year hunting activity and success. We assigned each hunter to a success stratum for woodcock based on his or her response to the question, "How many woodcock did you shoot last season? None, 1–30, or more than 30." For sampling purposes, we combined "1–30" and "more than 30" responses into a single stratum because less than 0.5% of the hunters responded "more than 30." States in which less than 1% of the migratory bird hunters hunted woodcock simplified the question to, "Did you hunt woodcock last season? Yes or no." The stratification enabled us to maximize sampling efficiency by applying high sampling rates (e.g., 5% in Wisconsin and 20% in New Hampshire) to the small group of active/successful hunters and much lower rates (e.g., 0.2% in Wisconsin and 1% in New Hampshire) to the very large group of hunters who rarely, if ever, hunt woodcock.

State-specific sampling rates were established prior to the first sample selection in August. We established the sampling rates based on the number of migratory bird hunter name and address records that we expected from each state and the state-specific sample sizes needed to obtain desired precision levels. Depending on the number of names and addresses provided, the sample sizes for each state were adequate, inadequate, or excessive. We adjusted sampling rates annually in an attempt to maximize precision and minimize cost.

The goal of HIP surveys was to reduce or eliminate several common sources of survey bias while maximizing survey response rates. A daily hunting diary format was used to reduce memory and prestige bias, both of which result in overestimation (Atwood 1956). Hunters selected for the woodcock survey were asked to record the date of each hunt, the state and county where they hunted that day, and their daily bag. They also were asked to report the number of days they hunted woodcock, their seasonal bag, and the number of birds they knocked down but were unable to retrieve. Thus hunters provided useful data even if they forgot to record their daily hunting information or if they did not receive the form until after the hunting season began. Participation in the survey was voluntary.

The surveys were conducted using Dillman's Total Design Method for mail surveys (Dillman 1978, Dillman 1991). This is a survey implementation method designed to maximize survey response rates and ensure quality and timely responses. The survey packet consisted of 1) a personalized letter that explained the purpose of the survey, instructions for completing the survey, and why participation was vital to the survey's success, 2) the diary-format survey, and 3) a postage-paid envelope for returning the survey to the USFWS at the end of the hunting season. Soon after the initial batch of names and addresses was received from a state, we selected stratified samples according to the predetermined sampling rates. We mailed the first survey forms to selected hunters just prior to the start of the state's woodcock hunting season. The sample selection and initial mailing process continued for each subsequent batch of names and addresses (roughly twice per month) with the last initial mailing occurring on or shortly after the day the state's woodcock season closed. For all hunters who received their initial packets before the hunting season ended, we sent reminder postcards at the close of the season asking hunters to return their completed survey forms. For hunters who received the initial packet after the close of the hunting season, a reminder postcard was mailed approximately 1 week after the initial packet. About 3 weeks after the reminder postcard, we sent a follow-up packet via regular mail to hunters who had not responded. Finally, about 4 weeks later, we sent another follow-up packet to the remaining non-respondents.

When we received hunters' responses, we summarized each record as the total reported number of days afield, birds bagged (retrieved kill), and birds knocked down but not retrieved (unretrieved kill) for the entire season in the sample state. We then applied standard statistical analysis methods for stratified samples (Cochran 1977, Steel and Torrie 1980) to those state-specific season totals to obtain estimates of harvest and hunter activity for each state. For each stratum, we estimated the mean number of days hunted, mean retrieved kill, and mean unretrieved kill and their respective variances. In addition, we calculated the proportion of active hunters (hunted at least once) and its variance for each stratum. Then, combining the stratum-specific means and variances with the number of hunters in each stratum, we estimated stratum- and state-level totals for days afield, retrieved kill, and unretrieved kill and their variances. We also estimated state-level totals of active hunters and their variances, by combining the stratum-specific proportions with the number of hunters in the appropriate stratum.

We calculated management unit-level and national estimates of total days afield, retrieved kill, and unretrieved kill by summing the state-level estimates. However, we were unable to estimate directly the number of active hunters at the management unit and national levels because some people hunted in more than 1 state. Although we reported the sum of the state-level active hunter estimates, those sums include some duplication and therefore were biased high.

RESULTS

The annual nationwide sample for the federal duck stamp-based survey ranged from about 40,000–100,000 duck stamp purchasers and the response rate was typically about 65%. Kelley (2003) presented the year-, state-, and management unit-specific woodcock hunter activity and harvest estimates for 1964–2001, the entire

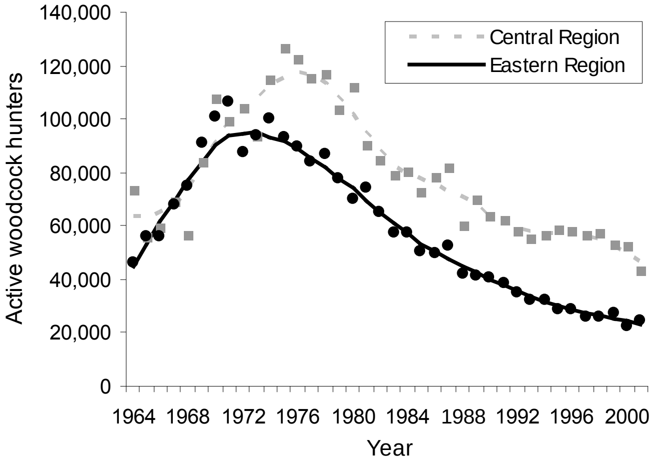


Figure 1. Long-term trends in woodcock hunter numbers derived from the federal duck stamp-based harvest survey, 1964–2001.

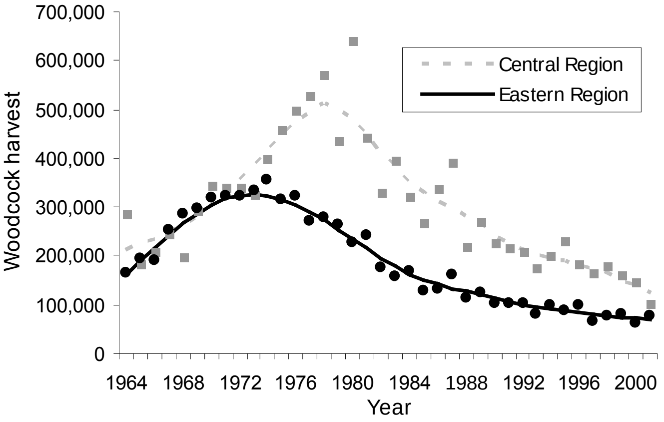


Figure 2. Long-term trends in woodcock harvest estimates derived from the federal duck stamp-based harvest survey, 1964–2001.

period during which the survey was conducted. The number of active woodcock hunters among duck stamp purchasers in the Eastern Region peaked in the early 1970s, then gradually declined for the rest of the time series (Figure 1). The long-term trend was similar in the Central Region, except the peak occurred in the mid-1970s. Although long-term trends in woodcock harvest tracked the active hunters trends in both regions (Figure 2), hunter success trends seemed to differ between regions. Seasonal harvest per active hunter declined slightly in the Eastern Region from 3.5 birds per hunter before stabilizing at about 3 birds per hunter in the mid-1980s (Figure 3). In contrast, hunter success in the Central Region reached a peak of about 4.5 birds per hunter in the late 1970s, followed by a gradual decline to <3 birds per hunter by the early 2000s. Hunter success also was more variable in the Central Region.

Sample sizes for the 1999–2005 HIP woodcock harvest surveys ranged from about 12,000–22,000 and annual response rates were about 60%. Although this time series was insufficient for examining long-term trends, survey results provided harvest estimates based on a much more complete sample frame (Table 1). The year-to-year changes in active hunters (Figure 4) and harvest (Figure 5) were similar for both surveys even though the HIP estimates were about twice that of the federal duck stamp-based ones. The duck stamp-based survey estimated somewhat greater success per hunter in the Eastern Region than the HIP survey did, but the 2 sets of harvest-per-hunter estimates were similar for the Central Region (Figure 6).

DISCUSSION

Harvest surveys require complete sampling frames to ensure that (1) the sample of hunters is representative of the target population, and (2) estimates derived from the sample are expanded to the entire population

Table 1. Woodcock harvest estimates and 95% confidence intervals (CI) derived from the Harvest Information Program's woodcock survey, 1999–2005.

	Region			
	Eastern		Central	
Year	Harvest estimate	95% CI	Harvest estimate	95% CI
1999	129,400	33,600	315,400	85,200
2000	97,900	24,500	293,000	73,200
2001	111,600	31,200	230,300	55,300
2002	71,000	19,000	194,500	44,800
2003	89,200	28,500	213,500	49,100
2004	61,500	12,900	234,800	47,000
2005	72,200	11,600	225,000	42,800

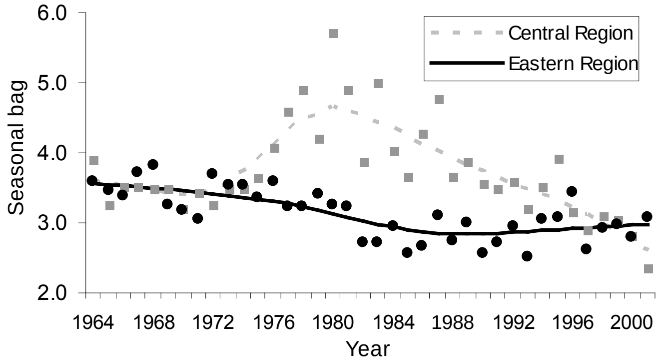


Figure 3. Long-term trends in mean seasonal woodcock bag derived from the federal duck stamp-based harvest survey, 1964–2001.

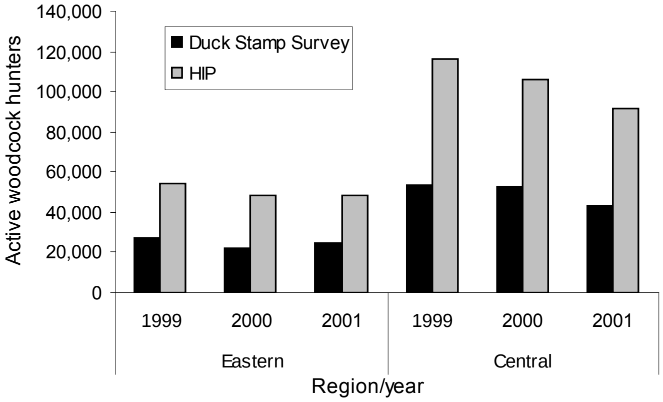


Figure 4. Comparison of woodcock hunter estimates from the federal duck stamp-based harvest survey and the Harvest Information Program woodcock harvest survey.

of hunters. An incomplete sampling frame causes non-coverage error (Dillman 1991) that, in the case of harvest surveys, results in underestimating hunter activity and harvest. Recognizing that federal duck stamp purchasers represented only a fraction of woodcock hunters, Clark (1972) estimated that the federal duck stamp-based survey captured less than half of the total woodcock harvest in the United States. Our comparisons of the 1999–2001 HIP and duck stamp-based survey results suggested that the latter survey's estimates probably represented about half of the active woodcock hunters and their harvest.

Comparisons also illustrated nearly identical changes in active hunters and harvest from year to year. We believe this strongly suggests that the federal duck stamp-based survey provided accurate annual indices of hunter activity and harvest for those 3 years. However, the comparison took place when federal duck stamp sales were high (Martin and Padding 2002) due to abundant duck populations. It is possible that more of the nation's woodcock hunters bought duck stamps during those years than they did when duck populations and duck stamp sales were low, as they were in the late 1980s and early 1990s, for example. If that occurred, then the duck stamp-based survey estimates represented a smaller proportion of the true number of hunters and their harvest during years of lower duck stamp sales, and a larger proportion during years when more duck stamps were sold. Because we found no evidence of this, we strongly suspect that the long-term patterns indicated by that survey's results accurately reflected trends in woodcock hunter numbers and harvest.

The USFWS discontinued the federal duck stamp-based survey after the 2001 hunting season, replacing it permanently with HIP surveys. The primary intent of the HIP was to provide the USFWS with complete sampling frames of all types of migratory bird hunters rather than just waterfowl hunters. Although the HIP sampling frame theoretically includes all woodcock hunters, HIP

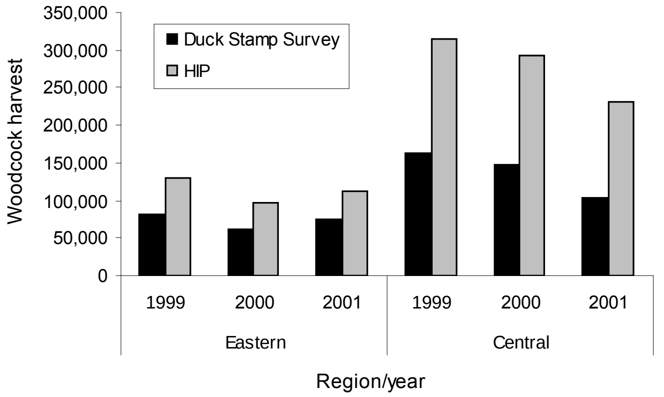


Figure 5. Comparison of woodcock harvest estimates from the federal duck stamp-based harvest survey and the Harvest Information Program woodcock survey.

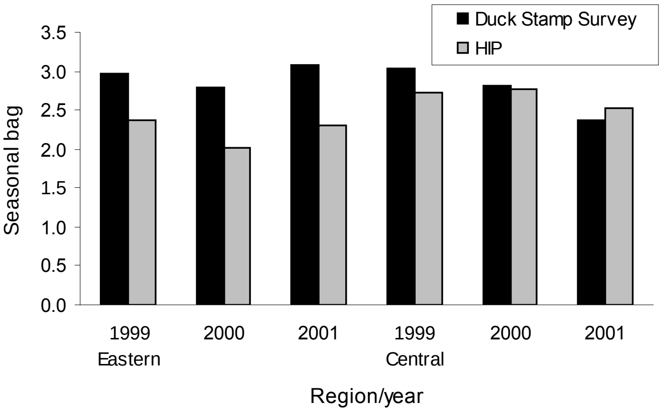


Figure 6. Comparison of mean seasonal woodcock bag estimates from the federal duck stamp-based harvest survey and the Harvest Information Program woodcock survey.

woodcock hunter activity and harvest estimates can only be accurate if all woodcock hunters comply with the legal requirement that they register for the HIP. Before the program was fully implemented nationwide, there were some indications that not all woodcock hunters were registering for the HIP (Padding et al. 2002). But since then, most states have clarified and enforced the HIP registration requirement. We believe that current compliance rates are high (USFWS, Division of Migratory Bird Management, unpublished data). Thus, we also believe that the annual HIP woodcock harvest surveys are producing reliable estimates of hunter activity and harvest.

MANAGEMENT IMPLICATIONS

If the federal duck stamp-based estimates of woodcock hunters and harvest represent reliable indices, then the 3 years during which we conducted both surveys concurrently could provide the basis for converting those indices into accurate estimates. Those estimates could be used to examine the effects of changes in hunting regulations, such as season length and daily bag limits, on harvest. Furthermore, accurate estimates of woodcock harvest and hunter effort also could provide key elements to future woodcock population modeling efforts that are used to assess population trends and harvest potential.

LITERATURE CITED

Atwood, E. L. 1956. Validity of mail survey data on bagged waterfowl. Journal of Wildlife Management 20: 1–16.

Clark, E. R. 1972. Woodcock status report, 1971. U.S. Fish and Wildlife Service Special Scientific Report No. 153.

Cleveland, W. S., and S. J. Devlin. 1988. Locally weighted regression: an approach to regression analysis by local fitting. Journal of the American Statistical Association 83: 596–610.

Cochran, W. G. 1977. Sampling Techniques. Third edition. Wiley and Sons, New York, New York, USA.

Cooch, F. G., S. Wendt, G. E. J. Smith, and G. Butler. 1978. The Canada migratory gamebird hunting permit and associated surveys. Pages 8–39 *in* H. Boyd and G. Finney, editors. Migratory game bird hunting in Canada. Canadian Wildlife Service Report Series No. 43.

Dillman, D. A. 1978. Mail and telephone surveys: the Total Design Method. Wiley and Sons, New York, New York, USA.

Dillman, D. A. 1991. The design and administration of mail surveys. Annual Review of Sociology 17: 225–249.

Elden, R. C., W. V. Bevill, P. I. Padding, J. E. Frampton, and D. L. Shroufe. 2002. A history of the development of the Harvest Information Program. Pages 7–16 *in* J. M. Ver Steeg and R. C. Elden, compilers. Harvest Information Program: evaluation and recommendations. International Association of Fish and Wildlife Agencies, Migratory Shore and Upland Game Bird Working Group, Washington, D.C., USA.

Geissler, P. H. 1990. Estimation of confidence intervals for federal waterfowl harvest surveys. Journal of Wildlife Management 54: 201–205.

Kelley, J. R., Jr. 2003. American woodcock population status, 2003. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Martin, E. M., and S. M. Carney. 1977. Population ecology of the mallard IV: a review of duck hunting regulations, activity, and success, with special reference to the mallard. U.S. Fish and Wildlife Service Resource Publication 130.

Martin, E. M. 1979. Hunting and harvest trends for migratory game birds other than waterfowl: 1964–76. U.S. Fish and Wildlife Service Special Scientific Report No. 218.

Martin, E. M., and P. I. Padding. 2002. Preliminary estimates of waterfowl harvest and hunter activity in the United States during the 2001 hunting season. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Owen, R. B., Jr, J. M. Anderson, J. W. Artmann, E. R. Clark, T. G. Dilworth, L. E. Gregg, F. W. Martin, J. D. Newsom, and S. R. Pursglove, Jr. 1977. American woodcock (*Philohela minor* = *Scolopax minor* of Edwards 1974). Pages 149–186 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Padding, P. I., S. M. Barton, L. R. Lange, R. D. Games, R. C. Boyd, P. T. Seng, and D. A. Shipes. 2002. The scope and impact of hunter non-compliance with the Harvest Information Program. Pages 39–46 *in* J. M. Ver Steeg and R. C. Elden, compilers. Harvest Information Program: evaluation and recommendations. International Association of Fish and Wildlife Agencies, Migratory Shore and Upland Game Bird Working Group, Washington, D.C., USA.

SAS Institute Inc. 1999. SAS Online Doc®, Version 8. SAS Institute Cary, North Carolina, USA.

Sheriff, S. L., J. H. Schulz, B. D. Bales, M. T. Moore, P. I. Padding, and D. A. Shipes. 2002. The current reliability of Harvest Information Programsurveys. Pages 51–68 *in* J. M. Ver Steeg and R. C. Elden, compilers. Harvest Information Program: evaluation and recommendations. International Association of Fish and Wildlife Agencies, Migratory Shore and Upland Game Bird Working Group, Washington, D.C., USA.

Steel, R. G., and J. H. Torrie. 1980. Principles and Procedures of Statistics. McGraw-Hill, New York, New York, USA.

Tautin, J., S. M. Carney, and J. B. Bortner. 1989. A national migratory gamebird harvest survey: a continuing need. Transactions of the North American Wildlife and Natural Resources Conference 54: 545–551.

Mary T. Moore received a B.S. in Environmental Studies from the University of Maine in 1979 and a Master of Life Science and a Master of Statistics from North Carolina State University in 1986. She worked as a research associate at the University of Florida from 1986–1992 in the Department of Statistics, and from 1992–2008 she served as a statistician with the Division of Migratory Bird Management, U.S. Fish and Wildlife Service in the Branch of Harvest Surveys where she was involved in the national implementation of the Migratory Bird Harvest Information Program and provided statistical and survey sampling expertise on all surveys conducted by the Branch. She is currently a research analyst with the University of Georgia in Athens, GA.

Paul I. Padding (center) received an M.S. and a Ph.D. in wildlife biology from Michigan State University. He joined the U.S. Fish and Wildlife Service's Division of Migratory Bird Management as a wildlife biologist in 1991 and served as the chief of the Division's Branch of Harvest Surveys from 1994–2007, overseeing the nationwide implementation of the Migratory Bird Harvest Information Program. He currently serves as the Atlantic Flyway Representative.

Kenneth D. (Ken) Richkus (right) is a wildlife biologist with the U.S. Fish and Wildlife Service's Division of Migratory Bird Management at Patuxent Research Refuge in Laurel, Maryland. He received his B.S. degrees in biology, and forestry and wildlife science (wildlife science option) from Virginia Tech, and his Ph.D. in wildlife and fisheries science from Louisiana State University. His professional interests include all aspects of migratory bird ecology and management. In his free time, Ken enjoys hunting and fishing.

Elwood M. (Woody) Martin (left) retired after a 44-year career as a wildlife biologist with the U.S. Fish and Wildlife Service's Division of Migratory Bird Management at the Patuxent Wildlife Research Center in Laurel, Maryland. He received both his B.S. and M.S. degrees from Iowa State University, with the latter degree earned in wildlife management through the Iowa Cooperative Wildlife Research Unit. His lifelong interest in wildlife in general and birds in particular (with emphasis on waterfowl and raptors) ranges from bird watching to volunteering for various bird surveys and banding studies that still keep him active in retirement.

MONITORING OF THE EUROPEAN WOODCOCK POPULATIONS, WITH SPECIAL REFERENCE TO FRANCE

10th American Woodcock Symposium
Roscommon, Michigan, USA

YVES FERRAND [1], Office national de la chasse et de la faune sauvage, CNERA Avifaune Migratrice,
BP 20 St-Benoist, 78612 Le-Perray-en-Yvelines cedex, France

PHILIPPE AUBRY, Office national de la chasse et de la faune sauvage, Direction des études et de la recherche,
BP 20 St-Benoist, 78612 Le-Perray-en-Yvelines cedex, France

FRANÇOIS GOSSMANN, Office national de la chasse et de la faune sauvage, CNERA Avifaune migratrice,
39 Bd Albert Einstein, CS 42355, 44323 Nantes Cedex 3, France

CLAUDINE BASTAT, Office national de la chasse et de la faune sauvage, CNERA Avifaune migratrice,
39 Bd Albert Einstein, CS 42355, 44323 Nantes Cedex 3, France

MICHEL GUÉNÉZAN, Office national de la chasse et de la faune sauvage, CNERA Avifaune migratrice,
39 Bd Albert Einstein, CS 42355, 44323 Nantes Cedex 3, France

Abstract: The woodcock (*Scolopax rusticola*) breeds in, winters in, or migrates through all European countries. Successful management of sustainable exploitation requires data collection to monitor breeding and wintering population trends and other demographic parameters. Four countries have collected data during the breeding period, and 2 countries have collected data during the wintering period. The analysis of abundance indices shows stable breeding and wintering numbers. A more detailed interpretation of trends requires additional information on demographic parameters. Wing collection provides an estimate of the proportion of woodcock young that are harvested in 4 countries. This allows us to detect spring seasons with low breeding success. Finally, information on harvest is provided by annual or periodical surveys in some European countries. The actions developed to monitor the European woodcock populations in the Western Palearctic region may appear to be incomplete and heterogeneous from one country to another, due to variations in culture, economy, and hunting practices. Future objectives should focus on completing the panel of monitoring actions and collecting more information on the habitat trends.

Proceedings of the American Woodcock Symposium 10: 37–44

Key words: European woodcock, monitoring, Europe, France.

Sustainable exploitation is a common goal for agencies managing game species, but the ways to reach this objective depend on knowledge of the species concerned (Sutherland 2001). Successful implementation of sustainable exploitation requires both quantitative data (population size changes) and explanatory factors (demographic parameters, environmental changes) to explain how and why populations fluctuate and how human exploitation impacts those fluctuations (Sutherland 2001). The integrated monitoring concept combines multiple data sources to monitor population variables and identify factors that cause change in population variables (Baillie 1990). We apply a similar approach to the European woodcock populations.

The European woodcock is an important quarry species throughout Europe. The Eupropean woodcock breeds in northern and eastern Europe and breeds and winters in southern and western Europe (Cramp and Simmons 1983). The annual European harvest has been estimated at 3 million to 4 million birds (Ferrand and Gossmann 2001) primarily in Italy, Greece, and France (Ferrand and Gossmann 2000*a*). Current estimates suggest these countries represent about 90% of the annual European harvest, but we consider this to be an overestimate because of the lack of data from the Iberian Peninsula where woodcock hunting is popular.

---

[1] E-mail: y.ferrand@oncfs.gouv.fr

Table 2. Decision rules to classify woodcock breeding number trends account for both the trend of the proportion of positive sites and the trend of the proportion of high abundance sites.

Trend of the proportion of high abundance sites (number of contacts ≥5)	Trend of the proportion of positive sites (number of contacts ≥1)		
	Increase	**Stability**	**Decrease**
Increase	Certain increase	Possible increase	Stability
Stability	Possible increase	Stability	Possible decrease
Decrease	Stability	Possible decrease	Certain decrease

As a result of increasing interest in woodcock hunting, especially in the southwestern part of its wintering range, some European countries have launched monitoring programs. We focus on woodcock populations living in Europe, of which a small part winter in North Africa (Wetlands International 2002). Recent banding analyses have shown that there are 2 migratory flyways in Europe (Bauthian et al. 2007). The Feno-Scandinavian flyway includes woodcock that breed in Norway, Sweden, Finland, and Denmark and winter mainly in the British Isles and northwestern France. The Eastern flyway includes woodcock that breed in Russia and central Europe and winter mainly in southwestern France, the Atlantic coast of the Iberian peninsula, and in the Mediterranean regions. The Baltic Sea separates the 2 flyways. During migration and wintering, the 2 flyways overlap in the western part of France, but only the eastern flyway is represented in southeastern France. Genetic analysis in progress has failed to demonstrate the existence of different populations in Europe (Cardia 2004). Genetic structure seems rather to be continuous across the continent.

Survival rate estimation is presented elsewhere (Tavecchia et al. 2002; Bauthian et al. 2006) but we present here methods used to monitor population size and distribution and breeding success. We present the methods used, their results, and also the difficulties encountered due to woodcock biology, the constraints in data collection, and the diversity in hunting practices. We focus on monitoring efforts in France where the woodcock monitoring program is the most complete.

METHODS

Monitoring Breeding Woodcock

The method for monitoring breeding woodcock based on the observation of singing males has been described in Ferrand (1993). This observation takes place in May and June at listening points in a randomly selected sample of 10% of potential roding (singing or displaying) sites (90% forested 280-ha squares). The listening point is the centre of the site. The number of contacts of roding males per point (n) have been used to determine 2 classes of abundance (low abundance: $1 < n \leq 4$; high abundance: $n \geq 5$; Ferrand 1993). The trend of the proportion in positive sites ($n \geq 1$) is tested to detect any temporal variation in spatial occupation. The trend is analyzed in 10-year periods and for a constant geographical area (French *départments*, where observations were carried out without interruption). The qualitative assessment of the trend in breeding woodcock numbers is based on a 3x3 table of decision rules (Table 2), which assumes an increasing or decreasing breeding population if the proportion of both positive and high-abundance sites increases or decreases, respectively. In all other cases, no trend is clearly defined. Every 4 to 5 years, observations are carried out in all French *départments* to detect a possible extension of the breeding area.

This method has been applied in France since 1992 (Ferrand and Gossmann 2000*b*) and in western Switzerland since the early 1990s (Estoppey 2001). A similar survey has been carried out in Russia since 2000 after local adjustments (randomization applied on 12x2 km and 24x24 km quadrants).

In Great Britain, a survey to estimate the total number of breeding woodcock was carried out in 2003 (Hoodless et al. 2004). This was based on the census of roding males at randomly chosen sites in different types of habitat using a stratified sampling design. The relationship between the contacts and the number of different males was calculated for different types of habitat on the basis of acoustic analysis (Ferrand 1987). The breeding Eurasian woodcock population in Britain was estimated at 78,346 males (Hoodless et al. 2009).

Monitoring Wintering Woodcock

Three indices are calculated for the monitoring of wintering woodcock. The first is based on data collected during nocturnal banding trips. A nocturnal index of abundance (IAN) is defined as the number of observations per hour per trip (Ferrand et al. 2006). The other indices are calculated from hunting data. The ICP repre-

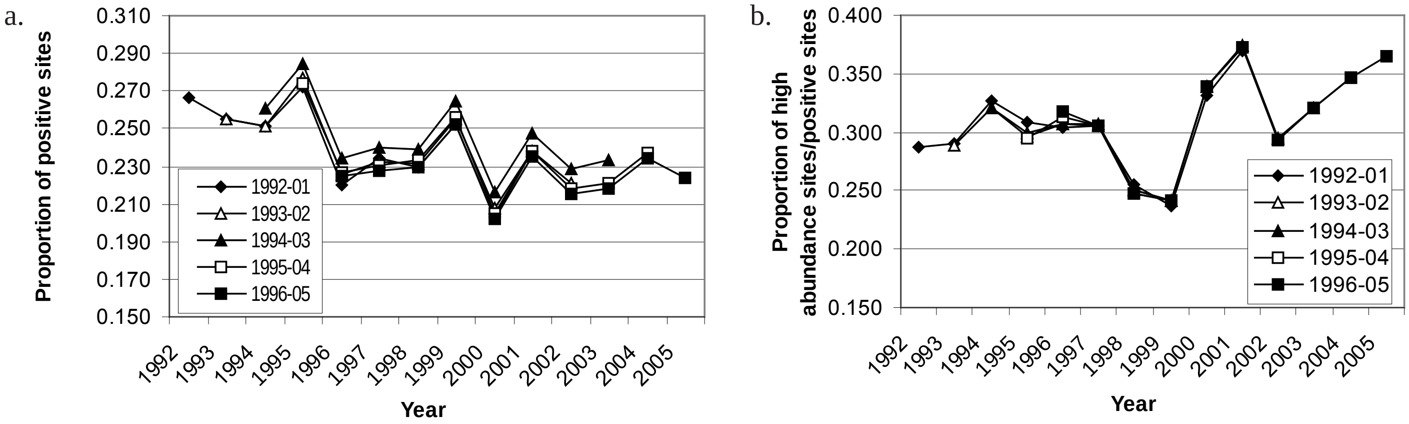


Figure 1. Interannual variations in the proportion of positive sites (a) and of high-abundance sites/positive sites (b) from roding data collected in France from 1992-2005 expressed in five 10-year periods.

sents the number of woodcock shot per standardized hunting trip (i.e., 3.5 hours), and the ICA represents the number of woodcock seen per standardized hunting trip (Cau and Boidot 2006). ICP and ICA have been applied only in France since 1996–97. Winter counts based on nocturnal banding were performed in 1994 and 1996 in Great Britain but no trend is available.

Estimating Annual Recruitment

The woodcock is a species much too secretive for an accurate brood census in spring-summer. The only way to estimate the annual recruitment is to determine the proportion of first-year birds in counts of banded or bagged woodcock. Woodcock banding is mainly performed at night at feedings sites during migration and wintering periods (Gossmann et al 1988). France is the only country that bands sufficient woodcock to support recruitment analyses (Gossmann et al 2005). Wing collections provide data for Denmark (Clausager 2006), France (ONCFS and *Club national des bécassiers*), Ireland (L. Taaffe, National Woodcock Association of Ireland, personal communication) and Italy (Spano and Galli 2000) over at least 15 years.

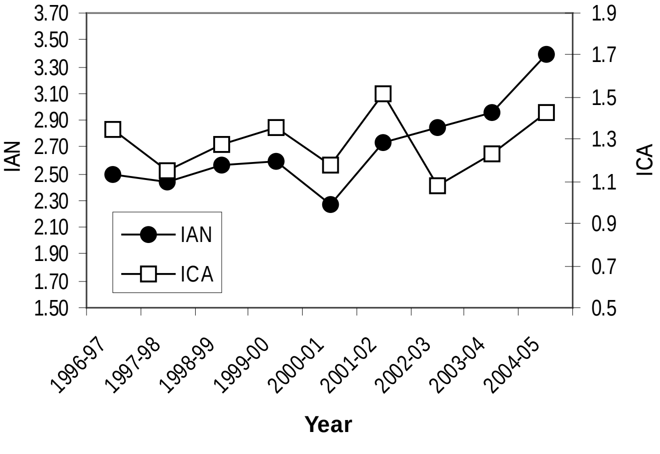


Figure 2. Interannual variations of IAN (nocturnal index of abundance) and ICA (number of woodcock seen per standardized hunting trip) (source: *Club national des bécassiers*) in France, 1996–2005.

STATISTICAL ANALYSIS

We looked for temporal trends in the breeding and wintering woodcock populations. We tested the trend in breeding population abundance with the Cochran-Armitage statistic (Armitage et al. 2002) applied to a 2 x *k* contingency table with the number of positive sites and negative sites (number of contacts = 0) in rows and years in columns. We used a Monte Carlo test (10^6 simulations) to compute the *p*-value. We tested the trend in the proportion of high-abundance sites using a Cochran-Armitage test on a table with the number of high-abundance sites and low-abundance sites in rows and the years in columns. We tested for trends of ICA and IAN with the Lehmann statistic (Lehmann 1975; Hatfield et al. 1996) by a permutation test (Good 1994). This statistic is similar to the Spearman correlation applied between the index and years. We studied the pattern of variations in the annual proportions of first-year birds in banded and/or in bagged woodcock in 4 European countries using the Ω statistic described in Appendix A. The Ω statistic measures the synchrony of time series between the countries.

RESULTS

Trends of breeding woodcock

The proportion of positive breeding sites decreased slightly (*p*-values = 0.009 (1992–2001); 0.05 (1993–2002); 0.026 (1994–2003); 0.079 (1995–2004) before

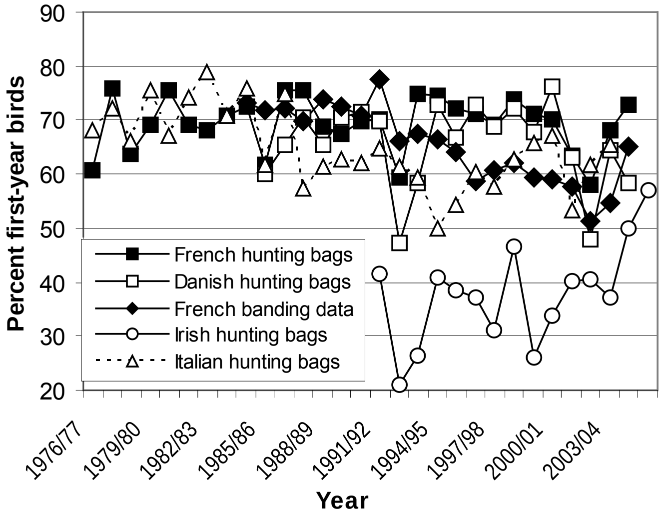


Figure 3. Interannual variations in the proportion of first-year woodcock in hunting bags in France, Italy, Denmark, and Ireland and in banding data in France, 1976-2006.

stabilizing (*p*-value = 0.71) from 1996 to 2005 whereas the proportion of high-abundance sites is stable at first (*p*-values = 0.55; 0.57; 0.52; 0.116; resp.) and then slightly increases in the final period (*p*-value = 0.033) (Figure 1). In Russia, the monitoring period is too short to test for any trend.

Trends of Wintering Woodcock

From 1996–2005 we calculated annual IAN from about 5,000 hours of nocturnal banding trips (3,200–7,000) performed by more than 300 banders. In the same way, we calculated ICA from about 1,000 hunters taking some 30,000 hunting trips (29,000–33,000). Both ringers and hunters form a large network well distributed over France. Over the study period, IAN increased (*p*-value < 0.0001) while ICA remained stable (*p*-value = 0.372).

The interannual variations of IAN and ICA followed the same pattern until the 2001–02 season (Figure 2). But in 2002–03, the values differed greatly, and then a strong correlation was again observed in the following seasons after an inversion of the curves.

Annual Recruitment

In France and Italy, the proportion of first-year birds is available since 1976–77 for woodcock harvest and since 1984–85 for banded woodcock in France. In Denmark, these data are available since 1985–86. The values range from 47.5% to 79% (Figure 3). Another data set is available since 1991–92 for Ireland (National Association of Regional Game Councils, unpublished report). We tested several pairs of time series to detect a possible synchrony in the proportion of first-year birds between countries (Table 1). Synchrony was detected only between France and Denmark data (Ω = 0.678; *p* = 0.0028). The synchrony between French data obtained by banding and by hunting bags was marginally significant (Ω = 0.438; *p* = 0.0318).

DISCUSSION

Trends in the number of breeding woodcock in Europe are difficult to assess due to the limited geographic and temporal extent of the breeding woodcock surveys. Ideally monitoring should be available in the major part of the continent's breeding area, especially in northern and central Europe.

Trend analysis usually requires a long time period. However, we believe the geographic coverage of the data collection also plays a role in trend interpretation. In France, we chose to analyze data collected during 10-year periods in *départments* which applied the protocol without interruption. This choice allows us to keep the study area as close to the French breeding area as possible; every year data was analyzed from 47–50 of the 73 *départments* where woodcock are certainly or probably breeding (Ferrand 1994). Indeed, the central, northeastern regions and the mountainous areas which constitute the major part of the French woodcock breeding area are included in every 10-year period analysis. The results suggest that in the last 14 years the woodcock breeding area in France probably decreased slightly but birds tended to be more concentrated in the best breeding sites. This leads us to conclude that the numbers of breeding woodcock in France probably did not vary during the study period.

The method developed in western Europe encountered some limits in its application in the core of the

Table 1. Synchrony tests performed on time series of the proportion of first-year woodcock collected in different European countries from hunting bags and on data collected in France during banding (B) and from hunting bags (HB).

Pair of countries	Ω value	*p*-value
France – Denmark	0.6782	0.0028
Denmark – Ireland	0.4406	0.0890
France – Ireland	0.4331	0.0913
France – Italy	0.3143	0.1014
Italy – Ireland	–0.1922	0.3000
Denmark – Italy	0.0200	0.4800
France (B) – France (HB)	0.4383	0.0318

breeding area. In Russia, the application of the method used in France showed that the proportion of positive sites annually exceeds 90%. The detection of a trend is difficult due to lack of variation.

Due to the lack of a specific sampling design, ICA and IAN are certainly biased. However, we considered these indices to be representative of the demographic trend because of their synchrony (Ferrand et al. 2006). The change in IAN values since 2002–03 is probably due to an observer bias. IANs are estimated from banding trips during which the aim is to band the greatest possible number of woodcock. In the past few years, banders tended to optimize the banding time due to the reduction of working time devoted to this activity (Ferrand, unpublished data). They limited their banding trips to the best areas, which led to an increase in the IAN values. At the same time, hunters did not change their habits and the ICA collection pattern remained the same.

The results of tests on synchrony of the proportion of first-year birds in the time series seems to confirm the different geographical origins of woodcock wintering in different European regions as shown from banding analysis (Hoodless 2002; Bauthian et al. 2007). The positive synchrony between Danish and French series expresses a similar origin of the concerned woodcock populations (Feno-Scandinavian Flyway). The different pattern of the variations of the proportion of first-year birds in Italy compared to other countries like France and Ireland is consistent with a central Europe origin (Eastern Flyway) of woodcock migrating and/or wintering in this country. As shown by Fadat (1981), the proportion of first-year birds in hunting bags is affected not only by recruitment but also by the hunting pressure following the wintering site fidelity. For instance, the low absolute values registered in Ireland do not mean a lower recruitment for the Irish wintering population but rather a generally lower hunting pressure in Ireland than in the other countries.

An important issue in the European woodcock monitoring is the lack of precise harvest estimates which can be a way to estimate hunting pressure on the species when estimation of abundance is also available. Hunting bag assessments vary in methodology among the different nations. For example, they are performed by inquiries which are compulsory (in Russia, Denmark, Germany, and Hungary) or not (in France, Great Britain, Finland, and The Netherlands); annual (Russia, Sweden, Finland, Denmark, Switzerland, and Hungary) or not (France, Ireland, and The Netherlands); and national or not (Sweden). Additionally, many countries have only a rough estimation based on managers' interpretations without collection of sufficient data to validate assumptions.

These discrepancies in hunting bag assessments likely originate from the cultural diversity that exists in Europe. Additionally, hunting periods and regulations vary considerably among nations. Contrary to North America, the cultural diversity in Europe is so great that organizing standardized monitoring protocol for any migratory bird will be a monumental task. Moreover, dedicated specific Game and Wildlife Institutes that could oversee a monitoring program do not exist in every country. However, a European Union management plan for woodcock is now in progress and aims to maintain or increase woodcock numbers and habitats over the next three years (Jensen and Lutz 2006).

Compared to the distribution range of woodcock in Europe, the monitoring programs developed at present may appear to be weak. However, their main objective is to determine the woodcock conservation status. Despite the lack of precise information, the conservation status of woodcock in the Western Palearctic region is considered unfavorable (SPEC 3W category) by BirdLife International (2004) and stable by Wetlands International (2002). According to available information based on monitoring, European woodcock does not seem to be endangered. However, caution is required since few data have been collected in the core of the breeding range. Moreover, research on the evolution of woodcock habitat in Europe still has to be carried out in order to have a complete understanding of the situation.

ACKNOWLEDGMENTS

Many of the results presented in this paper are the fruit of the huge field work carried out by hundreds of observers. The authors are very grateful to all the people who collaborated with the French banding and roding programs in the framework of the ONCFS/FNC woodcock network: professionals of the ONCFS and the *Fédérations départementales des chasseurs*, volunteers of the *Club national des bécassiers*. We also thank the *Club national des bécassiers* in France (J. P. Boidot); the *Club de la Beccaccia* (S. Spano) and *Amici di Scolopax* (A. Tedeschi) in Italy; the National Environmental Research Institute in Denmark; and the National Woodcock Association of Ireland (L. Taaffe/NARGC) for providing data on ICA and/or age ratio in hunting bags for their own country.

LITERATURE CITED

Armitage, P., G. Berry, and J. N. S. Matthews. 2002. Statistical Methods in Medical Research. Fourth Edition. Blackwell Science, Oxford, United Kingdom.

Baillie, S. R. 1990. Integrated population monitoring of breeding birds in Britain and Ireland. Ibid 132: 151–166.

Bauthian, I. 2005. Dynamique spatiales des espèces d'intérêt cynégétique. L'apport des modèles de dynamique des populations. Ph.D. Thesis. University of Paris VI., France. [In French.]

Bauthian, I., I. Iljinsky, S. Fokin, R. Julliard, F. Gossmann, and Y. Ferrand. 2006. Survival rates of Russian Woodcocks. Pages 61–64 *in* Y. Ferrand, editor. Sixth European Woodcock and Snipe Workshop—Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group, 25–27 November 2003, Nantes, France. Wetlands International Global Series 18, International Wader Studies 11, Wageningen, The Netherlands.

Bauthian, I., F. Gossmann, Y. Ferrand, and R. Julliard. 2007. Quantifying the origin of woodcock wintering in France. Journal of Wildlife Management 71(3): 701–705.

BirdLife International. 2004. Birds in Europe: population estimates, trends and conservation status. BirdLife Conservation Series No. 12, Cambridge, UK.

Brownie, C., D. R. Anderson, K. P. Burnham, and D. S. Robson. 1985 Statistical inference from band recovery data—a handbook. Fish and Wildlife Service Resource Publication 156.

Buonaccorsi, J. P., J. S. Elkinton, S. R. Evans, and A. M. Liebhold. 2001. Measuring and testing for spatial synchrony. Ecology 82: 1668–1679.

Cardia, P., A. L. Machado, D. Gonçalvès, Y. Ferrand, and N. Ferrand. 2004. Population genetic analysis of β-fibrinogen intron 7 in Western Palearctic populations of the Eurasian woodcock (*Scolopax rusticola*). Evolution Conference 2004, Colorado State University , Fort Collins, USA.

Cau, J. F., and J. P. Boidot. 2006. Assessment of the abundance of woodcock over the last ten hunting seasons in France. Pages 23–25 *in* Y. Ferrand, editor. Sixth European Woodcock and Snipe Workshop—Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group, 25–27 November 2003, Nantes, France. Wetlands International Global Series No.18, International Wader Studies 11, Wageningen, The Netherlands.

Clausager, I. 2006. Wing survey of woodcock and snipes in Denmark. Pages 106–112 *in* Y. Ferrand, editor. Sixth European Woodcock and Snipe Workshop—Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group, 25–27 November 2003, Nantes, France. Wetlands International Global Series No.18, International Wader Studies 11, Wageningen, The Netherlands.

Cramp, S., and K. E. L. Simmons. 1983. *Scolopax rusticola* woodcock. Pages 444–457 *in* S. Cramp and K. E. L. Simmons, editors., Handbook of the Birds of Europe, the Middle East and North Africa. Vol. III Waders to Gulls. Oxford University Press, Oxford, United Kingdom.

Estoppey, F. 2001. Suivi démographique des populations nicheuses de Bécasse des bois *Scolopax rusticola* en Suisse occidentale de 1989 à 2000. Nos Oiseaux 48(2): 105–112. [In French.]

Fadat, C. 1979. Estimation des variations relatives de densités de bécasses (*Scolopax rusticola*) par la méthode des indices cynégétiques d'abondance (ICA). Bulletin mensuel ONC. N° Spécial Scientifique et Technique, décembre 1979, 71–110. [In French.]

Fadat, C. 1981. Age-ratio des tableaux de chasse de bécasses (*Scolopax rusticola*). Signification biologique et utilisation pour la bonne gestion des populations bécassières. Bulletin mensuel ONC. N° Spécial Scientifique et Technique, novembre 1981, 141–172. [In French.]

Ferrand, Y. 1987. Reconnaissance acoustique individuelle de la Bécasse des bois (*Scolopax rusticola*) à la croule. Gibier Faune Sauvage (4)3: 241–254. [In French.]

Ferrand, Y. 1993. A census method for roding Eurasian Woodcock in France. Pages 19–25 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Ferrand, Y. 1994. Bécasse des bois *Scolopax rusticola*. Pages 298–299. *in* D. Yeatman-Berthelot and G. Jarry, editors. Nouvel Atlas des oiseaux nicheurs de France 1985–1989. S.O.F. Paris, France. [In French.]

Ferrand, Y., and F. Gossmann. 2000a. Enquête nationale sur les tableaux de chasse à tir. Saison 1998–1999. La Bécasse des bois. Faune Sauvage. Cahiers techniques N° 251, août/septembre 2000, 96–105. [In French.]

Ferrand, Y., and F. Gossmann. 2000b. Trend of the breeding woodcock population in France from 1992 to 1997. Pages 34–36. *in* H. Kalchreuter, editor. Fifth European Woodcock and Snipe Workshop—Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group 3–5 May 1998. Wetlands International Global Series No. 4. International Wader Studies 11, Wageningen, The Netherlands.

Ferrand, Y., and F. Gossmann. 2001. Elements for a woodcock (*Scolopax rusticola*) management plan. Game & Wildlife Science 18(1): 115–139.

Ferrand, Y., F. Gossmann, C. Bastat, and M. Guénézan. 2006. What census method for migrating and wintering populations? Pages 36–42 *in* Y. Ferrand, editor. Sixth European Woodcock and Snipe Workshop—Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group, 25–27 November 2003, Nantes, France. Wetlands International Global Series No.18, International Wader Studies 11, Wageningen, The Netherlands.

Good, P. 1994. Permutation tests. A practical guide to resampling methods for testing hypotheses. Springer-Verlag, New York, USA.

Goodman, L. A., and Y. Grunfeld. 1961. Some nonparametric tests for comovements between time series. Journal of the American Statistical Association 56: 11–26.

Gossmann, F., Y. Ferrand , Y. Loidon, and G. Sardet. 1988. Méthodes et résultats de baguages des bécasses des bois (*Scolopax rusticola*) en Bretagne. Pages 34–41 *in* P. Havet and G.H. Hirons, editors. Compte-rendu $3^{\text{ème}}$ Symposium européen sur la bécasse et les bécassines. Paris, 14–16 octobre 1986. [In French.]

Gossmann, F., Y. Ferrand, S. Fokin, and I. V. Iljinsky. 2000. Ringing of woodcock (*Scolopax rusticola*) in Russia from 1991 to 1997. Pages 10–14 *in* H. Kalchreuter, editor. Fifth European Woodcock and Snipe Workshop—Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group 3–5 May 1998. Wetlands International Global Series No. 4. International Wader Studies 11, Wageningen, The Netherlands.

Gossmann, F., C. Bastat, M. Guénézan, and Y. Ferrand. 2005. 2004–2005 French Woodcock Report. Woodcock and Snipe Specialist Group Newsletter 31: 20–22.

Hatfield, J. S., W. R. Gould, B. A. Hoover, M. R. Fuller, and E. L. Lindquist. 1996. Detecting trends in raptor counts: power and type I error rates of various statistical tests. Wildlife Society Bulletin 24(3): 505–515.

Hoodless A. 2002. Eurasian Woodcock *Scolopax rusticola*. Pages 319–322 *in* C. V. Wernham, M. P. Toms, J. H. Marchant, J. A. Clark, G. M. Siriwardena, and S. R. Baillie, editors. The migration atlas: movements of the birds of Britain and Ireland. T. & A. D. Poyser, London.

Hoodless, A., N. Aebischer, D. Lang, and R. Fuller. 2004. The 2003 breeding woodcock survey in Britain. Woodcock and Snipe Specialist Group Newsletter 30: 40–42.

Hoodless, A. N., D. Lang, N. J. Aebischer, R. J. Fuller, and J. A. Ewald. 2009. Densities and population estimates of breeding Eurasian Woodcock *Scolopax rusticola* in Britain in 2003. Bird Study 56: 15–25.

Iljinsky, I. V., S. A. Fetisov, V. G. Ptschelinzev, M. Verevkin, V. I. Golovan, D. V. Chistyakov, and F. Gossmann. 2000. First results of woodcock (*Scolopax rusticola*) ringing in the northwest regions of Russia. Pages 15–18 *in* H. Kalchreuter, editor. Fifth European Woodcock and Snipe Workshop—Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group 3–5 May 1998. Wetlands International Global Series No. 4. International Wader Studies 11, Wageningen, The Netherlands.

Jensen, F. P., and M. Lutz. (In press) European Union management plan for woodcock *Scolopax rusticola* 2006–2009.

Lehmann, E. L. 1975. Nonparametrics: Statistical methods based on ranks. Holden-Day, San Francisco, USA.

Manly, B.F.J. 1997. Randomization, bootstrap and Monte Carlo methods in biology. Second edition. Chapman and Hall, London, UK.

Spano, S., and L. Galli. 2000. Age-ratios des bécasses (*Scolopax rusticola*) tuées en Italie pendant 24 saisons de chasse (1976–1999). Woodcock and Snipe Specialist Newsletter 26: 13–14. [In French.]

Sutherland, W. J. 2001. Sustainable exploitation: a review of principles and methods. Wildlife Biology 7(3): 131–140.

Tavecchia, G., R. Pradel, F. Gossmann, C. Bastat, Y. Ferrand, and J. D. Lebreton. 2002. Temporal variation in annual survival probability of the Eurasian woodcock *Scolopax rusticola* wintering in France. Wildlife Biology 8: 21–30.

Wetlands International. 2002. Waterbird population estimates. Third edition. Wetlands International Global series No.12, Wageningen, The Netherlands. 164.

APPENDIX A

The general problem of quantification and test of synchrony between two time series was studied by Goodman and Grunfeld (1961) and recently reviewed by Buonaccorsi et al. (2001). However, the statistics proposed for testing synchrony—the G statistic of Goodman and Grunfeld (1961) or the A statistic of Buonaccorsi et al. (2001)—do not take into account the amplitude of the difference between two successive dates. This appears to be questionable, as a low difference amplitude could have no biological significance when a high one could be very significant. We propose to tackle this problem as follows: Let the two observation series $X_1, X_2, \ldots, X_n$ and $Y_1, Y_2, \ldots, Y_n$ be carried out at dates $t_1, t_2, \ldots, t_n$. At each date t_i a pair of observations (X_i, Y_i) is available. The objective is to test a possible link between the successive variations of X and Y, i.e. between $W_i = X_{i+1} - X_i$ and $Z_i = Y_{i+1} - Y_i$ for $i = 1,2, \ldots, n-1$. The W_i or the Z_i are considered to be exchangeable (Good 1994).

Following these notations, the proposed statistic can be written:

$$\Omega = \frac{\sum_{i=1}^{n-1} W_i Z_i}{\left[\sum_{i=1}^{n-1} W_i^2 \sum_{i=1}^{n-1} Z_i^2\right]^{1/2}}$$

The denominator aims to standardize Ω which varies from –1 (perfect anti-synchrony) to +1 (perfect synchrony). The value 0 corresponds to the absence of synchrony.

This statistic leads to the following result: the product of two difference amplitudes with low absolute values but with same signs has a low positive contribution to the statistic; the higher the difference amplitudes, the higher the positive contribution. Conversely, the product of two difference amplitudes with low absolute values but with opposite signs has a low negative contribution to the statistic; again, the higher the difference amplitudes, the higher the negative contribution.

Finally, this statistic can be easily tested using a randomization test (Manly 1997), by virtue of the exchangeability of the first-order increment of the observations for at least one of the series.

Yves Ferrand is currently in charge of woodcock and snipe research at the ONCFS, France. He received an M.S. in Animal Behaviour from the University of Besançon, France, and a Ph.D. in Zoology from the University of Montpellier, France. He is the Chair of the IUCN SCC / Wetlands International Woodcock and Snipe Specialist Group since 2002 and, in this way, promotes the research on these species in different countries.

Philippe Aubry received a B.S. in Biology of Organisms and Populations and an M.S. in Geoinformatics from the University of Paris 6, France, then an M.S. and a Ph.D in Biometry from the University of Lyon 1, France. He worked as statistical software engineer for private companies till 2004. He is now in charge of statistical support at the ONCFS. Although currently concerned with wildlife and ecological statistics, his past interests include geomatics and geostatistics.

François Gossmann (center) received an M.S. from the University of Rennes, France. He works as a biologist at the ONCFS, France, and is currently in charge of a network devoted to woodcock and constituted of about 500 ringers and observers. He is also involved in woodcock research in Russia. ***Claudine Bastat*** (left) and ***Michel Guénézan*** (right) are currently involved in the management of the French woodcock network and especially of the ringing data base. Administration, training and communication about the woodcock network also come within their competence.

RESEARCH AND MANAGEMENT OF THE AMERICAN WOODCOCK AT THE MOOSEHORN NATIONAL WILDLIFE REFUGE – PAST, PRESENT, AND FUTURE

10th American Woodcock Symposium
Roscommon, Michigan, USA

ANDREW P. WEIK[1], USFWS, Moosehorn NWR,
103 Headquarters Road, Baring, ME 04694 USA

Abstract: Moosehorn National Wildlife Refuge, located in eastern Maine, is the site of the longest running research program on the ecology and habitat needs of American woodcock. The refuge was established in 1937 out of concerns about declining a woodcock population. Much of the land had been farmed and logged extensively, and subjected to wildfire in the early 1900s. By the 1930s the young, second growth forest had developed into prime habitat for woodcock, and research revealed high population densities. By the 1950s the woodcock population had peaked. However, very little timber harvest had taken place during the first four decades of the refuge, and as the forest matured beyond the optimum for woodcock, populations declined. Increased research activity in the 1970s designed to improve habitat and reverse the population decline led to a new forest management program and increased timber harvest via small clear cuts. The refuge's woodcock population increased as a result of improved habitat. Research activity continued at a high level during the 1980s and 1990s. Over 40 peer-reviewed papers and graduate theses on woodcock and the effects of forest management on population dynamics have resulted from research at the refuge, and numerous popular works for general audiences were produced. Timber harvest ceased in 2009 pending completion of a new refuge plan.

Proceedings of the American Woodcock Symposium 10: 45–50

Key words: American woodcock, Moosehorn, National Wildlife Refuge, Maine, habitat, management, research, *Scolopax minor*.

Moosehorn National Wildlife Refuge in eastern Maine was established by executive order of President Franklin D. Roosevelt in 1937 as a migratory bird refuge, with special emphasis on woodcock. In a 1937 letter to Roosevelt, Secretary of Agriculture Henry Wallace stated "…The protection of the woodcock, however, is the paramount purpose for the establishment of the refuge…" and further noted the importance of Moosehorn's habitat and location on the landscape for woodcock migrating to and from the Canadian maritime provinces.

Most of the uplands of present-day Moosehorn had been farmed, logged, or subject to wildfire by the early 1900s. As the timber supplied declined, many of the farms that were tied to the forest industry were abandoned, and came under the ownership of the federal Resettlement Administration. By the 1930s the reverting farmland had developed into prime woodcock habitat. Moosehorn was one of the first "duck stamp" refuges, purchased with funds raised by the Migratory Bird Conservation Act of 1929.

The Refuge consists of two divisions that are approximately 20 miles apart. The Baring Division is 20,096 acres (8,136 ha) in size and is located southwest of the City of Calais, on the international border with New Brunswick, Canada. The Edmunds Division is located to the south, between the towns of Dennysville and Whiting; it is currently 8,799 acres (3,562 ha) in size. The Refuge is now 90% forested, with species composition varying from nearly pure stands of spruce-fir to mixed hardwoods of aspen, paper birch, red maple, red oak, and beech. White pine is also an important component of many stands. The forest is interspersed with natural and human-made water bodies, several meadows, and managed blueberry fields. Alder stands are common along streams and are invading abandoned fields.

One of the first in-depth studies on the life history, habits, and habitat requirements of the American woodcock began on the Moosehorn prior to its establishment as a national wildlife refuge. Gustav Swanson, Howard Mendall, and Clarence Aldous began woodcock studies in the 1930s on the land that would be Moosehorn NWR while it was still owned by the Resettlement Ad-

---

[1] Email: rgsweik@gmail.com

ministration. In addition to elucidating the life history of woodcock, their experiments demonstrated that clear cutting could be used to rejuvenate woodcock coverts and that singing males would use newly cleared sites. In 1943, Mendall and Aldous, at the Maine Cooperative Wildlife Research Unit (CWRU), published the results of this landmark study in *The Ecology and Management of the American Woodcock.* This work was the foundation for subsequent research on woodcock at Moosehorn over the next several decades.

In 1950, University of Maine graduate student James Reardon completed his master's thesis research, finding that woodcock numbers increased on the Refuge's managed habitats. Eldon Clark became the refuge biologist in 1953, and began a series of small scale experimental timber harvests for woodcock. Moosehorn's woodcock population likely peaked in the 1950s. The burgeoning deer population at that time, however, was negatively affecting forest regeneration, which prompted the Refuge to open to deer hunting in 1954; a harvest of 349 deer was tallied on the Refuge that first season. For comparison, Moosehorn's current deer density has no perceptible effect on forest regeneration, and annual harvests typically are fewer than 10 bucks (hunter numbers are not limited, and antlerless deer are protected).

During April 17-19, 1956, the Refuge hosted a meeting of state, federal, and university woodcock experts of the day, which included Howard Mendall (ME CWRU), William Sheldon (MA CWRU), Bruce Wright (CWS), Steve Licsinsky (PA Game Commission), Fred Greeley (UNH), Ward Sharp (PA CWRU), and Allan Studholme (USFWS), among others. This meeting predated the Woodcock Workshops and Symposia.

In 1961, University of Maine master's student Frederick Payne completed an investigation of beaver flooding of alder woodcock habitat on Moosehorn NWR. During the 1960s, refuge biologist Clark focused on woodcock capture techniques and population studies. Dr. Fant Martin (USFWS Bureau of Sport Fisheries and Wildlife) and an assistant spent seven weeks of the summer of 1962 at Moosehorn, experimenting with methods of woodcock capture; 238 woodcock were banded that year during July and August. The banding program subsequently was expanded, and became a cooperative venture with the ME CWRU; a steady stream of wildlife students from the University of Maine made op the bulk of summer banding crews. From 1961 to 2005, the Refuge banded 10,739 woodcock, which have provided valuable information on population size, survival, breeding ground fidelity, wintering site associations, and migration. Clark transferred from Moosehorn NWR to Patuxent Wildlife Research Center (WRC) in 1968. In 1969 Moosehorn hosted a field trip of the Third American Woodcock Workshop, which was held in Orono, ME.

Woodcock research at Moosehorn NWR increased markedly in the 1970s, with substantial involvement of researchers from Patuxent WRC. Tom Dwyer of Patuxent led a long term study beginning in 1976 to examine population size and structure, breeding behavior, production, and response to habitat management of the local woodcock population (Dwyer et al. 1988), and ultimately to develop forest management techniques that small landowners and commercial forestry operators could use that would improve habitat for woodcock and other wildlife. In 1976, Greg Sepik began graduate research at Moosehorn NWR, in addition to collaborating on the Patuxent study. In 1979 Sepik was appointed refuge biologist of Moosehorn NWR. The management techniques developed from this research at Moosehorn were made available to the public in *A Landowner's Guide to Woodcock Management in the Northeast* (Sepik et al.1981). The Landowner's Guide has been used widely to guide habitat management for woodcock and other early successional wildlife across the northern part of the woodcock breeding range.

From the Refuge's establishment in 1937 to 1975, less than 370 ac (150 ha) of forest had been harvested. By the 1970s, the second growth forest had matured beyond the optimum for woodcock and other early successional wildlife. The woodcock population of the Moosehorn study area was declining at a rate similar to the statewide trend, and estimates of woodcock population density on the study area were significantly lower than densities from the Maine State Singing-ground Survey. Forty-five years earlier, Mendall and Aldous (1943) had estimated a population density of woodcock that was nearly 5 times the peak density on the refuge estimated by Dwyer et al. (1988). Assuming the estimation methods are comparable, it is clear that the habitat quality of Moosehorn study area in the late 1970s had the potential to be much improved.

In the early 1980s, Sepik prepared a forest management plan for the Baring Division of Moosehorn NWR based on the research conducted at the Refuge, to improve habitat for woodcock (with assumed benefit to many other early successional wildlife), diversify the age structure of the forest, achieve economic benefit from the harvest, and provide a research and demonstration area to exhibit forest management techniques that landowners can use to manage forest habitat and make a profit. Approximately one-third (5,159 ac or 2,089 ha) of the 1979 forested acreage of the Baring Division would be subject to harvest over the 45-year plan, with the remainder unmanaged and allowed to continue succession. Hardwood and mixed wood stands were regenerated by clear cutting 5 ac (2 ha) patches, with an average of about 130 ac (53 ha) to be harvested annually. However actual annual harvests usually were less due to vagaries of access, stand stocking, market demand, weather, and changes in management objectives for specific stands. Within five years after Moosehorn initiated the forest management plan, the number of adult male woodcock on the Baring Division increased 77%; over the next 20 years the number of singing male woodcock increased 73%, however, the estimated population density was still over 60% below that estimated by Mendall and Aldous 65 years earlier. In 1993, a similar forest management plan for the Refuge's Edmunds Division was prepared with financial assistance from the Ruffed Grouse Society.

Through the 1980s and 1990s Moosehorn NWR staff and research partners maintained a high level of research activity. Sepik collaborated with Patuxent WRC researchers Jerry Longcore and Dan McAuley, and others, on telemetry studies of woodcock movements, habitat selection, and survival during the breeding season through fall migration. Patuxent collaborators assessed the response of the avian community to Moosehorn's forest management. Five graduate student theses (Derleth 1986, Phelps 1986, Vander Haegen 1992, McGinley1996, Rudnicky 1991) contributed to this body of research. In the early 1990s, Sepik was appointed zone biologist and woodcock specialist for Region 5 of the USFWS, but he remained stationed at Moosehorn NWR and continued to guide woodcock monitoring and research activities.

In addition to the more than 40 peer-reviewed publications on the conservation and ecology of woodcock that resulted from research and management activities at Moosehorn NWR, numerous presentations were given and popular articles for the general public were published. Sepik contributed over 30 articles to publications of the Ruffed Grouse Society, including his *Woodcock's Way* column that appeared in their quarterly magazine. Two audio-video productions on woodcock ecology and management were filmed at Moosehorn during the 1980s: *Woodcock Woodlands* aired on Maine public television, and Marty Stouffer's *Wild America* television episode—"Timberdoodles of the Moosehorn"—reached national audiences.

Staff based at Moosehorn NWR have provided technical assistance and outreach to public land managers and private landowners interested in managing forest for woodcock and other wildlife, and have participated in national woodcock research and management programs such as the Singing Ground Survey, Woodcock Wing Bee, American Woodcock Symposia, Woodcock Taskforce, and the Northern Forest Woodcock Initiative.

Greg Sepik died unexpectedly in 1998, and his position as FWS Region 5 zone biologist was not filled. In 2004, a second refuge biologist position was created at Moosehorn, with responsibilities for woodcock and forest management. The author was appointed to this position, which he held until 2010.

In 2005, Moosehorn began the new Refuge System planning process. The Refuge's Comprehensive Conservation Plan (CCP), when complete, will guide all Refuge activities for the following 15 years. The CCP process, from planning through implementation of the plan, follows NEPA guidelines such as formulating a range of alternative approaches to refuge management, consideration of public input, and selecting an alternative that best adheres to the purpose for which the specific refuge was established. By law, the CCP must be completed by 2012. Timber harvesting and alder management under the Refuge's previously approved forest management plans was terminated in 2009, and active forest management may not be implemented again until the Refuge has an approved CCP and Habitat Management Plan.

The extent that the goals, objectives, and strategies of Moosehorn NWR's CCP strengthen or diminish the Refuge's continued contribution to conservation of American woodcock will depend on support from the Service's Regional Office for the woodcock/early successional forest wildlife program relative to competing priorities, and on public input. In the meantime, Moosehorn staff and collaborators have continued to monitor the Refuge's woodcock population and support the statewide SGS, and are assisting Patuxent WRC in a study of fall habitat use by woodcock migrating through the vicinity of Cape May NWR. The Refuge recently produced educational signs about wildlife and forest management, and installed them along trails through managed habitat to interpret forest wildlife management techniques. Moosehorn staff currently are administering a grant to the Ruffed Grouse Society to reproduce Sepik's *A Woodcock in the Hand.*

MOOSEHORN NWR/AMERICAN WOODCOCK-RELATED PUBLICATIONS

Clark, E. R. 1966. Woodcock capture techniques and population studies at Moosehorn National Wildlife Refuge. Proceedings of the Northeast Section of the Wildlife Society. Fish and Wildlife Conference, Boston, Massachusetts.

Clark, E. R. 1967. Woodcock summer banding operations at the Moosehorn National Wildlife Refuge, Maine. Pages 28-30 *in* W. H. Goudy, compiler. Woodcock research and management, 1966. U.S. Bur. Sport Fish. Wildl., Spec. Sci. Rep.-Wildl. 101. 40pp.

Clark, E. R. 1969. Woodcock research and management – past, present, but primarily future. Third Woodcock Workshop. Univ. Maine, Orono. 11pp.

Derleth, E. L. 1986. Summer-fall survival estimates of American woodcock in Maine. Master's Thesis, Penn. State Univ., State College. 54pp.

Derleth, E. L., D. G. McAuley, and T. J. Dwyer. 1989. Avian response to small-scale habitat disturbance in Maine. Can. J. Zool. 67:385-390.

Derleth, E. L., and G. F. Sepik. 1990. Summer-fall survival of American woodcock in Maine. J. Wildl. Manage. 54:97-106.

Dwyer, T. J., E. L. Derleth, and D. G. McAuley. 1982. Woodcock brood ecology in Maine. Pages 63–70 *in* T. J. Dwyer and G. L. Storm, tech. cords. Woodcock ecology and management. U. S. Fish Wildl. Serv., Wildl. Res. Rep. 14.

Dwyer, T. J., G. F. Sepik, E. L. Derleth, and D. G. McAuley. 1988. Demographic characteristics of a Maine woodcock population and effects of habitat management. U. S. Fish and Wildl. Serv., Fish and Wildl. Res. Rep. 4. 29pp.

Krohn, W. B., and E. R. Clark. 1977. Band-recovery distribution of eastern Maine woodcock. Wildlife Society Bulletin 5(3): 118–122.

Krohn, W. B., F. W. Martin, and K. P. Burnham. 1974. Band-recovery distribution and survival estimates of Maine woodcock. In Proceedings of the Fifth American Woodcock Workshop. Athens, Georgia. USA.

Licht, D. S., D. G. McAuley, J. R. Longcore, and G. F. Sepik. 1989. An improved method to monitor nest attentiveness using radio-telemetry. Journal of Field Ornithology 60(2): 251–258.

Longcore, J. R., D. G. McAuley, G. F. Sepik, and G. W. Pendleton. 1996. Survival of breeding male American woodcock in Maine. Canadian J. Zoology 74(11): 2046–2054.

Longcore, J. R., D. G. McAuley, G. F. Sepik, and G. W. Pendleton. 2000. Survival of female American woodcock breeding in Maine. Pages 65–76 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1990. Renesting by American woodcocks (*Scolopax minor*) in Maine. Auk 107: 407–410.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993. Behavior of radio-marked breeding American woodcocks. Pages 115–124 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993. Techniques for research into woodcocks: experiences and recommendations. Pages 5–11 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

McAuley, D. G., J. R. Longcore, G. F. Sepik, and G. W. Pendleton. 1996. Habitat characteristics of American woodcock nest sites on a managed area in Maine. Journal of Wildlife Management 60(1): 138–148.

McAuley, D. G., J. R. Longcore, D. A Clugston, A. B. Allen, A. Weik, S. Williamson, J. Dunn, B. Palmer, K. Evans, W. Staats, G. F. Sepik, and W. Halteman. 2005. Effects of hunting on survival of American woodcock in the Northeast. Journal of Wildlife Management 69(4): 1565–1577.

McGinley, K. E. 1996. Habitat selection in spring by male American woodcock in Maine. Thesis, University ofMassachusetts, Amherst, Massachusetts, USA.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit, University of Maine, Orono, Maine, USA.

Mendall, H. L. 1938. A technique for banding woodcock. Bird-Banding 3(9): 153–155.

Payne, F. J. 1961. Effects of beaver flooding of alder woodcock habitat on the Moosehorn National Wildlife Refuge. Master's Thesis, University of Maine, Orono, Maine, USA.

Peppard, J. W. 1971. Current woodcock studies in Maine. Fourth American Woodcock Workshop. Higgins Lake, Michigan, USA.

Phelps, N. E. 1986. The influence of earthworm abundance on woodcock diurnal habitat use in Maine. Thesis, Pennsylvania State University, State College.

Owen, R. B. Jr. and W. B. Krohn. 1973. Molt patterns and weight changes of the American woodcock. Wilson Bulletin 85(1): 31–41.

Rearden, J. D. 1950. Woodcock utilization of improved covers in eastern Maine. Thesis. University of Maine, Orono, Maine, USA.

Sanford, T. S. 1971. Moosehorn banding program. Fourth American Woodcock Workshop. Higgins Lake, Michigan, USA.

Sepik, G. F., D. M. Mullen, T. J. Dwyer, E. L. Derleth, and D. G. McAuley. 1986. Forest-wildlife management techniques on the Moosehorn National Wildlife Refuge. Pages 333–339 *in* Miscellaneous publication–University of Maine, Agricultural Experiment Station, Apr 1986 (689).Orono, Maine, USA.

Sepik, G. F., R. B. Owen, Jr., and M. W. Coulter. 1977. Experimental woodcock management at the Moosehorn National Wildlife Refuge. Pages 83-91 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Sepik, G. F., and B. Blumenstock. 1993. Management and research on the American woodcock at the Moosehorn National Wildlife Refuge. Pages 136-137 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Sepik, G. F., D. G. McAuley, and J. R. Longcore. 1993. Critical review of the current knowledge of the biology of the American woodcock and its management on the breeding grounds. Pages 98-104 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Sepik, G. F., and E. L. Derleth. 1993. Premigratory dispersal and fall migration of American woodcocks in Maine. Pages 36–40. *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Sepik, G. F., and E. L. Derleth. 1993. Habitat use, home range size, and patterns of moves of the American woodcock in Maine. Pages 41–49 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Sepik, G. F., D. G. McAuley, and E. L. Derleth. 1989. Habitat requirements and management of woodcock in the Northeast: assessment of knowledge and needs. Pages 97–109 *in* J. C. Finley and M. C. Brittingham, editors. Timber management and its effects on wildlife. Proceedings of the 1989 Pennsylvania state forest resources issues conference, University Park, Pennsylvania, USA.

Sepik, G. F., and T. J. Dwyer. 1982. Woodcock response to habitat management in Maine. Pages 106–113 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Proceedings of the Seventh Woodcock Symposium U. S. Fish and Wildlife Service, Wildlife. Research Report 14.

Sepik, G. F., R. B. Owen, Jr., and T. J. Dwyer. 1983. The effect of drought on a local woodcock population. Transactions of the Northeast Fish and Wildlife Conference 40: 1–8.

Sepik, G. F., and B. Blumenstock. 1989. The American woodcock: a species on the decline. Maine Agricultural Experimental Station. Miscellaneous Report 336: 260.

Sepik, G. F., R. B. Owen, Jr., and M. W. Coulter. 1981. A landowner's guide to woodcock management in the Northeast. Univ. Maine (Orono) Life Sci. Agric. Exp. Stn. Misc. Rep. 253. vii + 23p.

Sepik, G. F., R. B. Owen, Jr., and W. B. Krohn. 1993. Effects of weather on earthworm abundance and foods of the American woodcock in spring. Pages 26–31 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Sprankle, K. E., G. F. Sepik, D. G. McAuley, and J. R. Longcore. 2000. Assessing habitat selection in spring by male American woodcock in Maine with a geographic information system. Page. 117 in D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Vander Haegen, W. M., W. B. Krohn, and R. B. Owen, Jr. 1993. Care, behavior, and growth of captive-reared American woodcocks. Pages 57–65 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

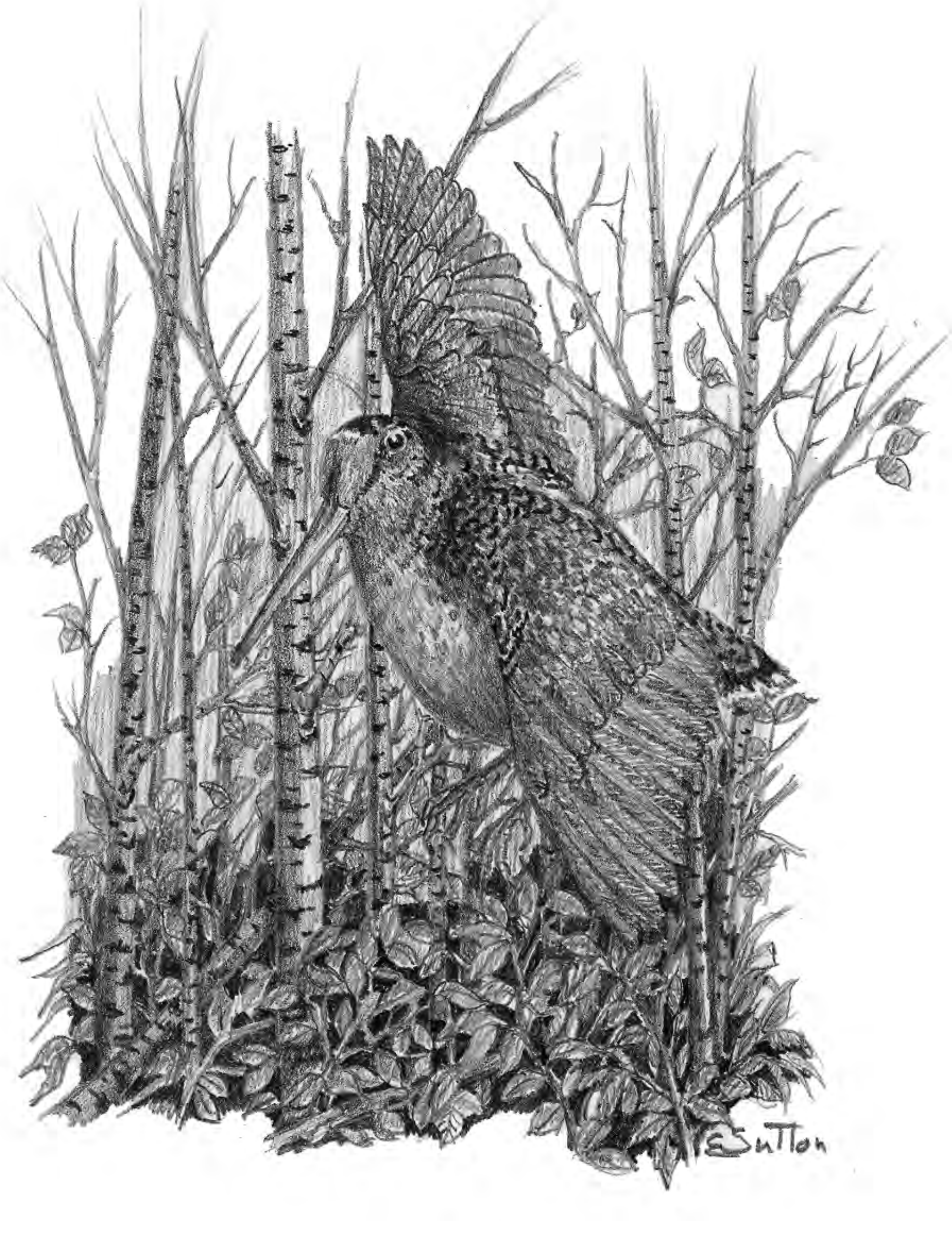
Vander Haegen, W. M. 1992. Energetic aspects of woodcock habitat use during the breeding season at Moosehorn National Wildlife Refuge. Ph.D. Thesis, University of Maine, Orono, Maine, USA.

Vander Haegen, W. M., and D. T. Jennings. 1990. Spiders (Araneae) in the diet of American woodcock in Maine. Journal ofArachnology 18: 360–362.

Andy Weik is the Ruffed Grouse Society's (RGS) regional biologist for New York, New England, and Canada. Prior to coming to RGS in 2010, Andy was refuge biologist at Moosehorn NWR and had been leader of the Migratory and Upland Game Bird Program for Maine Department of Inland Fisheries and Wildlife. He received a B.S. (1987) in Forestry and Wildlife Management from the University of Maine and an M.S. (1994) from Cornell University. Andy is past-president of the Maine Chapter of The Wildlife Society. His professional interests include sustainable habitat management for young-forest dependent wildlife, and forest landowner education.

Chapter II

Habitat Ecology



GIS-BASED ASSESSMENT OF AMERICAN WOODCOCK HABITAT AT TWO SPATIAL SCALES IN NEW BRUNSWICK

10th American Woodcock Symposium
Roscommon, Michigan, USA

MARGO MORRISON[1,2], Fish and Wildlife Branch, Department of Natural Resources,
P.O. Box 6000, Fredericton, NB, CA, E3C 2G6

KEVIN J. CONNOR, Fish and Wildlife Branch, Department of Natural Resources,
P.O. Box 6000, Fredericton, NB, CA, E3C 2G6

GRAHAM J. FORBES, New Brunswick Cooperative Fish and Wildlife Research Unit,
P.O. Box 44555, University of New Brunswick, Fredericton, NB, CA, E3B 6C2

Abstract: The number of singing male American woodcock (*Scolopax minor*) recorded during the annual singing-ground survey, an index of the breeding woodcock population, has declined across the breeding range since 1968. Survey results in New Brunswick have been consistent with this trend. Changes in land-use and land-cover patterns as well as decreases in available habitat are believed to play an important role in this apparent decline in the population. Characteristics of breeding habitat and their historic changes (1982–2000) were quantified at 2 scales using 43 singing-ground survey (SGS) routes in New Brunswick. These results were compared to a provincial scale analysis with the use of 2 GIS forest inventories (1982–1986 and 1993–2000). Based on the most recent data (1993–2000), SGS routes are currently representative of the proportion of available woodcock habitat found in the province. The temporal analysis revealed the area of singing grounds are increasing across the province (+17%), whereas the area of available singing grounds in regions surveyed by the SGS routes are decreasing (–7%). Trends of the SGS routes in New Brunswick coincide with habitat changes along routes but neither corresponds to changes in habitat at the provincial scale. Interpretation of declines in woodcock population trends should not be made independent of changes in habitat over the same period.

Proceedings of the American Woodcock Symposium 10: 53–61

Key words: American woodcock survey, *Scolopax minor*, habitat trends, representivity, Singing-ground Survey routes.

The welfare and population status of the American woodcock has been a concern to outdoors people and biologists for decades due to its importance as a game bird and its declining population levels (Steketee 2000, Bateman 2002). Results from the annual North American singing-ground survey have documented an annual decline since the survey began in 1968. The annual singing-ground survey (SGS) was developed to exploit the conspicuous courtship display of the male woodcock. Mendall and Aldous (1943) were among the first to note that counts of singing males could provide indices to woodcock abundance. In Canada, the Canadian Wildlife Service (CWS) coordinates spring counts of occupied American woodcock singing grounds along established routes. Long-term (1968–2002) declines ($P < 0.01$) of 2.3% per year of singing males in the Eastern Region, and 1.6% per year in the Central Region (Kelley 2002) have been documented through this survey. The singing-ground index for New Brunswick in 2000 was 21.1% below the 25-year mean (Bateman 2001).

Woodcock depend on young forest habitat to provide the necessary structure for the various stages of their annual life cycle. Many research studies have speculated that the decline can be attributed to a decreasing abundance of early successional forest stands and shrub-dominated areas in their breeding range (Hudgins et al. 1985, McAuley et al. 1996, Dessecker and McAuley 2001). As habitat quality and quantity decrease, woodcock are forced to use habitats where food may be less abundant and vulnerability to predators may be greater. The high stem density of early successional stands protects woodcock from predators and enables larger local populations than in mature forests (Dessecker and McAuley 2001).

---

[1] Present address: Nature Conservancy of Canada, 1-924 Prospect St., Fredericton, NB E3B 2T9

[2] E-mail: margo.morrison@natureconservancy.ca

The apparent habitat loss can be attributed to many direct and indirect factors across the woodcock's range. Increased fire and pest suppression have allowed forest stands to enter mature seral stages of development when in the past they would have been damaged or destroyed (Steketee 2000). Other causes such as decreased farm abandonment, limited regeneration of hardwood stands, and changes in forest management objectives and techniques are considered factors in the net loss of available woodcock habitat (Straw et al. 1994, Dessecker and McAuley 2001). Potential causes vary by region. The eastern United States have reported a severe decline in the amount of early successional woodlands, with only 8% of the forest currently in this age class (Brooks and Birch 1988). New Brunswick, however, is largely owned by the public (Crown) and large industrial freehold in which intensive forest management practices are conducted. Currently, 38% of New Brunswick's woodlands are in a regenerating or young age class (Nicolacopoulos 2003).

In order to effectively assess the woodcock population status, population indices need to 1) accurately reflect the actual population trends and 2) be representative of the landscape. Survey routes were established mainly along permanent roads, but these routes may not reflect changes occurring elsewhere. If this is true, then the survey routes may not indicate actual woodcock population levels. Extensive monitoring has been conducted (Bateman 2002, Kelley 2002), yet little research has been done to determine how accurately the singing-ground indices reflect actual population declines, or whether the declines are caused by disproportionate habitat changes at the survey sites in relation to the overall landscape. This uncertainty could prevent the development of effective strategies for woodcock conservation and management in New Brunswick. An assessment of woodcock habitat along survey routes is required to better comprehend the relationship between long-term population trends and changes in available habitat along existing survey routes and across New Brunswick.

In order to determine habitat and land use changes at each survey route, we used GIS technology to assess three major objectives:

1. To characterize woodcock habitat types, stand structure, stand composition, and land use at existing singing-ground routes in New Brunswick.
2. To compare present characteristics of habitat at singing-ground routes (i.e. woodcock habitat types, forest stand structure, composition, and land use) to a landscape scale of New Brunswick.
3. To determine how habitat characteristics and land use have changed across New Brunswick in relation to woodcock singing-ground survey results over time.

STUDY AREA

This study was conducted in the province of New Brunswick, Atlantic Canada. New Brunswick was heavily forested (85%) and had a 300-year history of European settlement. The province was located in the Acadian Forest Region (Rowe 1972), comprised of 7 ecoregions, a maritime climate, and rolling topography (0–820 m). Private woodlot owners held and managed 51% of this forested landscape, which was the third largest percentage of private ownership compared to other Canadian provinces (Canadian Forest Service 2002). The Maritime Region also had the highest percentage of forest products derived from private lands in Canada. Even-aged harvesting was still the dominant harvesting method; however, uneven-aged management was increasing on Crown and private land (Armson 1999).

METHODS

Site Selection

We selected the locations of the singing-ground routes for this study from existing or historical locations of the SGS routes in New Brunswick (Figure 1). We analyzed woodcock habitat types, stand structure, stand composition, and land use within a 300-m buffered area surrounding each of the 43 woodcock singing-ground routes using ARC/INFO software (ESRI 2002) to represent habitat within listening range of observers when completing SGS routes. Approximately one half of these routes are surveyed every year and the remaining routes are recorded as "constant zeros" (Kelley 2002).

To complete the habitat and stand characterization along each existing route (Department of Natural Resources and Energy [DNRE] 1989), we used the current digital forest inventory covering 1993 to 2002. The 2001 and 2002 aerial photograph interpretations were not completed at the time of this study and were eliminated from the analysis; together they represented approximately 1.8 million hectares of the total 7.3 million-hectare area (Figure 1).

We used a second complete digital forest inventory from the preceding interpretation cycle to determine how habitat characteristics and land use have changed in relation to woodcock SGS results from 1982 to 1986. Both of these digital inventories were interpreted from aerial photographs at a scale of 1:12,500 with a reported accuracy of 85%. We grouped and assigned age classes to 1 of 4 categories using the provincial inventories: 1) Regenerating/young – trees predominantly < 3m in height, trees predominantly 2–7 m in height and 1–9 cm diameter at breast height, merchantable layer,

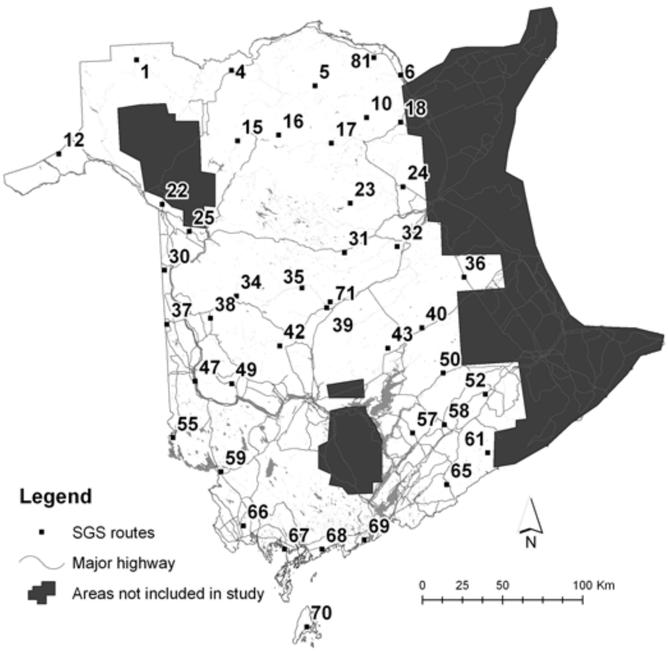


Figure 1: Locations of woodcock singing-ground routes in New Brunswick included in the study and areas eliminated from the analysis, (1993–2000). Photo interpretation of 2001 and 2002 blocks was not complete at the time of study.

accumulating volume rapidly; 2) Immature – merchantable layer, accumulating volume slowly; 3) Mature – merchantable layer, stable volume (growth and mortality about equal); and 4) Overmature – merchantable layer, volume declining due to natural mortality.

Land Use and Habitat Characterization

We used the forest inventory to classify potential woodcock habitat as identified by previous studies conducted in the breeding range. Woodcock use a variety of habitat types for displaying, feeding, nesting, roosting, and brood rearing (Mendall and Aldous 1943, Sepik and Dwyer 1982). Due to a large amount of overlap between the characteristics of some of the habitat types, we only characterized nesting/feeding habitat and singing-ground habitat.

We summarized singing grounds within the 300-m buffers, identifying those within 90 m of any nesting and feeding cover to explore this spatial requirement. The nesting and feeding cover used in the proximity analysis could have been located outside of the buffers. As the digital soil coverage did not have a fine enough resolution to detect worm abundance, we could not use it to distinguish appropriate soil conditions for feeding grounds.

We then characterized habitat types within the 300-m buffers around each existing SGS route. We identified singing-ground habitat and nesting and feeding habitat using an algorithm in ARC/INFO created from specific stand characteristics (Nicolacopoulos 2003). Once all singing grounds and nesting and feeding habitat had been identified, we clipped the habitat coverage against the buffers using ARC/INFO software (ESRI 2002) so that only habitat within listening range was being analyzed.

Analysis

We calculated representivity of the SGS routes based on a comparison of the proportion of each cover and habitat type for 1) the New Brunswick landscape and 2) SGS route areas defined by the 300-m buffer. These proportions reflect absolute areas of cover types, or entire populations, rather than samples of cover types. Thus, we did not use inferential statistics to determine significant differences when the proportions at each scale were compared.

Once we summarized the current inventory for woodcock habitat types (singing grounds and nesting and feeding cover), stand structure, stand composition, and land use, we conducted the same process using the old inventory (1982–1986). Although the methodology used to interpret both inventories was similar, the 1986 classification scheme contained fewer land-cover classes and fewer detailed attributes (DNRE 1989). We made each digital inventory comparable by grouping classes into broader categories (Nicolacopoulos 2003). We used the same routes and landscape area in the old inventory analysis that was used for the current inventory analysis. We then calculated percent change based on the proportions found at each scale. We compared the rate of change found at the route scale to the rate of change found at the landscape (or forest) scale over the 2 time periods. We determined changes important to woodcock habitat based on the results from the habitat model. Stand characteristics required for woodcock survival were part of the algorithm used to identify suitable singing-ground habitat (Nicolacopoulos 2003).

RESULTS

Land-cover Representivity and Changes over Time

The area defined by 300-m buffers surrounding the 43 SGS routes in the new inventory was 69% forested and 31% non-forested. A summary of the entire province revealed the relative proportion of forested landscape is 15% greater than that of the sum of the routes. Despite the differences in the relative proportions of forested and non-forested cover types, the proportions of stand types and age classes are representative of those in the landscape. One exception was the immature age class, which occurred in greater proportions at the route scale.

Table 1. Proportions (%) and changes in abundance of age classes in the SGS routes and New Brunswick landscape from the old inventory (1982–1986) to the current inventory (1993–2000).

Age class	1982–1986 (%)	1993–2000 (%)	% change
Routes			
Regenerating/young	28.4	38.1	34.2
Immature	39.7	26.7	–34.9
Mature	30.3	28.8	–8.1
Overmature	1.6	6.4	285.5
Total	100	100	–3.4
Landscape			
Regenerating/young	24.5	38.4	56.7
Immature	29.2	18.0	–38.4
Mature	42.8	36.3	–15.2
Overmature	3.6	7.3	103.7
Total	100	100	–0.1

Table 2. Proportions (%) and changes in abundance of cover types and stand types in the SGS routes and New Brunswick landscape from the old inventory (1982–1986) to the current inventory (1993–2000).

Cover type	1982–1986 (%)	1993–2000 (%)	% change
Routes			
Deciduous forest	26.6	27.1	1.7
Coniferous-mixed forest	40.5	41.5	2.6
Occupied	4.6	7.1	54.5
Roads	4.7	4.8	1.6
Rock outcrops	0.1	0	–65.8
Cultivated	10.9	11.0	1.1
Wetlands/water	7.7	7.7	0
Unclassified	4.9	0.8	–83.7
Total	100	100	0
Landscape			
Deciduous forest	33.1	33.7	1.8
Coniferous-mixed forest	46.1	48.4	5.1
Occupied	1.3	1.8	44.9
Roads	1.2	1.2	2.3
Rock outcrops	0.1	0	–54.1
Cultivated	4.5	3.9	–14.3
Wetlands/water	8.9	8	–10.0
Unclassified	4.8	3	–37.5
Total	100	100	0

Table 3. Proportions (%) and changes in abundance of woodcock breeding habitat in the SGS routes and New Brunswick landscape from the old inventory (1982–1986) to the current inventory (1993–2000).

Habitat type	1982–1986 (%)	1993–2000 (%)	% change
Routes			
Singing grounds	29.3	27.6	–5.8
Singing ground within 90 m	23.1	20.6	–10.8
Total area in routes	100	100	–0.7
Landscape			
Singing grounds	19.7	23.9	21.3
Singing ground within 90 m	14.7	18.7	27.2
Total area in province	100	100	–0.5

Approximately 38% of the forest within the buffers around the routes is in a regenerating or young condition, whereas 61% is in a mature successional stage (immature, mature and overmature age classes) (DNRE 1989). Similar results were found in the New Brunswick landscape analysis (Table 1).

In the old inventory (1982–1986), the relative proportion of forested to non-forested cover types along the routes compared to the proportion across the landscape is similar to the current inventory. The area defined by 300-m buffers surrounding the SGS routes was 67% forested and 33% non-forested. The landscape, however, had 12% more forested land than the SGS routes. While the majority of the stand types were representative of the proportions found across the landscape, the proportion of age classes differed when both scales were compared (Table 2). Regenerating/young and immature age classes were more common along the routes than in the landscape, while mature and overmature age classes had greater proportions in the New Brunswick summary. Non-forested cover types associated with human settlement (e.g. roads) were all in higher proportions along the routes (Table 2).

The rate of change between the route scale and the landscape scale were markedly different, especially with the age class of stand types. While there was an increase over time in the relative proportion of regenerating stands at the route scale (% change = +34.2), the landscape experienced a greater rate of change with an increase of 57% over the same time period. Overmature stands, however, have experienced a greater increase at the route scale than across the landscape (Table 1). Cultivated land has changed very little at the route scale but is experiencing a large decrease in the landscape (% change = ~14.3), while the proportion of human settlement (i.e. occupied land) greatly increased at both scales (% change = +54.5%, +44.9%, respectively).

Representivity of SGS Routes

Approximately 28% of the total area of the routes in the current inventory was suitable for singing grounds, but only 75% of those singing grounds were within 90 m of a suitable nesting area. Area within the buffers identified as potential nesting habitat was the least abundant, with 11% of the area being considered suitable. In total, 24% of the area in New Brunswick was suitable for singing grounds but only 79% of those singing grounds were within 90 m of a suitable nesting area.

The current inventory (1993–2000) analysis revealed that the proportions of suitable woodcock habitat on the 43 SGS in this study are found to be representative of those found in the landscape. A similar comparison with the old inventory (1982–1986) revealed an overrepresentation of all categories of suitable woodcock habitat at the route scale. The routes are currently more representative of the available woodcock habitat found across the landscape than they were 20 years ago.

Woodcock Habitat Changes over Time

The rate of change of woodcock habitat along the routes is minor compared to the change across the landscape (Table 3). The total amount of suitable singing grounds and singing grounds within 90 m of nesting and feeding cover has decreased by 5.8% and 10.8%, respectively, for the buffered routes. Across the landscape, both habitat categories increased during the time period from the old to the current inventory.

DISCUSSION

Representivity

Several authors have recognized that abundance data obtained from roadside surveys may not be representative of the overall landscape (Steketee 2000, Donovan and Flather 2002). In contrast, we found in general that stand and cover types suitable for woodcock along the woodcock SGS routes were representative of the New Brunswick landscape in the current inventory (1993–2000). These findings support that current estimates of woodcock abundance as estimated by the SGS routes are reasonably indicative of breeding population levels in New Brunswick. While most variables were representative, there were a few differences between the two scales. Roadside areas tend to be more dominated by cover types associated with human settlement, such as roads, occupied land, and cultivated areas. Similar trends occurred in studies of cover type bias in the Breeding Bird Survey (BBS) routes, which is also a roadside-based survey (Betts et al. 2007).

Current timber harvest activities, which produce many open areas for which woodcock have an affinity (Sepik et al. 1994, Straw et al. 1994), are commonly associated with road systems that did not exist when routes for the singing-ground survey were originally established in 1968 (Woehr 1999). The abundance of suitable non-forest cover for singing grounds along the routes may offset the effect of a slightly lower occurrence of regenerating stands. Woodcock along the SGS routes are most likely using roads, pastures, cultivated fields, lawns, and reverting agricultural fields as singing grounds where forest openings are less abundant (Mendall and Aldous 1943, Straw et al. 1994).

Representivity of stand characteristics in the old inventory differed from the current inventory in some cover types with respect to magnitude of over- or under-representation. Regenerating and young stands were overestimated at the route sites compared to the landscape (Table 1). One possible explanation is the development along the routes. Routes that were located on forest roads in the 1980s may now be in an area associated with less forest harvesting in the current inventory (i.e. residential areas, as suggested by rates of change in occupied land at the route scale). Similarly, it is common practice today for forest companies and private woodlot owners to leave mature forest buffers along roadsides to limit the negative aesthetic impact of clearcuts (Lansky 1992). More people are becoming sensitive to clearcuts in highly visible areas along travel ways, whereas this sensitivity was not as prevalent 20 years ago (Lansky 1992). The practice of leaving mature forest buffers along roads can also explain why there were more young stands along roadsides in the 1980s than across the landscape. Less mature and overmature stands were found along roadsides in the past due to higher levels of harvesting taking place in these areas.

Changes over Time

While the routes are currently representative of the New Brunswick landscape, changes in relative abundance of woodcock habitat over time at the route sites has changed disproportionately from changes that have occurred across the landscape. Some of the differences in abundance of cover types from 1982 to 2000 can be explained by examining changes in management practices in New Brunswick. Prior to 1992, management strategies were primarily focused on maximizing sustainable softwood harvest. After this time, mature coniferous habitat objectives were added, as this stand type would have been lost completely in 40 years from 1992 (Erdle and Sullivan 1998). The resulting forest condition on Crown land created under this strategy is one with virtually all stands kept at or below the age of peak annual increment, and therefore truncating the age class (Erdle and Sullivan 1998). Even though more mature and overmature forest habitat objectives have been developed in recent years, intensive forest management on Crown, industrial freehold, and some private woodlots are still creating a younger forest. This trend is evident when comparing percent change of regenerating and young stands from the old inventory to the current inventory.

On a provincial scale, the abundance of regenerating and young stands increased in the forest at a faster rate than that found along the routes, which indicates the rate of change over the same period of early successional stands at the route scale is not representative. As a result, woodcock singing grounds across the province have increased by 17% compared to a concurrent 7% decrease at the route scale. Similar trends existed for singing grounds in close proximity (≤90 m) to nesting and feeding cover.

Many studies have identified that male woodcock are choosing singing grounds in close proximity to suitable nesting cover occupied by females, so a decrease in available nesting and feeding cover may be influencing the number of males heard along the routes (Mendall and Aldous 1943, Dessecker and McAuley 2001). The study by Mendall and Aldous (1943) found 83% of singing grounds were less than 90 m from nest or diurnal cover. They, among others (Dwyer et al. 1988), regarded ≤90 m to be the distance that most woodcock will travel between singing grounds and nesting-diurnal cover, although longer distances traveled between cover types have been recorded (Sepik and Derleth 1993). Male woodcock may be moving to more suitable sites away from the routes to where there is a large increase in suitable nesting and feeding areas with females.

Even though SGS routes are representative of the availability of woodcock singing grounds, the rapid increase in the provincial availability of singing grounds will most likely reverse this trend in the near future. Mature stand types are still more common in the landscape, which means harvest rates in these areas are likely to continue to increase, unless mature coniferous habitat objectives are substantially increased. In order to minimize timber loss resulting from natural tree mortality and to maximize profits, the forest industry in New Brunswick tends to harvest the oldest stands first (Erdle and Sullivan 1998).

The increasing abundance of suitable woodcock habitat across the New Brunswick landscape is not consistent with trends in other regions. Bruggink (1997) documented seedling-sapling abundance and American woodcock population trends in 11 north-central and northeastern states. Most seedling-sapling stand types in the forestlands decreased from the 1970s to the late 1990s, as did the woodcock population trends. Maine, however, was one of the states that did not experience a decrease (Bruggink 1997).

In addition to their neighboring geographic locations, New Brunswick and Maine have many similarities which explain why they are experiencing different trends compared to other regions. Unlike other jurisdictions, both have experienced an increase in seedling-sapling abundance over roughly the same time period. Maine's seedling-sapling forest increased by 34% from 1971–1995 (Bruggink 1997), whereas New Brunswick's young forest abundance increased by 38% from 1982–2000 as identified by this study; however woodcock population trends decreased in both regions (Bateman 2001, Kelley 2002). This lack of correlation between young forest and woodcock population trends may be the result of one or several factors such as the following: 1) not all seedling-sapling forest is suitable woodcock habitat; 2) woodcock population declines may be independent of habitat availability; or 3) the SGS routes do not accurately represent the overall landscape. The latter is supported by our findings of an overrepresentation of the abundance of singing grounds and nesting habitat along the SGS routes, especially in the old inventory. The overestimation of habitat along the routes in the 1980s could have inherently conveyed a population decrease over time when in fact the abundance of suitable woodcock habitat was increasing in the landscape. The routes may now be more representative of the actual population levels instead of overestimating them as in the past.

Another similarity, which is seemingly different in other regions, is the level of intensive forest management practiced in the province or state. Between the early 1970s to mid-1980s, more than 60% of the basal area was removed from only 4% of the forest stands in West Virginia and from 8% of the stands in New England. On most sites removal of only 60% of the basal area is not adequate to establish quality early successional habitat (Dessecker and Pursglove 2000). In Maine, data suggest that at least 80% of the stand basal area has been removed from 13% of the timberland (Dessecker and Pursglove 2000).

This occurrence is probably because the forest products industry owns 47% of Maine's timberland, which is higher compared to other regions (Dessecker and Pursglove 2000). New Brunswick, however, has an even higher percentage of land managed by forestry companies, due in part to the way public land is managed. New Brunswick Crown lands are managed under 10 separate timber licenses requiring that licensees develop 25-year management plans outlining all forest management activities for the license. Together with private industrial freehold (not including harvesting on small private woodlots), about 70% of New Brunswick's forests are under intensive forest management, with clear cutting being the most common harvesting technique used in these areas (Arson 1999). Several studies (Sepik and Dwyer 1982, Sepik et al. 1994) have documented the effectiveness of clear cutting (strips or patches) as a technique that creates excellent singing grounds and eventually nesting and feeding cover.

MANAGEMENT IMPLICATIONS

Based on the 1993–2000 data, SGS routes are currently representative of available woodcock habitat found in the landscape; however, woodcock populations may not be decreasing in New Brunswick at rates predicted by the SGS results. While decreases in available woodcock habitat may occur in some regions with low amounts of intensive forest management and agricultural land abandonment, this trend was not supported by our analysis of changes in the New Brunswick landscape from the 1980s to 2000. We found that the abundance of singing grounds and nesting/feeding cover is increasing across the province over time, and at a more rapid rate than in the area surveyed by the SGS routes. Other data, such as increasing levels of woodcock harvest per successful hunter in Canada from 1975–2000, suggest that woodcock populations are increasing (Bateman 2002). If these differences are not considered during the interpretation of woodcock survey trends, then the need for conservation efforts may be misguided by inaccurate estimates of woodcock abundance and rate of change over time in New Brunswick.

ACKNOWLEDGMENTS

Invaluable advice and guidance from many individuals helped make this report possible. D. Keppie, D. McAuley and M. Betts answered many questions with respect to the analysis and the construction of the habitat model. Thanks to S. Makepeace and C. Brittain for review of this manuscript. The Canadian Wildlife Service, Wildlife Management Institute, and the New Brunswick Department of Natural Resources provided financial support to make this project possible. Special thanks are extended to B. Rau and D. Grecian for their technical support.

LITERATURE CITED

Armson, K. 1999. Canada's forests: a primer. First Foundation Resource Group, Midhurst, Ontario, Canada.

Bateman, M. C. 2001. Status of the woodcock in Canada. Canadian Wildlife Service, Sackville, New Brunswick, Canada.

Bateman, M. C. 2002. Status of the woodcock in Canada. Canadian Wildlife Service, Sackville, New Brunswick, Canada.

Berdeen, J., and D. Krementz. 1998. The use of fields at night by wintering American woodcock. Journal of Wildlife Management 62: 939–947.

Betts, M. G., D. Mitchell, A. W. Diamond, and J. Bêty. 2007. Uneven rates of landscape change as a source of bias in roadside wildlife surveys. Journal of Wildlife Management. 71: 2266–2273.

Bourgeois, A. 1977. Quantitative analysis of American woodcock nest and brood habitat. Pages 109–118 *in* D. M. Keppie and R. B. Owen Jr., editors. Proceedings of the Sixth Woodcock Symposium, Fredericton, New Brunswick, Canada.

Brooks, R. T., and T. W. Birch. 1988. Changes in New England forests and forest owners: Implications for wildlife habitat resources and management. Transactions of the North American Wildlife Natural Resource Conference 53: 78–87.

Bruggink, J. G. 1997. American woodcock harvest and breeding population status, 1997. U.S. Fish and Wildlife Service. Laurel, Maryland, USA.

Canadian Forest Service. 2002. The state of Canada's forests 2001–2002: reflections of a decade. Natural Resources Canada, Canadian Forest Service, Ottawa, Ontario, Canada.

Department of Natural Resources and Energy (DNRE). 1989. New Brunswick forest inventory (1986) report. Timber Management Branch, Forest Utilization and Inventory Section, Fredericton, New Brunswick, Canada.

Dessecker, D., and D. McAuley. 2001. Importance of early successional habitat to ruffed grouse and American woodcock. Wildlife Society Bulletin 29: 456–465.

Dessecker, D., and S. Pursglove, Jr. 2000. Current population status and likely future trends for American woodcock. Pages 3–8 *in* D. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Donovan, T. M., and C. H. Flather. 2002. Relationships among North American songbird trends, habitat fragmentation, and landscape occupancy. Ecological Applications 12: 364–374.

Dwyer, T. J., G. F. Sepik, E. L. Derleth, and D. G. McAuley. 1988. Demographic characteristics of a Maine woodcock population and effects of habitat management. U.S. Fish and Wildlife Service Research Report 4, Washington, D.C., USA.

Environmental Systems Research Institute (ESRI). 2002. The ARC/Info Geographic Information System, Version 8.1. Redlands, California, USA.

Erdle T., and M. Sullivan. 1998. Forest management design for contemporary forestry. Forestry Chronicle 74: 83–90.

Hudgins, J. E., G. L. Storm, and J. S. Wakeley. 1985. Local movements and diurnal-habitat selection by male American woodcock in Pennsylvania. Journal of Wildlife Management 49: 614–619.

Kelley, J. R., Jr. 2002. American woodcock population status. 2002. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Keppie, D. M., and R. M. Whiting, Jr. 1994. American woodcock (*Scolopax minor*) Pages 1–27 *in* A. Poole and F. Gill, editors. The Birds of North America, No.100. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C., USA.

Lansky, M. 1992. Beyond the beauty strip. Tilbury House Publishers, Gardiner, Maine, USA.

McAuley, D. G., J. R. Longcore, G. F. Sepik, and G. W. Pendleton. 1996. Habitat characteristics of American woodcock nest sites on a managed area in Maine. Journal of Wildlife Management 60: 138–148.

Mendall, H., and C. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit, University of Maine, Orono, Maine, USA.

Nicolacopoulos, Margo. 2003. GIS-based assessment of American woodcock (*Scolopax minor*) habitat at two spatial scales in New Brunswick. Honours thesis, University of New Brunswick, Fredericton, New Brunswick, Canada.

Rowe, J. S. 1972. Forest regions of Canada. Department of the Environment, Canadian Forest Service Publication No.1300, Ottawa, Ontario, Canada.

Sepik, G. F., and E. L. Derleth. 1993. Habitat use, home range size, and patterns of moves of the American woodcock in Maine. Pages 41–49 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

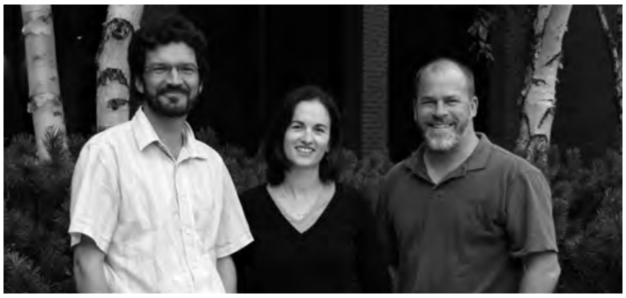
Sepik, G. F., and T. J. Dwyer. 1982. Woodcock response to habitat management in Maine. Pages 106–113 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Proceedings of the Seventh Woodcock Symposium. U.S. Fish and Wildlife Service Research Report 14. Washington, D.C., USA.

Sepik, G. F., R. B. Owen Jr., and M. Coulter. 1994. A landowner's guide to woodcock management in the Northeast. Moosehorn National Wildlife Refuge, U.S. Fish and Wildlife Service Miscellaneous Report 253., Maine Agricultural and Forest Experiment Station, University of Maine, Orono, Maine, USA.

Steketee, A. K. 2000. Predicting Habitat Suitability for American Woodcock and Landscape-level Assessment of Habitat in West Virginia. Dissertation, West Virginia University, Morgantown, USA.

Straw, J. A. Jr., D. G. Krementz, and M. W. Olinde. 1994. American woodcock (*Scolopax minor*). Pages 97-114 *in* T. Tacha and C. Braun, editors. Migratory shore and upland game bird management in North America. The International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Woehr, J. R. 1999. Declines in American woodcock populations: probable cause and management recommendations. Report to International Association of Fish and Wildlife Agencies, Washington, D.C., USA.



Margo Morrison (center) is Registered Professional Forester and conservation planner with the Nature Conservancy of Canada, Atlantic Region in Fredericton, New Brunswick. After receiving a Bachelor of Science in Forestry and Environmental Management, Margo has focused much of her work on identifying priority landscapes for conservation in the Maritime provinces. Other interests include geographic information systems, species at risk and forest management. ***Kevin J. Connor*** (left) is a wildlife biologist with the New Brunswick Department of Natural Resources. He received his B.Sc. in 1995 and his M.Sc. in biology in 1999 at the University of New Brunswick. Kevin's current work interests include wetland conservation, remote sensing, forest management and integrated land-use planning. ***Dr. Graham Forbes*** (right) is Director of the New Brunswick Cooperative Fish and Wildlife Research Unit and a cross-appointed Professor in Forestry and Environmental Management and Biology at the University of New Brunswick, Fredericton. After completing graduate work on moose and wolves with the University of Waterloo, Ontario he conducted research on numerous species, including black bear, white-tailed deer, mustelids, and small mammals and birds, typically in association with forestry companies and government agencies. He is co-chair of the Terrestrial Mammal Committee of Canada's Endangered Species program.

DIURNAL MICROHABITAT USE BY AMERICAN WOODCOCK WINTERING IN EAST TEXAS

10th American Woodcock Symposium
Roscommon, Michigan, USA

CODY B. BERRY, Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, *Nacogdoches, TX, 75962, USA*

WARREN C. CONWAY[1], Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, *Nacogdoches, TX, 75962, USA*

R. MONTAGUE WHITING, JR., Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, *Nacogdoches, TX, 75962, USA*

JEFFREY P. DUGUAY, Biological and Physical Sciences, Delta State University, *Cleveland, MS, 38733, USA*

Abstract: East Texas is the westernmost extent of the normal winter range of American woodcock (*Scolopax minor*). This study addressed information gaps surrounding diurnal winter habitat used by woodcock in east Texas. We measured 14 different habitat variables, including ground (i.e., bare soil, leaf litter, woody debris, grass, herbaceous, etc.), understory, tree canopy, horizontal, and overhead covers at 239 locations of 60 different radio-marked adults during winter of 2001–2002 and 2002–2003. Because of a shift in use from floodplain to upland habitats, several habitat parameters varied between years ($P \leq 0.05$). Although gross structural habitat cover varied between years, there were general similarities in used and random habitats and in male and female habitats within each year. Moreover, although habitat components changed during each year, microhabitats selected by woodcock remained consistent. Woodcock used habitats with varying amounts of ground cover, as in other studies, but were in locations with much less bare soil than in many previous studies. The woodcock's winter requirements—sparse ground cover and adequate overhead cover—are provided by 3 types of sites in east Texas: 1) early successional forests on upland and floodplain sites; 2) thinned pine sawtimber plantations that are regularly burned; and 3) mixed pine-hardwood sawtimber stands.

Proceedings of the American Woodcock Symposium 10: 63–75

Key words: American woodcock, diurnal winter habitat, *Scolopax minor*, Texas.

The American woodcock (*Scolopax minor*) is a migratory game bird that inhabits the eastern United States. The species has experienced long-term population declines (Kelley and Rau 2006), most likely caused by successional changes and habitat loss (Owen et al. 1977, Dwyer et al. 1983, Dessecker and Pursglove 2000). Early successional habitats are important for woodcock throughout the year because the species is disturbance-dependent (Dessecker and Pursglove 2000); however habitat use varies between diurnal and nocturnal periods. Diurnal habitat in the South has been characterized as dense thickets with sparse ground cover (Boggus and Whiting 1982, Straw et al. 1986) within regenerating clearcuts (Boggus and Whiting 1982, Roberts et al. 1984), intermediate-aged forests (Kroll and Whiting 1977), and mature forests (Horton and Causey 1979). Nocturnal habitat is typically more open because birds use old fields (Glenn et al. 2004) and recently harvested forests (Dyer and Hamilton 1977, Horton and Causey 1979).

During winter in east Texas, woodcock often move between diurnal and nocturnal habitats at dusk and dawn (Glenn et al. 2004, Berry 2006). Both sexes use diurnal habitat for feeding and roosting (Horton and Causey 1979), and starting in late January, some adult females also use diurnal habitats for nesting and then brood rearing (Whiting and Boggus 1982, Whiting et al. 2005). Such nesting activity suggests that there may be differences in diurnal microhabitat use by adult male and female woodcock, particularly during late winter. However, few studies have isolated specific requirements for males and females (Sepik and Derleth 1993) and no

---

[1] E-mail: wconway@sfasu.edu

published studies have described diurnal microhabitat components important to adult male and female woodcock in east Texas. To address this information gap, we compared diurnal microhabitat use between adult male and female woodcock and between woodcock flush sites and associated random sites in east Texas during fall and winter, 2001–2002 and 2002–2003.

METHODS

Study Area

This study was conducted on the Alazan Bayou Wildlife Management Area (ABWMA), the adjacent Stephen F. Austin Experimental Forest (SFAEF), and surrounding private lands in Nacogdoches County, Texas (Figure 1). The 835-ha ABWMA was managed by the Texas Parks and Wildlife Department. Approximately 243 ha of the ABWMA were abandoned upland pastures, and the remainder was bottomland hardwood forests in the Angelina River floodplain. Approximately 308 ha of the SFAEF, a part of the United States Forest Service system, were upland mixed pine-hardwood forests, and approximately 1038 ha of the SFAEF were bottomland hardwood forests in the Angelina River floodplain (Conner et al. 1994). Private lands adjacent to the ABWMA and SFAEF were managed by numerous owners and consisted of improved pastures, mixed pine-hardwood forests, pine plantations, bottomland hardwood forests, and residential areas. However, most of the private lands on which this study took place were comprised of 2 intensively managed pine plantations. One plantation was approximately 5 years old and the other was approximately 25 years old; the latter plantation had been thinned twice.

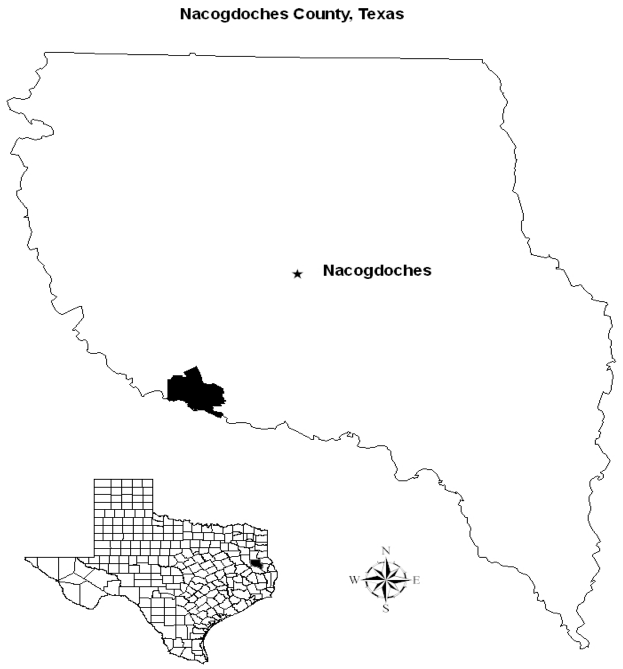


Figure 1. Location of American woodcock study sites at the Stephen F. Austin Experimental Forest and the Alazan Bayou Wildlife Management Area within Nacogdoches County, Texas.

Most upland soils in the area are loams or fine sandy loams in texture on slopes of 0–20%. These soils are deep, moderately to well drained with slow to moderate permeability. Bottomland soils are deep, poorly drained loams with moderate to slow permeability. Bottomland soils contain relatively high proportions of clay and may flood briefly during winter (Dolezel and Fuchs 1980).

Capturing and Radio-Locating Woodcock

We captured woodcock by night-lighting (Rieffenberger and Kletzly 1967) in the fields within the northernmost portion of the ABWMA during fall and winter, 2001–2002 and 2002–2003 (Figure 2). We sexed, aged (Martin 1964, McAuley et al. 1993), and fitted each captured bird with a United States Geological Survey (USGS) aluminum leg band. We attached radio transmitters weighing <6 g (<4% of bird mass) to adults (>1 year old) backpack style with livestock tag cement and a single-loop cable harness (McAuley et al. 1993) (USGS auxiliary marking authorization permit number 22931). In 2002–2003, the cable harness was replaced with a single thread of Gossamer Floss™. We released each bird at the capture site after transmitter attachment. We attempted to radiomark 15 adult males and 15 adult females each winter.

We allowed radio-marked birds 3 days to resume normal activities. Thereafter, we searched for each bird 1–5 times a week until 1 March 2002 and 2003. When a bird was found dead or was missing for 2 consecutive weeks prior to 1 February 2002 and 13 February 2003, we captured and radiomarked a new adult woodcock of the same sex. After these dates, missing or dead birds were not replaced.

Habitat Data Collection

We randomly located radio-marked birds with traditional telemetry techniques between 0800–1700 hours to ensure birds were found equally throughout the day. Upon locating each bird, we flushed it and the flush point was marked (i.e., the used point). If a bird appeared to move before flushing, we considered the original triangulation the used point. We also marked a point 30 m from the used point in a random direction (i.e., the random point). We chose a 30-m distance for random locations to constrain them 1) to diurnal microhabitat(s) that were potentially used by wood-

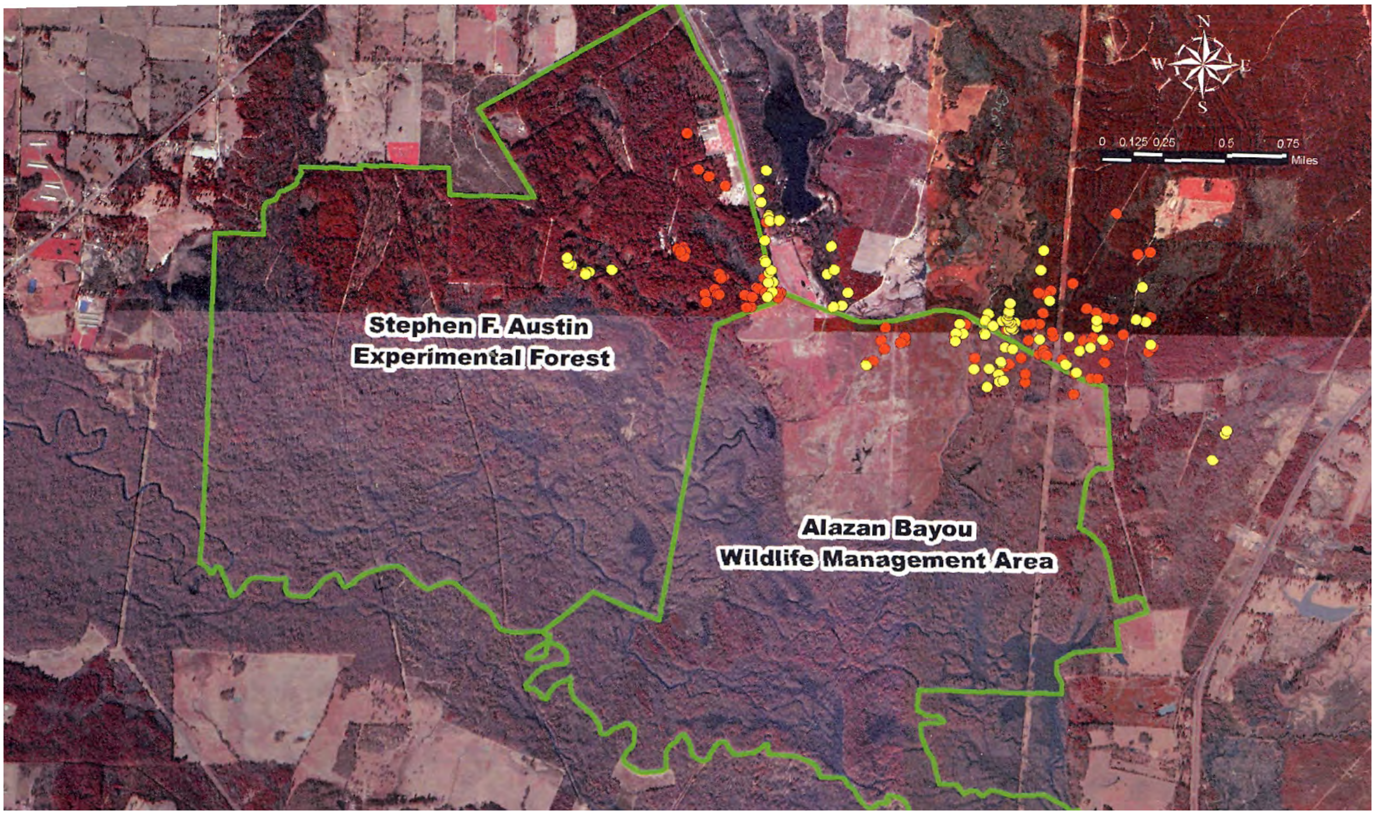


Figure 2. Detailed study area and a subset of American woodcock locations at the Stephen F. Austin Experimental Forest and Alazan Bayou Wildlife Management Area in east Texas, in 2001–2002 (yellow) and 2002–2003 (orange).

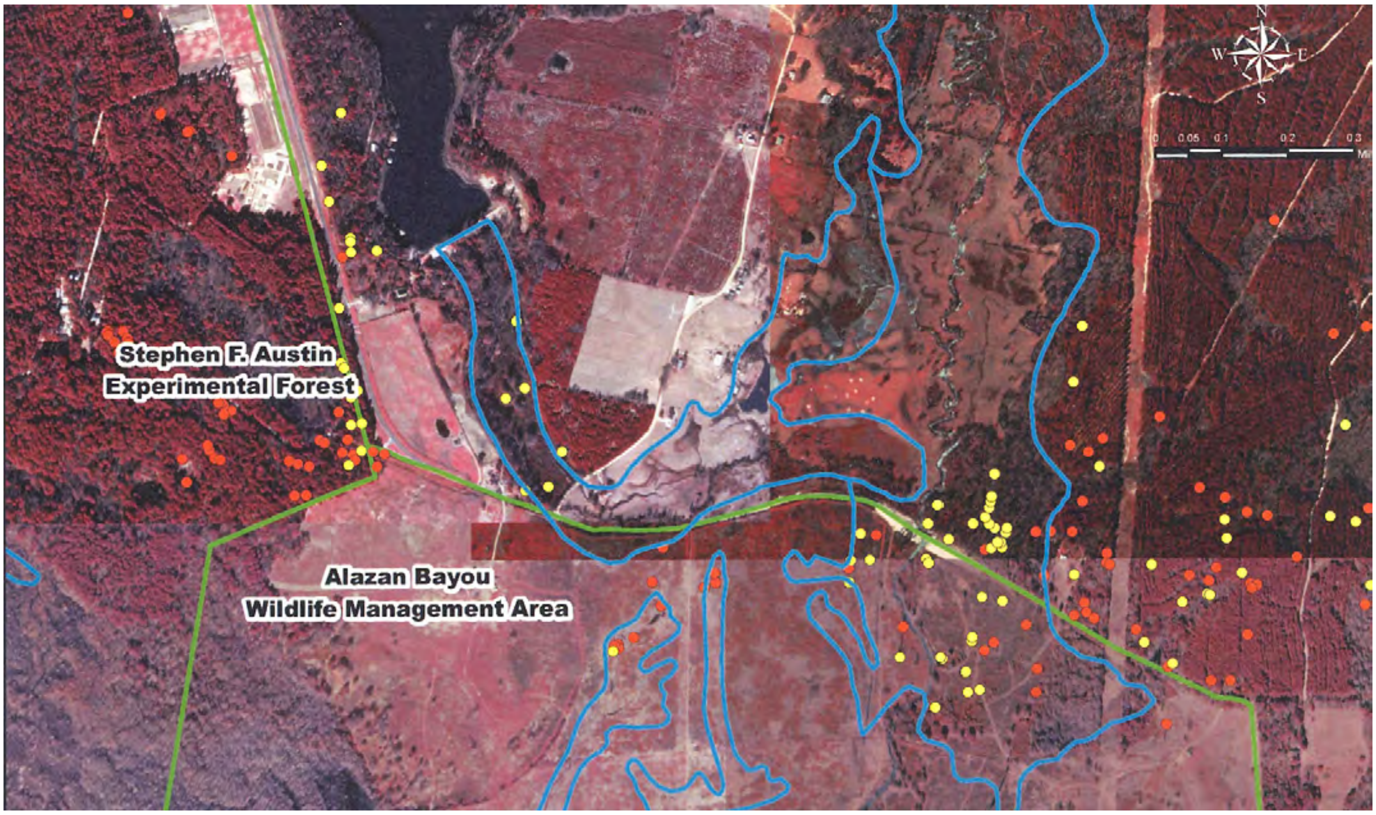


Figure 3. Floodplain soils (blue outline) on the Alazan Bayou Wildlife Management Area overlaid with a subset of American woodcock locations at the Stephen F. Austin Experimental Forest and Alazan Bayou Wildlife Management Area in east Texas, in 2001–2002 (yellow) and 2002–2003 (orange).

cock during this study, 2) from falling in locations in which woodcock would not generally be observed (i.e., roads, open water, etc.), and 3) to focus upon potentially relevant microhabitat features between used and random sites.

Within 1 week of flushing a bird, we collected microhabitat cover data at and around (i.e., used or random location) each used and random point. We recorded vegetative and physiognomic characteristics of the surrounding area. We then ocularly estimated percent ground cover (i.e., 0.0–0.1 m above the ground) in a 0.5 x 1.0-m plot centered on the used or random point for the following categories: water, rock, bare soil, leaf litter, woody debris, and grass, herbaceous, vine, deciduous, or evergreen plant. When green vegetation was above cover lying on the ground (e.g., herbaceous plant above leaf litter), we recorded both categories so that in some instances ground cover totals exceeded 100%. We also estimated the same ground cover categories in 4 additional plots, 1 in each cardinal direction 1 m from each point. We averaged ground cover estimates for the 5 plots by habitat cover category.

We measured understory (i.e., 0.1–6.0 m above the ground) and tree canopy covers (i.e., >6.0 m above the ground) at each location using the line intercept method (Canfield 1941). From each point, we placed a 5-m tape on the ground cover in a cardinal direction and recorded the length of vegetation (cm) directly above the tape for each stratum. We repeated the procedure in the remaining cardinal directions and averaged values for each cover stratum and converted to percentages.

We estimated horizontal vegetation cover in the stratum 0.0–1.5 m above the soil surface at each point. A 0.6 x 1.5-m cover board painted in a black and white checkered pattern of squares, each 15 x 15cm (i.e., 225 cm^2), was placed at each used and random point. We counted only the number of squares ≥50% obscured by vegetation at eye level from a distance of 5 m in each cardinal direction. Squares with <50% coverage were not counted to minimize potential bias towards overestimating horizontal obscurity. We averaged horizontal vegetation cover estimates from cardinal directions and converted the value to a percentage.

We measured overhead vegetation cover using a spherical densiometer with 24 squares (i.e., 96 corners) imprinted on the concave mirror. In an attempt to estimate overhead cover at each point from the perspective of a woodcock, we placed the densiometer on the ground at each used or random point, and then counted the number of corners on the densiometer that reflected vegetation. We performed this procedure while facing each cardinal direction to thoroughly estimate the overhead cover at each point. We averaged the 4 densiometer values and converted that value to a percentage.

Data Analyses

We used multivariate analysis of variance (MANOVA) to examine differences in habitat cover variables (i.e., ground cover by category, understory cover, horizontal vegetation cover, overhead vegetation cover, and tree canopy cover) between years, between used and random locations, between sexes and all interactions. Year was intentionally included as a main effect in initial analyses as yearly variation in habitat was of interest during this study. If interactions ($P < 0.05$) between year and any other main effect occurred, we performed subsequent analyses within each year. To more specifically examine sex-related differences in habitat, we also used MANOVA to examine differences in the same set of habitat variables between years, sexes, and season for used locations only. Each study year was subdivided into early (i.e., November and December) and late (i.e., January, February, and March) seasons in an attempt to examine gender-based habitat use changes within each year. We used MANOVA to maintain overall experiment-wide error rates of 0.05 and Wilks' λ was used as the test criterion because of its conservative power, analogy to univariate F statistics (Johnson and Wichern 2002), resiliency to multivariate non-normality (Olson 1976), and robustness to heterogeneity of variance-covariance matrices (Ito and Schull 1964). If differences ($P < 0.05$) occurred during MANOVA, we performed follow-up analyses of variance (ANOVA) using Type III Sums of Squares. Least squares mean separation was used to examine significant ($P < 0.05$) differences (Zar 1996).

RESULTS

All woodcock captured during each study year were on an upland site or adjacent minor streamside floodplain on the northern portion of ABWMA (Figure 3). In 2001–2002, the first woodcock was radiomarked on 13 December 2001 and the last on 29 January 2002. The first and last radio transmitters fitted in 2002–2003 were on 12 November 2002 and 12 February 2003, respectively.

Habitat

Habitat was measured at 89 woodcock locations (40 male and 49 female) of 12 males and 14 females between 17 December 2001 and 8 March 2002. Between 19 November 2002 and 16 March 2003, we collected habitat data at 150 woodcock locations (39 male and 111 female) of 12 males and 21 females; 1 male and 2 females were recaptures from the previous year. In 2001–2002, 52% of woodcock locations were in floodplain habitats, whereas in 2002–2003 only 24% of locations were in such habitats ($\chi^2 = 18.99$, df = 2, $P < 0.001$); use of mature upland pine stands doubled the second year (Table 1, Figure 3).

Habitat varied between years (Wilks' $\lambda = 0.20$, df = 14, 461, $P < 0.001$), between used and random locations (Wilks' $\lambda = 0.91$, df = 14, 461, $P < 0.001$), and there was a year x location interaction (Wilks' $\lambda = 0.87$, df = 14, 461, $P < 0.001$). Subsequent analyses examining habitat between used and random locations were performed within each year. Grass, understory, horizontal, and overhead covers were lower ($P < 0.05$) at used than random locations in 2001–2002 (Table 2). In 2002–2003, grass, water, and overhead covers were lower ($P < 0.05$) at used than random locations, but leaf litter, understory, and horizontal covers were higher ($P < 0.05$) (Table 2).

There was some variation in microhabitat at random locations between years, although grass ($F = 0.48$, df = 1, 236, $P = 0.487$), leaf litter ($F = 1.98$, df = 1, 236, $P = 0.161$), herbaceous ($F = 0.97$, df = 1, 236, $P = 0.326$) and overhead covers ($F = 1.08$, df = 1, 236, $P = 0.300$) were similar (Table 2). However, bare ground ($F = 6.00$, df = 1, 236, $P = 0.015$), deciduous ($F = 74.12$, df = 1, 236, $P < 0.001$), and horizontal covers ($F = 38.45$, df = 1, 236, $P < 0.001$) were greater in 2001–2002 than 2002–2003, but understory cover ($F = 222.9$, df = 1, 236, $P < 0.001$) was higher in the latter winter (Table 2). Overall habitat at used locations, irrespective of sex, varied (Wilks' $\lambda = 0.14$, df = 14, 222, $P < 0.001$) between years, but was similar between sexes (Wilks' $\lambda = 0.92$, df = 14, 222, $P = 0.207$). Bare soil, woody, deciduous, vine, and tree canopy covers were all higher in 2001–2002 than in 2002–2003, but understory cover was lower in 2001–2002 than in 2002–2003 (Table 3). Few strongly sex-related habitat differences emerged in either year (Table 4). In 2001–2002, habitats used by males and females were similar, whereas in 2002–2003, herbaceous ground cover and overhead canopy cover were higher at male than female locations and female locations had more tree canopy cover ($P < 0.05$).

Finally, as some previous research indicated that females may begin using diurnal habitat for nesting in January (Whiting et al. 2005), we examined if season (i.e., prior to 1 January or after 1 January) influenced habitat use by sex in either year. As before, used habitat did not vary between sexes in 2001–2002 (Wilks' $\lambda = 0.83$, df = 19, 67, $P = 0.762$), but did in 2002–2003 (Wilks' $\lambda = 0.80$, df = 18, 128, $P = 0.028$). Used habitat varied between early and late seasons in 2001–2002 (Wilks' $\lambda = 0.65$, df = 19, 67, $P = 0.031$) (Table 5) and 2002–2003 (Wilks' $\lambda = 0.79$, df = 18, 128, $P = 0.018$) (Table 6), but there were no season x sex interactions in either year (Wilks' $\lambda = 0.85$, df = 19, 67, $P = 0.637$; 2001–2002) (Wilks' $\lambda = 0.86$, df = 18, 128, $P = 0.306$; 2002–2003), indicating that although habitat changed during winter, males and females selected habitats similarly over time. In both years, the amount of leaf litter declined between periods at used locations. However, in 2001–2002, used locations had more understory and horizontal covers in the early period (Table 5), but those same cover values did not differ over time in 2002–2003 (Table 6). Conversely, in 2001–2002, overhead and tree canopy covers were similar between periods (Table 5) whereas in 2002–2003, overhead cover increased and tree canopy cover decreased over time (Table 6).

Table 1. Number and percent (%) of points, categorized by habitat, from which data were collected for radio-marked adult male and female American woodcock during fall and winter of 2001-2002 and 2002-2003 in Nacogdoches County, Texas.

	2001–2002 (*n* = 89)		**2002–2003 (*n* = 150)**	
Habitat[a]	***n***	**%**	***n***	**%**
Floodplain				
Early successional hardwood	20	22.5	27	18.0
Early successional pine-hardwood	2	2.3	1	0.7
Early successional pine plantation	14	15.7	3	2.0
Mature hardwood	7	7.9	4	2.6
Mature mixed pine-hardwood	3	3.4	1	0.7
Total	46	51.8	36	24.0
Upland				
Early successional hardwood	1	1.1	0	0.0
Early successional pine hardwood	0	0.0	4	2.7
Early successional pine plantation	6	6.7	29	19.3
Mature hardwood	0	0.0	2	1.3
Mature mixed pine hardwood	22	24.7	28	18.7
Mature pine	14	15.7	51	34.0
Total	43	48.2	114	76.0

[a] Early successional and mature habitats were comprised of seedling-sapling and pole-sawtimber size trees, respectively. Mixed pine-hardwood stands contained both species types in varying proportions.

Table 2. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected at American woodcock diurnal locations and corresponding random locations during fall and winter of 2001–2002 and 2002–2003 in Nacogdoches County, Texas.

	Used		**Random**			
Parameter (%)[a]	**Mean**	**SE**	**Mean**	**SE**	***F***	***P***
2001–2002 (*n* = 89)						
Ground cover						
Bare ground	5.13	0.80	5.30 A[b]	1.02	0.10	0.751
Rock	<0.01	<0.01	0.19 A	0.19	0.79	0.375
Leaf litter	90.49	1.24	84.20 A	2.47	3.48	0.064
Woody debris	3.50	0.44	3.63 A	0.51	0.04	0.845
Grass	9.93	1.42	17.20 A	2.39	5.93	0.016
Herbaceous	13.97	1.68	16.47 A	2.20	0.09	0.767
Deciduous	10.14	0.97	7.92 A	0.88	3.39	0.067
Vine	10.95	1.54	9.88 A	1.59	0.76	0.385
Evergreen	1.71	0.46	1.20 A	0.35	0.79	0.376
Water	1.48	0.52	1.98 A	0.71	0.24	0.623
Understory cover	20.05	2.02	33.35 B	2.87	13.11	<0.001
Horizontal cover	35.98	3.04	53.47 A	3.42	14.38	<0.001
Overhead cover	5.57	0.91	11.62 A	1.90	9.75	0.002
Tree canopy cover	68.54	3.57	66.86 A	4.07	0.01	0.909
2002–2003 (*n* = 150)						
Ground cover						
Bare ground	2.27	0.46	2.76 B	0.51	0.19	0.663
Rock	0.00	0.00	0.00 A	0.00	NA	NA
Leaf litter	86.31	1.83	79.13 A	2.44	4.51	0.035
Woody debris	2.76	0.34	3.17 A	0.41	0.49	0.484
Grass	10.65	1.20	15.22 A	1.69	4.08	0.044
Herbaceous	11.24	1.27	13.80A	1.55	1.44	0.232
Deciduous	2.10	0.21	1.76 B	0.17	1.70	0.194
Vine	3.14	0.56	3.76 B	0.69	0.00	0.969
Evergreen	3.10	0.70	1.84 A	0.41	1.80	0.181
Water	0.13	0.67	1.80 A	0.68	6.45	0.012
Understory cover	88.55	1.10	78.69 A	1.63	21.74	<0.001
Horizontal cover	43.08	1.93	30.93 B	1.91	20.04	<0.001
Overhead cover	6.45	0.92	14.40 A	1.69	19.64	<0.001
Tree canopy cover	31.57	2.94	36.44 B	3.13	1.72	0.191

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.

[b] Means of random habitat followed by the same letter within the same column are not different (*P* > 0.05) between years.

Table 3. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected at American woodcock diurnal locations during fall and winter of 2001–2002 and 2002–2003 in Nacogdoches County, Texas.

	2001–2002 (*n* = 89)		**2002–2003 (*n* = 150)**			
Parameter (%)[a]	**Mean**	**SE**	**Mean**	**SE**	***F*** [b]	***P***
Ground cover						
Bare ground	5.13	0.80	2.27	0.46	18.28	<0.001
Rock	<0.01	<0.01	0.00	0.00	1.25	0.265
Leaf litter	90.49	1.24	86.31	1.83	0.41	0.523
Woody debris	3.50	0.44	2.76	0.34	6.07	0.015
Grass	9.93	1.42	10.65	1.20	0.26	0.610
Herbaceous	13.97	1.68	11.24	1.27	0.19	0.661
Deciduous	10.14	0.97	2.10	0.21	106.31	<0.001
Vine	10.95	1.54	3.14	0.56	34.71	<0.001
Evergreen	1.71	0.45	3.10	0.70	0.61	0.686
Water	1.48	0.52	0.13	0.07	6.98	0.009
Understory cover	20.05	2.02	88.55	1.10	689.81	<0.001
Horizontal cover	35.98	3.03	43.08	1.92	3.33	0.069
Overhead cover	5.57	0.91	6.45	0.92	1.01	0.316
Tree canopy cover	68.54	3.57	31.57	2.93	78.80	<0.001

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.

[b] Reported *F* and *P* values from Type III Sums of Squares (df = 1, 235).

Table 4. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected at male and female American woodcock diurnal locations during fall and winter of 2002–2003 in Nacogdoches County, Texas.

	Male (*n* = 39)		**Female (*n* = 111)**			
Parameter (%)[a]	**Mean**	**SE**	**Mean**	**SE**	***F*** [b]	***P***
Ground cover						
Bare ground	1.44	0.42	2.56	0.60	0.19	0.660
Rock	0.00	0.00	0.00	0.00	NA	NA
Leaf litter	84.20	3.76	87.05	2.10	0.64	0.426
Woody debris	2.99	0.94	2.68	0.32	0.88	0.349
Grass	12.29	2.38	10.07	1.39	0.79	0.376
Herbaceous	16.81	2.72	9.28	1.39	8.57	0.004
Deciduous	2.39	0.58	1.99	0.20	0.12	0.728
Vine	2.50	0.62	3.37	0.72	1.11	0.293
Evergreen	0.69	0.32	3.94	0.92	5.86	0.017
Water	0.23	0.13	0.09	0.07	1.82	0.179
Understory cover	87.53	1.81	88.91	1.34	1.13	0.290
Horizontal cover	39.92	3.64	44.18	2.27	0.85	0.359
Overhead cover	10.27	2.53	5.11	0.84	6.17	0.014
Tree canopy cover	20.19	4.30	35.57	3.60	4.63	0.033

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.

[b] Reported *F* and *P* values from Type III Sums of Squares (df = 1, 146).

Table 5. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected early (i.e., prior to 1 January) and late (i.e., after 1 January) at American woodcock diurnal locations during fall and winter of 2001–2002 in Nacogdoches County, Texas.

	Early (*n* = 15)		Late (*n* = 74)			
Parameter (%)[a]	**Mean**	**SE**	**Mean**	**SE**	***F*** [b]	***P***
Ground cover						
Bare ground	1.72	0.60	5.83	0.94	3.92	0.051
Rock	0.00	0.00	0.00	0.00	0.16	0.687
Leaf litter	96.49	0.92	89.27	1.44	4.79	0.031
Woody debris	4.31	0.82	3.34	0.49	0.86	0.355
Grass	5.92	1.78	10.75	1.65	1.22	0.272
Herbaceous	6.62	3.00	15.46	1.89	3.81	0.054
Deciduous	7.17	1.09	10.74	1.13	2.01	0.159
Vine	7.61	1.77	11.62	1.80	1.55	0.216
Evergreen	0.13	0.13	2.03	0.54	2.18	0.144
Water	0.00	0.00	1.78	0.62	1.54	0.218
Understory cover	30.25	5.51	17.97	2.09	5.89	0.017
Horizontal cover	62.58	6.70	30.59	3.03	22.46	<0.001
Overhead cover	4.87	1.86	5.71	1.02	0.01	0.906
Tree canopy cover	52.68	7.04	71.76	3.97	3.94	0.050

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.

[b] Reported *F* and *P* values from Type III Sums of Squares (df = 1, 85).

Table 6. Means, Standard Errors (SE), *F* values, and *P* values resulting from analysis of variance for habitat cover data collected early (i.e., prior to 1 January) and late (i.e., after 1 January) at American woodcock diurnal locations during fall and winter of 2002–2003 in Nacogdoches County, Texas.

	Early (*n* = 69)		Late (*n* = 81)			
Parameter (%)[a]	**Mean**	**SE**	**Mean**	**SE**	***F*** [b]	***P***
Ground cover						
Bare ground	1.49	0.48	2.93	0.74	0.84	0.361
Rock	NA	NA	NA	NA	NA	NA
Leaf litter	90.37	2.43	82.85	2.64	6.55	0.012
Woody debris	2.98	0.33	2.57	0.56	0.02	0.899
Grass	8.82	1.86	12.22	1.54	2.32	0.130
Herbaceous	8.83	1.74	13.29	1.81	3.27	0.073
Deciduous	2.53	0.32	1.73	0.28	3.29	0.072
Vine	4.10	1.14	2.33	0.36	0.94	0.333
Evergreen	6.01	1.43	0.62	0.17	5.62	0.019
Water	0.04	0.04	0.21	0.12	0.86	0.355
Understory cover	86.51	1.73	90.29	1.38	0.08	0.772
Horizontal cover	41.55	2.62	44.38	2.79	0.06	0.806
Overhead cover	4.31	1.24	8.28	1.30	6.41	0.012
Tree canopy cover	48.08	4.55	17.51	3.06	18.32	< 0.001

[a] Ground cover, understory cover, and tree canopy cover were evaluated in the stratum 0.0–0.1 m, 0.1–6.0 m, and >6 m above the soil surface, respectively. Horizontal cover was estimated at a distance of 5 m from a density board, and overhead cover was evaluated using a spherical densiometer.

[b] Reported *F* and *P* values from Type III Sums of Squares (df = 1, 145).

DISCUSSION

Yearly Habitat Variation

The magnitude of overall habitat differences between years drove many of the analyses within this study, and likely influenced differences between used and random habitats and between male and female habitat use patterns. For example, habitat varied more between study years than between used and random locations or male and female locations within years. However, yearly differences in used and random locations were generally related to understory, horizontal, and tree canopy covers, not specific ground cover components, which were quite similar in both years (see Table 2). Moreover, these non-ground cover components were undoubtedly related to the general distribution of woodcock between years on the study site. For example, during 2001–2002, woodcock locations were evenly distributed between floodplain and upland habitats, but in 2002–2003, 75% of all the birds were located on upland sites. As expected, understory and horizontal cover patterns mirrored more open floodplain habitats in 2001–2002 and more dense upland habitats in 2002–2003. However, beyond gross differences in generalized habitat structure, we hypothesize that this dramatic shift from floodplains to uplands between years may be due to differences in moisture regimes.

Precipitation in Lufkin, Texas, prior to and during the study period of 2002–2003 was higher than that of either 2001–2002 or the 30-year average (Table 7). More precipitation in 2002–2003 may have increased both soil moisture and suitability of well-drained upland habitats by increasing earthworm availability (Rabe et al. 1983, Owen and Galbraith 1989). The habitat shift observed during this study mirrors woodcock habitat shifts in Alabama, where woodcock used mixed pine-hardwood uplands during wet periods, and hardwood floodplains during dry periods (Horton and Causey 1974). As such, variation in precipitation levels among years may promote facultative habitat shifts by woodcock in response to improved soil moisture conditions, allowing them to periodically occupy upland areas with soils that are too well drained to provide adequate soil moisture conditions in some years.

Differences Between Used and Random Locations

Despite yearly variation in gross structural cover, soil type, and distribution of woodcock in this study, there was little variation in habitats selected by woodcock within years. Likewise, although gross structural cover values varied, woodcock habitat selection patterns were similar between years. For example, most ground cover values were similar between random and used locations within each year, and although not statistically significant in many instances, the direction of most comparisons was similar between years. Conversely, the direction that understory and horizontal cover values changed for used and random locations differed between years, again reflecting the variation in distribution of woodcock on the study site.

Often, the availability of bare soil will partially explain woodcock selection patterns. However, in this study, bare soil proportions were similar between used and random locations within each year and our values (range 2.3–5.1%) are lower than those of other studies. Glenn et al. (2004), working on the ABWMA during winter, reported bare soil values of 14–23 % at nocturnal woodcock locations and 6–15% at random locations. Studies in other geographic regions have reported more bare ground at woodcock locations, even in habitats described as poor or avoided altogether. For example, Wishart and Bider (1976) found that good habitat in Quebec averaged 87% bare ground, whereas poor habitat averaged 56%. Woodcock in Pennsylvania selected areas of 12–17% bare ground and avoided areas with <2% bare ground (Straw et al. 1986). In Alabama, Horton and Causey (1979) found that woodcock activity centers had 53% open ground cover (i.e., void of standing

Table 7. Precipitation (cm) records (NOAA 2006) during fall and winter of 2001–2002 and 2002–2003 in Lufkin, Angelina County, Texas.

Month	Average 1971–72 to 2000–01	2001–2002	2002–2003
October	8.41	10.03	21.44
November	9.78	8.79	21.34
December	9.96	14.20	23.93
January	11.30	10.87	1.65
February	8.05	5.54	14.68
March	8.97	18.97	8.66
Total	56.46	68.40	91.69

vegetation). Beyond sampling differences among these studies, low values of bare ground and low grass cover values observed in this study may reflect the woodcock's propensity to select relatively open ground-level diurnal habitat with relatively high amounts of understory and horizontal covers (*sensu* Boggus and Whiting 1982).

Like bare ground cover, amounts of leaf litter, grass, and herbaceous cover did not vary between used and random locations. Although leaf litter cover values were relatively high in both years and similar to those reported in Glenn et al. (2004), our results are inconclusive and generally support Morgenweck's (1977) conclusion that woodcock use sites with varying levels of litter. During this study, woodcock locations had less grass cover (approx. 10%) than random locations (approx. 15%). These values are slightly lower than those of Glenn et al. (2004), although dissimilarities between these studies may reflect differential habitat use diurnally (this study) and nocturnally (Glenn et al. 2004). However, relatively high grass cover hinders woodcock movement (Boggus and Whiting 1982) and reduces available foraging substrate (Berdeen and Krementz 1998), whereas such grass cover may provide protection from nocturnal predators.

Understory and horizontal cover values were lower at woodcock locations than random locations in 2001–2002, but were higher and lower, respectively, in 2002–2003, reflecting a shift from floodplain to upland sites between years. Floodplain stands were dominated by early hardwood successional vegetation whereas upland stands were dominated by pines, thus the variation in these metrics. Conversely, overhead cover was lower at woodcock locations than random locations in both years; this was the only consistent variation in inter-year structural cover. Despite numerous inconsistencies between years, it appears that woodcock select habitats with little direct overhead cover and with varying amounts of both structural and ground cover. Such habitats may be more reflective of stand structure, residual litter, and vegetative characteristics within the stands than specific features that woodcock seek. As such, woodcock appear to select diurnal habitats based upon the entire vegetation profile and structure as well as the presence of near-ground openings. However, their occupancy or presence in a particular habitat may be facultative based upon soil moisture and precipitation conditions prior to and during winter in east Texas.

Habitat Use Between Sexes and Seasons

As with used versus random comparisons, there were few differences in habitat use between males and females in either year. These results are similar to Krementz and Pendleton (1994), who also found gross similarities between male and female habitat use in winter in Georgia, South Carolina, and Virginia. Although these similarities exist, evidence of female nesting activities initiating in January in east Texas (Whiting et al. 2005) may alter comparisons of habitat use between sexes in late winter and early spring. Although understory and horizontal covers declined at woodcock locations over time during this study, there were no sex x season interactions, indicating that woodcock did not change microhabitat selection during late winter and early spring. This is relevant as we demonstrated that male and female woodcock generally selected microhabitat similarly throughout the late winter and early spring even as habitat conditions changed.

MANAGEMENT IMPLICATIONS

East Texas forested habitats are important for wintering American woodcock (Kroll and Whiting 1977, Boggus and Whiting 1982, Whiting and Boggus 1982). In this study, different moisture regimes allowed for a facultative shift from floodplain habitats to upland habitats between years. Although gross structural habitat changed between years, as reflected in the general distribution of woodcock, early successional ground cover vegetation types were consistent microhabitat features of used habitat in both years. Moreover, although seasonal changes in microhabitats occurred, male and female woodcock selected habitats similarly over time, indicating that structural habitat management for woodcock can be accomplished without consideration of sex during winter. Subtle differences occurred between 1) male and female microhabitats and 2) used and random microhabitats, but dramatic changes in precipitation and subsequent soil moisture conditions between years likely drove the habitat use patterns observed in this study.

From a management perspective, suitable soil moisture conditions are dependent upon precipitation prior to and during winter. However, managers can provide the early successional structure by encouraging frequent disturbance in order to create and maintain woodcock habitat in almost every seral stage of forest. Creation and maintenance of pioneer communities (e.g., young pine plantations, abandoned pastures) permits development of suitable vegetative structure, where mowing, prescribed fire, and other techniques can be used to maintain less-dense areas for access and escape routes. Timber harvesting activities disturb understory vegetation and simultaneously reduce overhead cover, allowing more sunlight to reach the forest floor. Interspersing thinned and completely harvested stands will result in habitat variety suitable for woodcock during winter. Future research on diurnal habitat of American woodcock in east Texas should examine woodcock use of different habitat types as directly related to precipitation, soil moisture variability, and earthworm availability.

ACKNOWLEDGMENTS

J. Broussard, J. R. Glenn, J. LaRue, J. T. Steele, A. E. Thomas, M. A. Watson, K. K. Webb, and J. R. Williamson provided field and laboratory assistance. S. E. Richardson and L. A. Whiting assisted with manuscript preparation. Funding was provided by the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University and the U.S. Fish and Wildlife Service.

LITERATURE CITED

Berdeen, J. B., and D. G. Krementz. 1998. The use of fields at night by wintering American woodcock. Journal of Wildlife Management 62: 939–947.

Berry, C. B. 2006. Characteristics of diurnal microhabitat used by adult American woodcock in east Texas. Thesis, Stephen F. Austin State University, Nacogdoches, Texas, USA.

Boggus, T. G., and R. M. Whiting, Jr. 1982. Effects of habitat variables on foraging of American woodcock wintering in east Texas. Pages 148–153 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39: 388–394.

Conner, R. N., S. D. Jones, and G. D. Jones. 1994. Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. Wilson Bulletin 106: 242–257.

Dessecker, D. R., and S. R. Pursglove, Jr. 2000. Current population status and likely future trends for American woodcock. Pages 3–8 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Dolezel, R., and C. Fuchs. 1980. Soil survey of Nacogdoches County, Texas. U.S. Department of Agriculture, Soil Conservation Service and Forest Service, in cooperation with the Texas Agricultural Experiment Station, College Station, Texas, USA.

Dwyer, T. J., D. G. McAuley, and E. L. Derleth. 1983. Woodcock singing-ground counts and habitat changes in the northeastern United States. Journal of Wildlife Management 47: 772–779.

Dyer, J. M., and R. B. Hamilton. 1977. Analyses of several site components of diurnal woodcock habitat in southern Louisiana. Pages 51–62 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Glenn, J. R., R. M. Whiting, Jr., and J. P. Duguay. 2004. Microhabitat characteristics of nocturnal roost sites of American woodcock in east Texas. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 58: 302–311.

Horton, G. I., and M. K. Causey. 1974. Telemetric studies of woodcock in east central Alabama. Pages 1–12 *in* Proceedings of the Fifth Woodcock Workshop. Athens, Georgia, USA.

Horton, G. I., and M. K. Causey. 1979. Woodcock movements and habitat utilization in central Alabama. Journal of Wildlife Management 43: 414–420.

Ito, K., and W. Schull. 1964. On the robustness of the T^2 test in multivariate analysis of variance when variance-covariance matrices are not equal. Biometrika 51: 71–82.

Johnson, R. A., and D. W. Wichern. 2002. Applied multivariate statistical analysis. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Kelley, J. R., Jr., and R. D. Rau. 2006. American woodcock population status, 2006. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Krementz, D. G., and G. W. Pendleton. 1994. Diurnal habitat use of American woodcock wintering along the Atlantic Coast. Canadian Journal of Zoology 72: 1945–1950.

Kroll, J. C., and R. M. Whiting. 1977. Discriminant function analysis of woodcock winter habitat in east Texas. Pages 63–72 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Martin, F. W. 1964. Woodcock age and sex determination from wings. Journal of Wildlife Management 28: 287–293.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993. Techniques for research into woodcocks: experiences and recommendations. Pages 5–11 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Morgenweck, R. O. 1977. Diurnal high use areas of hatching-year female American woodcock. Pages 155–160 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Olson, C. L. 1976. On choosing a test statistic in multivariate analysis of variance. Psychology Bulletin 83: 579–586.

Owen, R. B., Jr., J. M. Anderson, J. W. Artmann, E. R. Clark, T. G. Dilworth, L. E. Gregg, F. W. Martin, J. D. Newsom, and S. R. Pursglove. 1977. American woodcock (*Philohela minor = Scolopax minor* of Edwards 1974). Pages 149–186 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington D.C., USA.

Owen, R. B., and W. J. Galbraith. 1989. Earthworm biomass in relation to forest types, soil, and land use: implications for woodcock management. Wildlife Society Bulletin 17: 130–136.

Rabe, D. L., H. H. Prince, and E. D. Goodman. 1983. The effect of weather on bioenergetics of breeding American woodcock. Journal of Wildlife Management 47: 762–771.

Rieffenberger, J. C., and R. C. Kletzly. 1967. Woodcock night-lighting techniques and equipment. U.S. Bureau of Sport Fisheries and Wildlife, Special Science Report-Wildlife, Number 101.

Roberts, T. H., E. P. Hill, and E. A. Gluesing. 1984. Woodcock utilization of bottomland hardwoods in the Mississippi Delta. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38: 137–141.

Sepik, G. F., and E. L. Derleth. 1993. Habitat use, home range size, and patterns of moves of the American woodcock in Maine. Pages 41–49 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Straw, J. A., Jr., J. S. Wakeley, and J. E. Hudgins. 1986. A model for management of diurnal habitat for American woodcock in Pennsylvania. Journal of Wildlife Management 50: 378–383.

Whiting, R. M., Jr., and T. G. Boggus. 1982. Breeding biology of American woodcock in east Texas. Pages 132–138 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14.

Whiting, R. M., Jr., D. A. Haukos, and L. M. Smith. 2005. Factors affecting January reproduction of American woodcock in Texas. Southeastern Naturalist 4: 639–646.

Wishart, R. A., and J. R. Bider. 1976. Habitat preferences of woodcock in southwestern Quebec. Journal of Wildlife Management 40: 523–531.

Zar, J. H. 1996. Biostatistical analysis. Prentice-Hall, Upper Saddle River, New Jersey, USA.

Cody Berry is currently a Natural Resources Specialist (Ranger) with the U.S. Army Corps of Engineers at Lake O' the Pines in northeast Texas. He received a B.S. in Wildlife Management from the University of Wyoming, and a M.S. from the Arthur Temple College of Forestry at Stephen F. Austin State University. After completing his M.S., he owned and operated a forestry and logging company and later served as a wildlife technician for the Texas Parks and Wildlife Department.

Not Pictured

Warren Conway received his B.S. in wildlife biology and management from the University of Rhode Island and his M.S. and Ph.D. in wildlife science from Texas Tech University. He is currently an Associate Professor of Wildlife Management at Stephen F. Austin State University, and his research interests focus upon wildlife-habitat relationships.

R. Montague Whiting, Jr. is Professor Emeritus in the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University (SFASU) in Nacogdoches, Texas. He joined the faculty of SFASU in 1972 and completed the Ph.D. on the Texas A&M - SFASU joint program in 1978. During his academic career, he taught several forestry and numerous wildlife courses. Most of his research involved game and nongame birds, especially northern bobwhite and American woodcock. Currently, he is enjoying retirement and hunting birds as often and in as many places as possible with the objective of bagging at least one of every game bird in the continental United States.

Jeffrey P. Duguay received a B.S. in Wildlife Biology from Unity College in Maine, an M.S. in Ecology from Eastern Kentucky University, and a Ph.D. in Wildlife Management from West Virginia University. Jeff is currently an associate professor of wildlife management at Delta State University where he developed the wildlife management degree concentration.

AMERICAN WOODCOCK POPULATIONS ASSOCIATED WITH AN ELECTRIC TRANSMISSION RIGHT-OF-WAY

10th American Woodcock Symposium
Roscommon, Michigan, USA

Richard H. Yahner[1], School of Forest Resources, The Pennsylvania State University,
University Park, PA 16802, USA

Abstract: I monitored traditional courtship (spring singing) sites of American woodcock (*Scolopax minor*) populations for 7 years (2000–2006) on the State Game Lands 33 Research and Demonstration Area (SGL 33 RDA), which is located along a 230-kV transmission line right-of-way (ROW) and is owned and maintained by FirstEnergy Corporation in the Allegheny Mountain Province, Centre County, Pennsylvania. The objective of my study was to determine the relative abundance of male woodcock at courtship sites in relation to different treatment units and wire versus border zones on the ROW. The number of courting (singing) male woodcock ranged from 1 in spring 2000 to >7 in springs 2004–06. Early successional habitat created on the ROW by the wire-border zone method of vegetation maintenance on the SGL 33 RDA presumably will have increasing importance to the long-term conservation of woodcock in the local vicinity.

Proceedings of the American Woodcock Symposium 10: 77–81

Key words: American woodcock, herbicides, rights-of-way, *Scolopax minor*, tree control.

Research on the State Game Lands 33 Research and Demonstration Area (SGL 33 RDA) has been ongoing since 1953, making this the longest continuous study documenting the effects of mechanical and herbicidal maintenance on plants and animals along an electric transmission right-of-way (ROW) (e.g., Yahner et al. 2002). This long-term study is invaluable from management and ecological perspectives by providing an understanding of plant and animal response to ROW maintenance practices.

In 1982, a maintenance technique called the wire-border zone method (Bramble et al. 1992) was applied to all treatment units on the ROW. This method combines mechanical and chemical techniques to produce a tree-resistant forb-low shrub-grass cover type in wire zones and a shrub cover type in border zones (Figure 1).

The American woodcock (*Scolopax minor*) is a migratory game bird that has shown population declines in the northeastern United States over the past few decades as a partial result of forest maturation and conversion of farmland to forestland (Coulter and Baird 1982, Storm et al. 1995, Dessecker and McAuley 2001). The American woodcock is on the National Watchlist of the Pennsylvania Audubon Society (www.audubon.org/bird/watchlist/bs-bc-pennsylvania.html). Studies of woodcock populations on the ROW are relevant because this species can be an indicator of vegetation maintenance effects on the local ecosystem (e.g., Bramble et al. 1992).

I began long-term monitoring of American woodcock on the SGL 33 RDA in spring 2000. Woodcock have used portions of the ROW as a traditional courtship area since at least the late 1980s. The objective of my study was to determine the relative abundance of male woodcock at courtship sites in relation to treatment units and use of wire versus border zones on the ROW. My study is important because highway construction has been ongoing over the last couple of years in the Bald Eagle Valley, about 10 km south of the ROW; building of the U.S. 99 Interstate began in 2002 (Yahner 2004, www.corridor-o.com). The Bald Eagle Valley represents an important habitat for breeding woodcock and includes many traditional courtship areas for singing male woodcock (Liscinsky 1972). Thus, highway construction potentially has eliminated or reduced courtship and nesting habitat for woodcock in the valley. As a consequence, the ROW in the SGL 33 RDA may become more valuable as alternate woodcock habitat in the region.

STUDY AREA

The study area was located on the SGL 33 RDA, which is along a 230-kV transmission line right-of-way (ROW) and is owned and maintained by FirstEnergy Corporation in the Allegheny Mountain Province, Centre County, Pennsylvania. Oak (*Quercus* spp.) and

---

[1] E-mail: rhy@psu.edu

red maple (*Acer rubrum*) were common trees in border zones of the ROW and in the adjacent forest (Yahner et al. 2002). On the ROW, common shrubs were blackberry (*Rubus allegheniensis*), dewberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), witch hazel (*Hamamelis virginiana*), and sweet fern (*Comptonia peregrina*); major forbs included goldenrod (*Solidago* spp.), hayscented fern (*Dennstaedtia punctilobula*), and bracken fern (*Pteridium aquilinum*); common grasses were poverty grass (*Danthonia spicata*) and meadow fescue (*Fescue elatior*).

METHODS

Treatments on the ROW

Six treatment units are present on the ROW, with at least 2 replicates each of 1) handcutting, 2) low-volume basal spray, 3) mowing plus herbicide, 4) stem-foliage spray, 5) foliage spray, and 6) mowing. The total length of the ROW used in this study was approximately 3.2 km, and treatment units vary in size from 0.8 to 1.5 ha. The ROW was treated most recently in July 2000 (Yahner et al. 2002, Yahner et al. 2003). Undesirable trees were cut in handcut units in wire and border zones, and undesirable trees and shrubs were treated with a low-volume basal spray of Garlon 4® (Dow AgroSciences, Indianapolis, IN) (25%) in basal oil (75%) in wire and border zones of other units. Handcut units were characterized by shrub-tree-forb (here the relative percentage of shrub cover type exceeded that of tree cover type; tree type exceeded that of forb type) cover type in wire zones and shrub-tree cover type in border zones. Low-volume basal spray units were shrub-forb-grass cover type in wire and border zones. Mowing plus herbicide units were forb-shrub-grass cover type in wire zones and shrub-forb cover type in border zones. Stem-foliage spray, foliage spray, and mowing units were shrub-grass cover type in both wire and border zones.

Surveys of American Woodcock

I conducted surveys of courting American woodcock 5 times per year for 7 years from late March to late April 2000–2006 on the ROW. Time between consecutive surveys on a given unit ranged from 4–7 days. I plotted locations of courting males with regard to treatment unit and zone (wire versus border). Courtship in male woodcock consists of a twittering flight song and buzzing "peent" call, which is performed at dusk (Tappe et al. 1989). I began each survey at dusk and continued for 45–60 minutes (Storm et al. 1995). I made vehicular stops along the ROW at approximately 0.4-km intervals, using an access road traversing the length of the ROW. At least 5–10 minutes were spent at each stop to note presence and location of individual male woodcock, based on courtship song or flight. I assumed that individual male woodcock remained in the same unit from night to night. However, because my survey was based on unmarked birds at dusk this assumption was difficult to verify.

RESULTS

In 2000, I documented 1 singing male woodcock on the ROW of the SGL 33 RDA (Table 1). In 2001, 3 woodcock used the ROW as a courtship area. In 2002, the number of woodcock singing on the ROW dropped to 2000 levels (n = 1). In 2003 I again surveyed 3 woodcock on the ROW. Then in 2004–2006, the number of woodcock observed on the ROW increased, ranging from 7 to 8. In addition, on at least 3 occasions during springs 2000–2004, I flushed >1 brood of woodcock in border zones along the ROW (R. H. Yahner, unpublished data), suggesting that the ROW was being used as nesting habitat by woodcock.

I found 1 singing male woodcock each year in a handcut unit (HC-2) from 2000–2002 and in 2003, 2 woodcock occurred in this unit (Table 1). In 2005, the number of woodcock in this unit increased to 3. The HC-2 is not a homogeneous unit because it was converted from a mowing-plus-herbicide to a handcut unit in 2000. Woodcock occurred on the HC treatment type during all years of the study (Table 1). From 2000 to 2003, I found singing male woodcock in 3 treatment types: HC, low-volume basal spray (BLV), and stem-foliage spray (SF) (Table 1). During the latter years of the project (2004–2006), woodcock also started using mowing only (M) and mowing-plus-herbicide (MH) treatment units (Table 1).

DISCUSSION

Interestingly, singing woodcock use of different treatment units from 2004–2006 corresponded to a regional increase in singing males as portrayed in survey results conducted by the U.S. Fish and Wildlife Service (Cooper and Parker 2009: Figure 4). My survey results suggest that treatment type becomes less important as populations increase. The important component of the ROW is a vegetation structure conducive to woodcock breeding and not necessarily the manner in which that structure is attained. I found that singing males used both wire and border zones of the ROW (Table 1).

The wire-border zone method of vegetation maintenance on the ROW created early successional habitat for

Table 1. Number of singing male woodcock heard during 5 surveys/year relative to treatment unit and zone (wire versus border) on the State Game Lands 33 Research and Demonstration Area, March–April 2000–2006. HC = handcut, BLV = low-volume basal spray, SF = stem-foliage spray, F = foliage spray, M = mowing, MH = mowing plus herbicide.

Year	Survey date	Unit	Zone	No. heard
2000	9 April	HC-2 (formerly M-2)	wire	1
	16 April	HC-2	wire	1
	20 April	HC-2	wire	1
2001	1 April	BLV-2	border	1
		HC-2 (formerly M-2)	border	1
	22 April	BLV-2	border	1
		HC-2	border	1
		SF-2	border	1
2002	17 April	HC-2	border	1
2003	2 April	HC-2	border	1
		BLV-2	wire	1
	9 April	HC-2	border	1
		HC-2	wire	1
		BLV-2	border	1
2004	30 March	HC-2	border	1
		M-3	wire	1
		M-3	border	1
		BLV-2	border	1
	7 April	MH-2	border	1
		F-2	border	1
		BLV-1	wire	1
		BLV-3	border	1
	14 April	BLV-1	wire	1
		BLV-1	border	1
		BLV-3	border	1
	17 April	HC-2	wire	1
		BLV-2	border	1
2005	27 March	HC-2	wire	1
		HC-2	border	2
	1 April	BLV-1	border	1
		MH-1	wire	1
		BLV-3	wire	1
	6 April	HC-2	border	2
		BLV-2	border	1
		SF-2	border	1
	10 April	BLV-3	border	1
	11 April	HC-2	wire	1
		BLV-2c	border	1
2006	31 March	HC-2	border	1
		BLV-1	border	1
		BLV-3	border	1
		SF-2	wire	1
	1 April	BLV-2	border	1
		MH-1	wire	1
	7 April	HC-2	wire	1
		BLV-2	wire	1
		BLV-2	border	1
		M-2	wire	1
		SF-2	border	1
	8 April	BLV-3	border	1
		MH-1	wire	1
	11 April	HC-2	wire	1

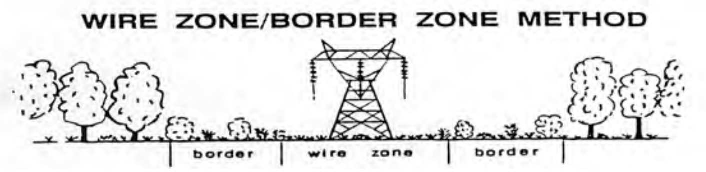


Figure 1. Diagram of a 230-kV electric transmission line, showing wire and border zones. A combination of a low-growing forb-shrub-grass cover type develops in the wire zone, and a tall-shrub cover type occurs in the border zone. Adjacent to the border zone often is uncut forest.

woodcock (Dessecker and McAuley 2001). Areas used by breeding woodcock as diurnal habitat and nest sites include a mixture of bare ground, large shrubs, and saplings (Straw et al. 1986, McAuley et al. 1996), which is similar to that found in border zones of the ROW (Figure 1). Shrubs in border zones of the ROW also provide cover for singing males, while open areas in both wire and border zones give woodcock an unobstructed path during courtship flights (Dessecker and McAuley 2001).

In conclusion, early successional habitat created by the wire-border zone method of vegetation maintenance on the ROW (Yahner et al. 2002) provides localized habitat for American woodcock, which typically is more important to species occurrence than landscape-scale habitat (Storm et al. 1995). Based on 7 years of data, I conclude that suitable courtship sites are available along the ROW for woodcock, especially in border zones characterized by shrubs and reduced canopy cover. Shrubs in border zones provide cover for singing males, while open areas in both wire and border zones give woodcock an unobstructed path during courtship flights. Additional research may show that habitat on the ROW will continue to become increasingly valuable to American woodcock as construction along I-99 in the valley progresses over the next few years or when the proposed Corridor O is constructed from Port Matilda, past Philipsburg, to I-80 (Yahner 2004, www.corridor-o.com).

ACKNOWLEDGMENTS

Cooperators were Asplundh Tree Expert Company, Dow AgroSciences, FirstEnergy (Penelec) Corporation, and the Pennsylvania Game Commission. I thank R. T. Yahner for field assistance.

LITERATURE CITED

Bramble, W. C., R. H. Yahner, and W. R. Byrnes. 1992. Breeding-bird population changes following right-of-way maintenance treatments. Journal of Arboriculture 18: 23–32.

Cooper, T. R., and K. Parker. 2009. American woodcock population status, 2009. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Coulter, M. W., and J. C. Baird. 1982. Changing forest land uses and opportunities for woodcock management in New England and the Maritime Provinces. Pages 75–85 in T. J. Dryer and G. L. Storm, technical coordinators. Woodcock Ecology and Management. USDA Forest Service Wildlife Research Report. Washington, D.C., USA.

Dessecker, D. R., and D. G. McAuley. 2001. Importance of early successional habitat to ruffed grouse and American woodcock. Wildlife Society Bulletin 29: 456–465.

Liscinsky, S. A. 1972. The Pennsylvania Woodcock Management Study. The Pennsylvania Game Commission, Harrisburg, Pennsylvania, USA.

McAuley, D. G., J. Loncore, G. F. Sepik, and G. W. Pendleton. 1996. Habitat characteristics of American woodcock nest sites on a managed area in Maine. Journal of Wildlife Management 60: 138–147.

Straw, J. A., J. S. Wakeley, and J. E. Hudgins. 1986. A model for management of diurnal habitat for American woodcock in Pennsylvania. Journal of Wildlife Management 50: 378–383.

Storm, G. L., M. J. Lovallo, D. S. Klute, W. M. Tzilkowski, and T. DeLong. 1995. Predicting American woodcock presence in Pennsylvania from local and landscape-level habitat variables. Northeast Wildlife 52: 39–48.

Tappe, P. A., R. M. Whiting, and R. R. George. 1989. Singing-ground surveys for woodcock in east Texas. Wildlife Society Bulletin 17: 36–40.

Yahner, R. H. 2004. Wildlife response to more than 50 years of vegetation maintenance on a Pennsylvania, U.S., right-of-way. Journal of Arboriculture 30: 121–124.

Yahner, R. H., R. J. Hutnik, and S. A. Liscinsky. 2002. Bird populations associated with an electric transmission right-of-way. Journal of Arboriculture 28: 123–130.

Yahner, R. H., R. J. Hutnik, and S. A. Liscinsky. 2003. State Game Lands 33 Research and Demonstration Project—51 years of continuous study. Annual Report to Cooperators. School of Forest Resources, The Pennsylvania State University, University Park, Pennsylvania, USA.

Richard H. Yahner is professor of wildlife conservation in the School of Forest Resources at The Pennsylvania State University. Previously, he was assistant director for Outreach in the School, associate dean of the Graduate School at Penn State, chair of the Intercollege Graduate Degree Program in Ecology at Penn State, assistant professor of wildlife at the University of Minnesota, and postdoctoral fellow at the Smithsonian Institution. He has taught in the areas of conservation ecology/biology, field wildlife techniques, ecology, wildlife management, animal behavior, wildlife natural history, and professionalism. He has published more than 300 research publications on wildlife ecology and conservation biology, with several of these focusing on plants and animals associated with rights-of-way in the East. He has been a research consultant on rights-of-way since 1987; in 2007, he was awarded an Honorary Life Membership by the International Society of Arboriculture.

FALL DIURNAL HABITAT USE BY ADULT FEMALE AMERICAN WOODCOCK IN THE WESTERN GREAT LAKES REGION

10th American Woodcock Symposium
Roscommon, Michigan, USA

JED MEUNIER[1,2], Department of Wildlife Ecology, University of Wisconsin-Madison,
226 Russell Labs, 1630 Linden Drive, Madison, WI 53706 USA

R. SCOTT LUTZ, Department of Wildlife Ecology, University of Wisconsin-Madison,
226 Russell Labs, 1630 Linden Drive, Madison, WI 53706 USA

KEVIN E. DOHERTY[3], Minnesota Cooperative Fish and Wildlife Research Unit, Department of Fisheries,
Wildlife, and Conservation Biology, University of Minnesota, *St. Paul, MN 55108 USA*

DAVID E. ANDERSEN, U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit,
Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota,
St. Paul, MN 55108 USA

EILEEN OPPELT, Department of Biology, Northern Michigan University,
1401 Presque Isle Avenue, Marquette, MI 49855 USA

JOHN G. BRUGGINK, Department of Biology, Northern Michigan University,
1401 Presque Isle Avenue, Marquette, MI 49855 USA

Abstract: We assessed how habitat structure and food availability influenced use of cover types at the habitat-patch and home-range scales by adult female (after hatch year) American woodcock in Michigan, Minnesota, and Wisconsin from 2002 through 2004. We also investigated use of alder (*Alnus* spp.) as a staging cover prior to fall migration. We selected this cover to investigate seasonally changing use of cover types based on past scientific studies. Seasonal changes in cover type use could have important ramifications for woodcock management intended to provide or improve woodcock habitat. We measured edge proximity, stem density, and earthworm abundance at woodcock locations and paired these locations to random locations at the microhabitat scale (2002 data), 20 m from use locations within the same stand. We also compared edge proximity with paired use and random locations at the home-range scale (2003 and 2004 data; >35 and <200 m from use locations across cover types) and investigated habitat selection at this scale. Adult female woodcock (n = 139) used a variety of cover types and the relative use of cover types changed among years and states. The greatest frequency of alder use across all states occurred in 2003, a drought year. We found no difference between alder use during the entire fall period and early fall (t = 0.01, P = 0.9) or late fall (t = 0.28, P = 0.7) indicating that alder was not used as staging cover prior to migration. Structural habitat features may be more important than food resources to habitat selection especially at the home-range spatial scale; cover types most heavily used by woodcock often had the lowest earthworm abundances. Woodcock selected habitats with generally lower total stem density and fewer mature stems in young cover types than we found at random locations. We found little evidence to suggest woodcock selected habitat based on food procurement needs, stem density, or edge proximity alone, however our results indicated that well developed shrub layers and lack of residual large diameter trees in early seral covers might be important. These findings may indicate that predator avoidance, measured by structural characteristics, may be more important than food abundance in selection of habitat by woodcock, which makes management objectives intended to provide woodcock habitat a feasible task.

Proceedings of the American Woodcock Symposium 10: 83–94

Key words: American woodcock, earthworms, Great Lakes region, habitat, *Scolopax minor*, structure.

---

[1] Present address: Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University, Fort Collins, Colorado 80523.

[2] E-mail: jmeunier@mail.colostate.edu

[3] Present address: United States Fish and Wildlife Service, Bismarck, ND 58501.

Long-term population declines in American woodcock (*Scolopax minor*) are often attributed to habitat changes, particularly the loss of early successional forests. Several research efforts have focused on woodcock habitat preferences; however, accurate estimates of woodcock habitat availability are difficult to obtain (Woehr 1999). Forest inventory data have been used to estimate availability of woodcock habitat, but correlations between gross trends in forest cover types and woodcock population trends have shown few significant relationships (e.g., Woehr 1999, Dessecker and Pursglove 2000). Thus, Woehr (1999) speculated that not all seedling-sapling hardwood forest is suitable woodcock habitat and other factors must be driving habitat selection. Supporting this contention, Gregg (1984) reported that a number of aspen (*Populus* spp.) stands within his study areas were not used by woodcock and that woodcock often only used small areas within selected stands.

Habitat structure and earthworm availability have been identified as the primary factors affecting habitat use by woodcock, although there is no consensus on which of these factors is most influential. Results of some studies indicated that structure was most important (Liscinsky 1972), while others found that woodcock habitat use was related primarily to earthworm abundance (Reynolds et al. 1977, Parris 1986). Several studies have noted no relationship between earthworm biomass and woodcock habitat use (e.g., Wishart and Bider 1976, Kroll and Whiting 1977).

Understanding woodcock habitat use is complicated by changing environmental conditions (e.g., soil moisture) and variation in habitat preference over seasons. Woodcock exhibit distinct changes in habitat preference by season (Mendall and Aldous 1943, Wishart and Bider 1976) and with different environmental conditions within and among years (Sepik et al. 1983, Gregg 1984). Wishart and Bider (1976), for example, found that resident woodcock use shifted to alder (*Alnus* spp.) cover types during autumn despite high soil moisture throughout their southwestern Quebec study areas. These authors suggested that perhaps alder cover serves as migration staging areas. Many shorebirds use staging areas with abundant food resources during migration, and Wishart and Bider (1976) speculated that in dry years alder woods would supply woodcock with food requirements for migration.

Woodcock show an affinity for forest edges in their selection of habitat; they nest near edges, select edges for diurnal cover during summer and fall, and courtship behavior occurs in openings near edges (Wishart and Bider 1976, Parris 1986, McAuley et al. 1996). Edge proximity and the simple nature of diurnal habitat structure—early seral and even-aged stands—may play an important role in diurnal habitat selection.

To assess fall habitat use and factors influencing habitat use, we used radio telemetry to monitor habitat use by after-hatch-year (AHY) adult female woodcock at 3 study areas in Michigan, Minnesota, and Wisconsin from 2002–2004. Our specific objectives were to 1) describe habitat use over space and time, 2) determine whether alder acts as a staging cover in fall, and 3) assess the relative importance of habitat structure versus food availability in habitat selection. Our research was conducted under the assumptions that structural selection is likely an effect of predator avoidance and earthworm abundance influences food availability.

STUDY AREAS

We conducted our research in the western Great Lakes region, which included study areas in Minnesota, Michigan, and Wisconsin (Figure 1). We selected study areas in large blocks of industrial private and public-owned forests with high woodcock densities. Study areas among the 3 states were comprised of similar principle forest types used by woodcock including alder, aspen, northern hardwood swamp (NHS), northern mesic forest (NMF), shrub-carr (shrub), conifer, and meadows as outlined in the Wisconsin Natural Heritage Inventory (NHI; Epstein et al. 2002). Conifer cover type included several communities included in the NHI: mesic cedar forest, black spruce swamp, and tamarack swamp. Meadow cover included the NHI northern sedge

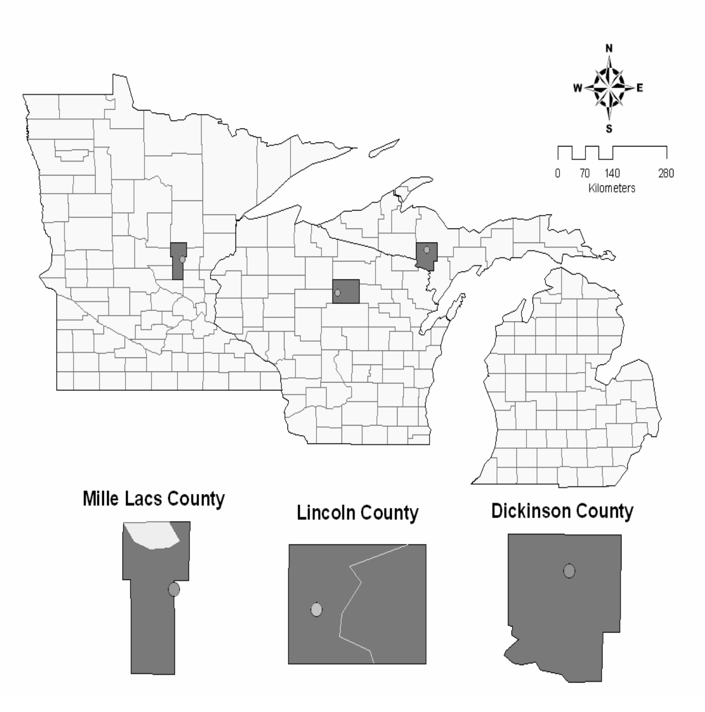


Figure 1. Location of American woodcock study areas in Michigan, Minnesota, and Wisconsin.

meadow community, old fields, and wildlife openings. There is no Great Lakes NHI community type for aspen (*Populus* spp.). Aspen stands are generally seral to other hardwood forest communities and are minor components without frequent disturbance. However, because aspen is an important woodcock cover, we included it as a separate cover type.

Study sites in Michigan were located within the Copper Country State Forest in northern Dickinson County in the Upper Peninsula. In Minnesota, study sites were located within the southern portion of the 15,672-ha Mille Lacs Wildlife Management Area and the adjacent 1,166-ha Four Brooks Wildlife Management Area. These sites were in east-central Minnesota in Mille Lacs County and had similar vegetative communities and management. Wisconsin study sites were in the Lincoln County Forest and Tomahawk Timberlands industrial forest. Both study sites were in Lincoln County in north-central Wisconsin and were managed primarily for timber production and recreational opportunities.

Our study areas were dominated by northern mesic forest stands. Sugar maple (*Acer saccharum*) dominated the better-drained soils and red maple (*Acer rubrum*) dominated the more mesic sites with aspen being a strong seral component in disturbed northern mesic forests. Wet basins contained spruce–fir (*Picea–Abies*) on wet mineral soils and spruce–tamarack (*Picea–Larix*) bogs on wet organic soils.

METHODS

Capture

We captured woodcock in Minnesota, Michigan, and Wisconsin between mid-August and the end of September from 2002 through 2004. We terminated our capture efforts on 30 September each year to reduce the possibility of capturing non-resident, migrating woodcock (Mendall and Aldous 1943, Gregg 1984). Capture techniques included spotlighting (Rieffenberger and Kletzly 1967) and intercepting woodcock flights to roost fields at dusk using mist nets (Sheldon 1960, McAuley et al. 1993). We used plumage characteristics and bill length to age and sex woodcock (Mendall and Aldous 1943, Greeley 1953, Martin 1964). We classified ages as hatch year (HY; fledged young-of-the-year) or AHY (all older birds). We weighed woodcock and attached a radio transmitter weighing approximately 4.4 g to birds >140 g using a single loop wire harness and livestock-tag cement following the techniques of McAuley et al. (1993). Following transmitter attachment, we released woodcock at capture sites.

Radiotelemetry

In early September of each year we randomly selected a subset of radio-marked AHY female woodcock (2002: n = 37, 2003: n = 54, and 2004: n = 48) across the 3 states for habitat sampling. We located our subset of woodcock ≥5 times per week using hand-held yagi and/or rubberized H-antennas and portable receivers. We took coordinates for each daily location within approximately 2–14 m of the true woodcock location using a hand-held Global Positioning System (GPS) because we did not want to flush birds and alter behavior when determining locations. We visually located woodcock to minimize chances of accidental disturbance and to describe habitat use more accurately. We obtained approximately 88% of all locations without flushing woodcock, thus minimizing our influence on habitat selection. If we were unable to locate woodcock from the ground, we relocated them via fixed-wing aircraft. We monitored woodcock until they died or migrated, which we inferred when we failed to detect a signal during 3 consecutive aerial telemetry flights.

Habitat Use

We collected habitat-use data at 2 spatial scales, microhabitat and home-range. We sampled habitat use during fieldwork in 2002 at the microhabitat scale; this corresponds to Johnson's (1980) fourth-order selection—the actual procurement of food items within a home range. The second level we investigated was the home-range scale, with data collected in 2003 and 2004; this corresponds to Johnson's third-order selection—"the usage made of various habitat components within the home range" (Johnson 1980). We selected these scales to better understand observations that characterize woodcock use of particular stands (third-order) and locations within stands (fourth-order).

Cover Type Use

We classified habitats where birds were located according to overstory cover type and size class of stems. We based our cover type classification on dominant canopy species defined by greatest percent cover. Cover types we included were aspen (AS), northern mesic forest (NMF), conifer, northern hardwood swamp (NHS) by size class and alder, shrub-carr (shrub), and meadow. We used three size classes: 1) seedling-sapling (S), <10 cm diameter at breast height (DBH); 2) pole (P), 10–30 cm DBH; and 3) mature (M), >30 cm DBH.

We tested the hypothesis that alder was used as a staging cover prior to migration. We used 2-sample *t*-tests and divided the fall period into 2 blocks of time: late August through September (early fall) and October through early November (late fall). If alder was used as a staging cover for resident woodcock we expected greater woodcock use of alder in late fall, just prior to migration (Meunier et al. 2008), than early fall. We constrained the alder preference analysis to individuals with ≥ 15 locations in each period. We tested for differences in frequency of alder use between the two periods with paired *t*-tests.

Microhabitat Use

In 2002, we paired woodcock use locations with random locations twice per week ($n = 266$) for comparisons at a microhabitat scale. We quantified habitat variables approximately 2–14 m from radio-equipped woodcock ("use" locations). We then sampled random locations approximately 20 m away from use locations at a random bearing, but within the same cover type. We compared stem density, density of *Rubus* spp., edge proximity, and earthworm abundance between all paired use and random points using paired *t*-tests (stem density and earthworm abundance comparisons) and chi-square tests (edge proximity).

We estimated stem density per 0.004 ha along bent transects with the starting location of the transect corresponding to the estimated woodcock use location. To avoid flushing woodcock, we used L-shaped transects turning 90° toward the woodcock at the midway point. We determined the transect length by the length of the observers' outstretched arms span (Penfound and Rice 1957). We counted each vertical woody stem within the bounded transect (arm span) that forked below breast height as an individual stem and tallied all stems counted within the bounded transect to estimate stem density (Penfound and Rice 1957). We used Braun-Blanquet (1932) cover classes to estimate density of *Rubus* spp. and analyzed stem density comparisons by cover type in addition to size class using data pooled across all woodcock by cover type. We used paired *t*-tests to compare the means of pooled cover type classes.

To determine if woodcock exhibited a preference in fall for close proximity to edges we quantified the distance to the nearest edge within 30 m and the edge type (e.g., adjacent cover types, water bodies, roads, trails etc.) for use and paired random locations. To assess preference for proximity to an edge, we calculated the proportion of use and random locations that were ≤ 15 m and >15 m from an edge and compared these proportions between location types using chi-square tests.

We estimated earthworm biomass within a 35-cm^2 (0.1225-m^2) plot at each daily use location with a spicy-mustard solution extraction method following the protocol of Lawrence and Bowers (2002). We collected earthworms that surfaced during a 5-minute period and subsequently determined the ash-free dry mass for each sample (± 0.0001 g) to compare samples over a large geographic area (Hale et al. 2004). We used earthworm biomass as an index to woodcock food availability and sampled at the location nearest to our woodcock. We used 2-sample *t*-tests to test for differences in earthworm biomass between use and random locations. Two-sample *t*-tests are less sensitive than paired tests, but we used this technique due to a very small number of random sample locations and instead pooled over the entire season, which, due to the large variance in earthworm samples over time, negated dependence among samples.

Home-range Scale Habitat Use

We used home-range-scale habitat data we collected in 2003 and 2004 to compare use and random locations across cover types to explore woodcock habitat selection. We defined cover types as "selected" when the observed use frequency was greater than the expected use frequency and when the corresponding random-location frequency was less than expected. Expected use frequency was that under our null hypothesis of equal use proportions between use and random locations. We analyzed cover-type data from use and random locations with chi-square tests using MINITAB (Minitab, Incorporated 1999).

In 2003 and 2004, we established random locations ($n = 2{,}534$) at the home-range scale by walking a random distance (between 35 and 200 m) and bearing from use locations. Eighty percent of all adult female woodcock movements between days are <200 m (Doherty et al. 2010), so this scale allowed a comparison of diurnal habitat features across cover types but constrained random locations to within the home-range scale.

We used the same analysis for home-range-scale edge-proximity data as we did for microhabitat-scale data collected in 2002. Analyses consisted of chi-square tests to compare the proportion of locations ≤ 15 m from an edge between use and random locations.

We used earthworms sampled at use locations from 2002 through 2004 to determine if earthworm abundance varied across cover types. To meet the assumption of normally distributed data we divided worm data based on earthworm presence or absence (i.e., samples where we found earthworms and samples where we did not). We analyzed the presence-absence data first, using chi-square tests. Second, we used analysis of variance (ANOVA) in SYSTAT (Systat 2000) to test for the main effects of state, year, and cover type for all presence data. Our response variable was the log weight of earthworm samples where we found earthworms (presence data, $n = 2{,}496$). We transformed data to the log scale to meet the assumption of normality. We also plotted the log weights against the date of sampling to determine if we needed to incorporate daily or seasonal effects. We used Tukey multiple comparisons (Systat 2000) to compare earthworm biomass among cover types.

RESULTS

Cover Type Use and Selection

We sampled >20 habitat-use locations for each of 90 AHY female woodcock (2002: n = 19, 2003: n = 38, and 2004: n = 33). Adult female woodcock used a variety of cover types (Table 1). The most commonly used cover type across states was seedling-sapling aspen (AS-S) and alder, but the relative importance of cover types differed among years and states (Table 1).

We found evidence of woodcock cover-type selection at the home-range scale (across cover types). Radio-marked woodcock used seedling-sapling aspen more than expected in all states and years except in Minnesota during 2004 (Tables 2 and 3). Woodcock also selected alder cover in Wisconsin during 2003 (χ^2= 11.08, df = 1, P < 0.01) and 2004 (χ^2 = 17.68, df = 1, P < 0.01) and Minnesota in 2003 (χ^2 = 18.97, df = 1, P < 0.01) and 2004 (χ^2 = 3.10, df = 1, P = 0.08). A greater proportion of random locations were in meadows and mature northern mesic forest, except in Minnesota during 2004, when we observed no difference between woodcock use frequency and random location frequency in mature northern mesic forest (χ^2 = 0.10, df = 1, P = 0.76).

We were not able to generalize about use of conifer and mature aspen cover types. In 2003, woodcock in Michigan selected conifer cover (χ^2 = 4.35, df = 1, P = 0.04), whereas woodcock in Wisconsin tended to avoid conifers (χ^2 = 5.00, df = 1, P = 0.03). Wisconsin woodcock were located in mature aspen in greater proportion (χ^2 = 10.60, df = 1, P < 0.01) than random locations in 2003, but in Michigan in 2004 (χ^2 = 4.90, df = 1, P = 0.03) and Minnesota in 2003 (χ^2 = 9.54, df = 1, P < 0.01) a greater proportion of random locations was within mature aspen.

We found no difference between the mean frequency of alder use over the entire fall and in August/September (t = –0.01, df = 27, P = 0.99) or October/November (t = –0.28, df = 27, P = 0.78).

Microhabitat Use

We sampled habitat data at random locations for roughly one-third of woodcock use locations in Wisconsin (n = 77) and Minnesota (n = 105), and in Michigan nearly half of use locations were paired with random locations (n = 54). Stem density comparisons indicated

Table 1. Cover types (% of total) used in 2002, 2003, and 2004 by after-hatch-year female American woodcock in Dickinson County, Michigan, Mille Lacs County, Minnesota, and Lincoln County, Wisconsin.

	Michigan			**Minnesota**			**Wisconsin**		
Habitat category	**2002 (*n* = 117)**	**2003 (*n* = 412)**	**2004 (*n* = 461)**	**2002 (*n* = 310)**	**2003 (*n* = 484)**	**2004 (*n* = 276)**	**2002 (*n* = 218)**	**2003 (*n* = 531)**	**2004 (*n* = 483)**
Alder	8.5	12.4	8.2	20	21.7	8.0	11	20.2	17.6
Aspen seedling–sapling	39.3	44.7	68.5	26.8	25.2	15.2	72.5	39.7	42.0
Aspen mature		5.6	2.2	7.7	4.8	9.4	2.3	14.7	7.2
Aspen pole	5.1	6.8	3.0	22.9	11.6	14.9	2.3	6.6	7.7
Conifer	19.7	27.7	11.3					3.4	5.2
Northern hardwood swamp mature	11.1	0.5			1.0	4.7		1.5	
Northern mixed forest mature	3.4	1.4	4.6	2.9	10.3	8.7	6.4	11.7	6.8
Northern mixed forest pole					3.3	3.6		0.8	1.4
Northern mixed forest sapling	12			0.3	1.9	0.4	2.3	0.9	7.0
Meadow		0.7	2.2	0.3	1.2	0.7			0.6
Shrub	0.9	0.2		19	19	34.2	3.2	0.2	4.3
Total	100	100	100	100	100	100	100	100	100

Table 2. Cover type selection (observed use frequency > expected, observed random location frequency < expected) chi-square test comparisons between woodcock use location frequency counts and randomly located point frequency counts in 2003.

	Michigan			Minnesota			Wisconsin		
Cover type	**Random**	**Use**	***P***	**Random**	**Use**	***P***	**Random**	**Use**	***P***
Alder	48	51	0.758	53	105	0.000	55	107	0.001
Aspen seedling-sapling	137	184	0.001	66	122	0.000	136	211	0.002
Aspen mature	22	23	0.885	47	23	0.002	36	78	0.001
Aspen poled	18	28	0.131	72	56	0.094	24	35	0.410
Conifer	88	114	0.037	1			29	18	0.025
Northern hardwood swamp mature	2	2	0.998	7	5	0.532	3	8	0.214
Northern mesic forest mature	24	6	0.001	102	50	0.000	100	62	0.000
Northern mesic forest pole				14	16	0.763	4	4	0.813
Northern mesic forest seedling-sapling	1			7	9	0.650		5	
Meadow	68	3	0.000	32	6	0.000	56		0.000
Shrub	3	1	0.315	71	92	0.108	5	1	0.065
Other									
Total	411	412		472	484		448	529	

Table 3. Cover type selection (observed use frequency > expected, observed random location frequency < expected) chi-square test comparisons between woodcock use location frequency counts and randomly located point frequency counts in 2004.

	Michigan			Minnesota			Wisconsin		
Cover type	**Random**	**Use**	***P***	**Random**	**Use**	***P***	**Random**	**Use**	***P***
Alder	31	38	0.418	12	22	0.078	40	85	0.000
Aspen seedling-sapling	199	316	0.000	43	42	0.892	135	203	0.000
Aspen mature	22	10	0.028	21	26	0.454	35	35	0.935
Aspen pole	15	14	0.818	41	41	0.986	35	37	0.871
Conifer	64	52	0.200				34	25	0.199
Northern hardwood swamp mature	1			6	13	0.104	4		
Northern mesic forest mature	57	21	0.000	26	24	0.757	67	33	0.000
Northern mesic forest pole				5	10	0.193	16	7	0.052
Northern mesic forest seedling-sapling					1		21	34	0.083
Meadow	60	10	0.000	73	2	0.000	62	3	0.000
Shrub	1			48	95	0.000	6	21	0.004
Other	4						19		
Total	454	461		275	276		474	483	

few statistically significant relationships across all 3 states; however, a few differences between use and random locations were in the same direction among states. For example, for data pooled by cover type and stem size, we found fewer stems at use locations in seedling-sapling aspen covers ($t = -1.82$, df = 113, $P = 0.07$), and higher mean total stem density at random locations was a general trend for most cover types (Table 4). However, in Minnesota shrub stem density was higher at use points than at random points within alder ($t = 2.20$, df = 18, $P = 0.04$) and seedling-sapling aspen ($t = 1.93$, df = 31, $P = 0.06$) cover types, and the density of *Rubus* spp. within shrub cover type was higher at use locations ($t = 3.78$, df = 33, $P < 0.01$). In contrast, woodcock use locations often had fewer mature stems than random locations. Examples are in seedling-sapling aspen in Wisconsin ($\mu = 5$ versus $\mu = 200$; we found no mature stems in seedling-sapling aspen in Michigan), and alder ($\mu = 13$ versus $\mu = 72$), shrub ($\mu = 41$ versus $\mu = 240$), and willow ($\mu = 46$ versus $\mu = 125$) covers in Minnesota.

Table 4. Paired *t*-tests by cover comparing mean stem densities (stems/ha) at sites used by woodcock and random sites within the same stand for radio-marked after-hatch-year American woodcock in Michigan, Minnesota, and Wisconsin, from September to November 2002.

Cover type	Use mean stems/ ha	Random mean stems/ ha	*t*	df	*P*
Alder	9,156	10,268	–0.79	28	0.436
AS-S[a]	10,277	11,355	–1.82	113	0.071
ASP	7,085	8,467	–1.43	26	0.164
NMF[b]	8,596	8,184	0.28	16	0.780
Shrub	11,418	12,231	–0.66	35	0.512
ALL[c]	9,560	10,294	–1.83	249	0.068

[a] Aspen seedling-sapling cover type.
[b] Northern mesic forest cover type.
[c] Aspen mature (*n* = 8), Conifer (*n* = 9), and Northern hardwood swamp (*n* = 4) covers were not analyzed individually due to small sample size.

Comparisons among states by stem size and cover type should be interpreted with some caution due to a high number of comparisons and large variance.

During 2002, woodcock in Wisconsin were located ≤15 m from an edge more than expected in seedling-sapling aspen ($\chi^2 = 15.55$, df = 1, $P < 0.01$) and mature northern mesic forest ($\chi^2 = 4.29$, df = 1, $P = 0.04$) cover types. In Minnesota in 2002, we located woodcock ≤15 m from an edge more than expected in seedling-sapling aspen ($\chi^2 = 5.80$, df = 1, $P = 0.02$) and shrub ($\chi^2 = 2.73$, df = 1, $P = 0.10$) covers. In Michigan, the proportion of distances ≤15 and >15 m to an edge were not different between use and random locations for any cover type (Table 5).

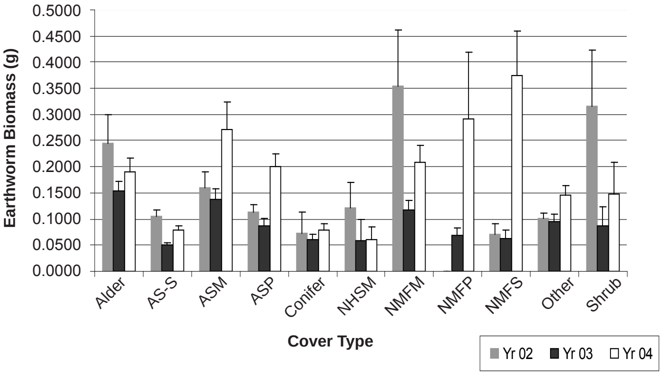
We found no differences in earthworm biomass between use versus random locations within cover type or pooled across all cover types (Table 6). We were unable to analyze earthworm abundance by cover type at the microhabitat level for Minnesota because too few random points were sampled for earthworms. Microhabitat scale earthworm comparisons were limited by small sample sizes for many covers and estimates of earthworm abundance exhibited high variability, which likely reduced our ability to detect differences.

Home Range-scale Habitat Use

We observed no consistent pattern of edge selection by AHY female woodcock among states or years (Table 5). In 2003 a greater proportion of use locations was ≤15 m from an edge than random locations for mature and pole-sized aspen in Michigan ($\chi^2 = 8.70$, df = 1, $P < 0.01$; $\chi^2 = 3.93$, df = 1, $P = 0.05$, respectively) and Wis-

Table 5. Chi-square comparisons (*P*-values) for distances < and >15 m to an edge for use and random points for after-hatch-year female American woodcock in 2002, 2003, and 2004 in Michigan, Minnesota, and Wisconsin.

	Michigan			Minnesota			Wisconsin		
Cover type	2002	2003	2004	2002	2003	2004	2002	2003	2004
Alder	0.134	0.979	0.738	0.421	0.717	0.638	0.160	<0.001	0.503
Aspen mature		0.003	0.186	0.172	0.811	0.596	<0.050	0.012	1.000
Aspen pole	>0.500	0.047	0.340	0.202	0.583	0.607		0.007	0.859
Aspen seedling-sapling	0.690	0.624	0.029	0.016	0.211	0.070	<0.001	0.851	0.773
Northern mesic forest mature			0.143		0.689	0.059	0.038	<0.001	0.008
Northern mesic forest pole					0.526	0.171			0.679
Northern mesic forest sapling							< 0.050		0.391
Northern mesic forest	0.401	0.656		0.513			0.369		
Shrub				0.098	0.940	0.763	0.381		0.650
Conifer	0.181	0.161	0.897					0.180	0.694
Northern hardwood swamp mature								0.007	
Northern hardwood swamp	0.825				0.038	0.637			
All Covers	0.781	0.046	0.015	0.418	0.822	0.009	<0.001	<0.001	0.578



AS-S = aspen seedling-sapling

ASM = aspen mature

ASP = aspen pole

NHSM = northern hardwood swamp mature

NMFM = northern mesic forest mature

NMFP = northern mesic forest pole

NMFS = northern mesic forest seedling-sapling

Figure 2. Mean ash-free dry earthworm mass (in g) by cover type and year for use and random sample locations (*n* = 2,497) in Michigan, Minnesota, and Wisconsin.

consin ($\chi^2 = 6.39$, df = 1, $P = 0.01$; $\chi^2 = 7.24$, df = 1, $P < 0.01$, respectively; Table 5). We found no difference in edge proximity between use and random locations in seedling-sapling aspen in 2003 in Michigan, Minnesota, or Wisconsin. In Wisconsin, a greater proportion of use points was in close proximity to edges (≤15 m) in mature northern mesic forest ($\chi^2 = 12.60$, df = 1, $P < 0.01$) and mature northern hardwood swamp ($\chi^2 = 7.22$, df = 1, $P < 0.01$) than for random locations.

In 2004, Wisconsin had higher numbers of use locations than random locations ≤15 m from an edge in mature northern mesic forest ($\chi^2 = 6.95$, df = 1, $P < 0.01$). In Michigan, use locations were ≤15 m from an edge in greater proportion than random locations for woodcock located in seedling-sapling aspen ($\chi^2 = 4.77$, df = 1, P = 0.03). In Minnesota, in both mature aspen and mature northern mesic forest, use locations were ≤15 m from an edge more frequently than random points ($\chi^2 = 3.28$, df = 1, $P < 0.07$, and $\chi^2 = 3.57$, df = 1, $P < 0.06$, respectively).

Types of edges most frequently encountered near woodcock locations included meadows, trails, logging roads, and ecotones—edges where ≥ 2 forest cover types met. Woodcock were also near streams, beaver ponds, and other water bodies. Across all states and years, meadows were the only edge type more frequently close to woodcock use locations than to paired random locations (Table 7).

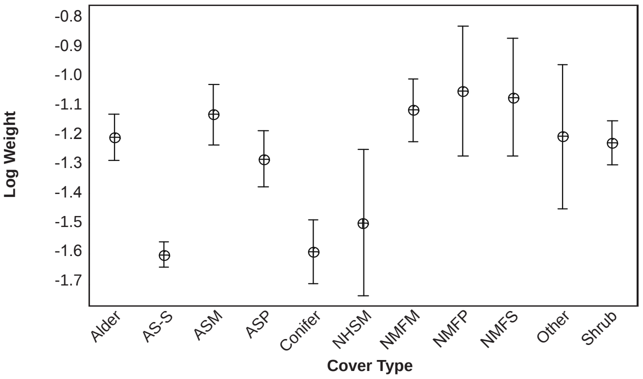


Figure 3. Least square mean with 95 % confidence intervals of the log earthworm weight by cover type for earthworms use and random locations sampled (*n* = 2,497) in Michigan, Minnesota, and Wisconsin from 2002–2004. See Figure 2 for acronym descriptions.

The proportion of locations we sampled for earthworms and where earthworms were present by cover type was similar to the proportion of sample locations where we encountered earthworms for all covers. The only evidence for differences in proportion of samples with earthworms present was in shrub and pole-sized aspen covers. We observed earthworm presence more frequently than expected for shrub ($\chi^2 = 15.64$, df = 1, $P < 0.01$) and pole-sized aspen ($\chi^2 = 4.98$, df = 1, $P = 0.03$) cover types. We also detected earthworm presence more frequently in mature aspen ($\chi^2 = 3.05$, df = 1, $P = 0.08$) and other ($\chi^2 = 3.78$, df = 1, $P = 0.05$) cover types. The only cover type with lower earthworm detection than expected was seedling-sapling aspen ($\chi^2 = 2.78$, df = 1, $P = 0.10$).

We did not find a seasonal or day effect on earthworm biomass, however we found differences in earthworm biomass among years ($F = 32.89$, df = 2, 2481, $P < 0.01$), states ($F = 60.35$, df = 2, 2481, $P < 0.01$), and cover types ($F = 14.77$, df = 10, 2481, $P < 0.01$). Earthworm biomass was lowest in 2003 and highest in 2004, though this relationship varied among cover types (Figure 2). Earthworm biomass was lowest in Michigan in all years, and highest in Wisconsin in both 2002 and 2003. Conifer, seedling-sapling aspen, and northern hardwood swamp cover types were lower in earthworm abundance than all other cover types and did not differ from one another (Figure 3).

DISCUSSION

Although many factors likely contribute to woodcock habitat selection, we focused our investigation on stand characteristics—stem density and edge proximity—and earthworm biomass as a surrogate of food

Table 6. Two-sample *t*-test comparisons of ash-free dry weight of earthworms sampled at locations used by after-hatch-year female American woodcock and random locations within the same cover type patch in fall 2002 in Michigan, Minnesota, and Wisconsin.

Location	Use	Random	df	*t*	*P*
Michigan					
Alder	0.0705	0.0458	8	0.577	0.579
Aspen S-S	0.1225	0.0571	45	1.439	0.157
Conifer	0.0165	0.1153	9	–1.122	0.291
NHSM	0.1196	0.0202	8	1.743	0.120
NMFM					
NMFS	0.0534	0.024	4	1.900	0.130
All Covers	0.0774	0.0599	73	0.608	0.545
Minnesota					
Alder					
Aspen S-S					
Conifer					
NHSM					
NMFM					
NMFS					
All Covers	0.0878	0.0817	15	0.120	0.906
Wisconsin					
Alder	0.5117	0.2151	25	1.524	0.140
Aspen S-S	0.0863	0.0561	174	1.175	0.242
Conifer					
NMFM	0.4716	0.7083	4	–0.451	0.675
NMFS	0.0936	0.0115		1.400	
NHSM					
All Covers	0.1789	0.1164	160	1.372	0.172

Table 7. Edge types encountered (% of total) near after-hatch-year female American woodcock use locations and random locations in Michigan, Minnesota, and Wisconsin from 2002–2004.

		Use locations					Random locations				
Year	Site	*n*	Meadow	Trail–Road	Ecotone	Water	*n*	Meadow	Trail–Road	Ecotone	Water
2002											
	MI	117	19.7	19.7	55.6	0	54	11.1	24.1	55.6	0
	MN	385	0.3	14.1	58.7	0	133	0	11.3	57.9	0
	WI	154	65.6	7.8	13.6	9.7	36	58.3	2.8	27.8	11.1
2003											
	MI	412	24.5	13.3	57.3	0.5	412	12.4	17.4	67.5	0
	MN	473	31.3	19.2	45	3	465	25.6	22.4	50.1	0.9
	WI	494	28.1	16.2	39.3	9.3	392	16.1	12.5	54.6	4.3
2004											
	MI	461	17.4	40.1	40.8	0	461	15.4	32.8	50.1	0.2
	MN	276	47.1	11.6	38.4	0.4	276	21.4	15.2	56.5	2.2
	WI	290	37.6	13.1	35.5	7.6	282	24.5	16	47.9	7.4

availability. AHY woodcock in our study used a variety of cover types and size classes, adding to the complexity of describing structural characteristics selected by woodcock where forest management often results in heterogeneity of seral stages and cover types. While our stem density and edge proximity comparisons lack strong patterns across all states and years, we observed interesting trends.

Woodcock locations preferred by adult female woodcock generally had lower stem density as compared to corresponding random locations (Table 4). This was similarly true in shrub cover types, though the abundance of shrubs stems was greater at use locations in seedling-sapling aspen cover and alder in Minnesota. Gregg (1984) noted that a shrub component appeared to be a prerequisite for woodcock use of many mature aspen stands in Wisconsin. High shrub density among covers may be a component of site quality, with greater species diversity in higher quality sites. Higher quality sites may provide non-suckering species an ability to compete with aspen and alder, for example. This could also be an edge effect, with greater competition between aspen and shrub species along edges due to increased sunlight near the forest floor, which provides greater opportunity for shrubs to flourish. We observed woodcock near edges though with little consistency among states, years, and cover types (Table 5). Examples of negative associations between mature stems and woodcock use of simple structured covers (seedling-sapling aspen, shrub, alder, and willow) may be a result of mature stems providing avian predator perches, that could negatively influence woodcock use. While mature stands with a developed shrub understory offer an abundance of perching trees, the structure of these stands is not as simple, perhaps affording woodcock greater protection.

Surprisingly, we found no difference in earthworm abundance between used and random locations at the microhabitat level. This suggests that either woodcock are not selecting habitat at the microhabitat level based on food abundance or that our sampling methodology was not sufficiently precise to detect differences. At the home-range scale woodcock also did not appear to be selecting covers based on earthworm abundance. Seedling-sapling aspen cover types, the most preferred cover type across the 3 states and 3 years, had the lowest earthworm biomass of all used cover types (Figure 3), indicating that on average our radio-marked woodcock selected areas with abundant adequate structure over areas with high earthworm biomass.

The proportion of alder use was greatest in all states in 2003, a drought year. Use of alder when conditions are drier is consistent with results of past research (Sepik et al. 1983, Gregg 1984) where habitat use changed with different environmental conditions. Alder stands probably offer foraging habitat for woodcock in drought conditions and are an important component of woodcock habitat. Earthworm biomass was lower in all cover types in 2003, but alder had the highest mean earthworm biomass during this period (Figure 2). This may indicate that under most conditions all habitats had sufficient earthworm availability for woodcock foraging. Under these average conditions structural characteristics of habitat may be of primary importance in woodcock use of cover types. We found no evidence that alder is used as a staging cover, as there was no difference in the frequency of alder use between early- and late-fall periods.

Our results illustrate the importance of structural heterogeneity in woodcock habitat use. Proximity to edge may facilitate escape routes (Parris 1986), high stem density may afford concealment from predators, and lack of mature trees in early seral (structurally simple) habitats may reduce predation risk from avian predators for woodcock during the fall. In addition, a dense shrub layer may be an important structural component in woodcock habitat selection of cover types. Further investigation of the relationships among total stem density, shrub stem density, and edge proximity as related to site quality may elucidate management options of these habitat features for woodcock management.

ACKNOWLEDGMENTS

Our research was funded by the United States Fish and Wildlife Service, Region 3; United States Geological Survey (Science Support Initiative); Wisconsin Department of Natural Resources; Minnesota Department of Natural Resources; Michigan Department of Natural Resources; Webless Migratory Game Bird Research Program; University of Wisconsin–Madison; University of Minnesota–Twin Cities; Northern Michigan University–Marquette; the Minnesota Cooperative Fish and Wildlife Research Unit; the Ruffed Grouse Society; Wisconsin Pointing Dog Association; and the North Central Wisconsin Chapter of the North American Versatile Hunting Dog Association. Special thanks to R. Tuszynski, K. Martin, R. Wissink, S. Guthrie, D. E. Beyer, D. G. McAuley, and J. Cary for their help in completing this investigation. We also thank S. Temple and R. Guries for initial reviews of this manuscript and our many field technicians.

LITERATURE CITED

Braun-Blanquet, J. 1932. Plant sociology: the study of plant communities. First Edition. McGraw-Hill. New York, New York. USA.

Dessecker, D. R., and S. R. Pursglove, Jr. 2000. Current population status and likely future trends for American woodcock. Pages 3–8 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S.Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Doherty, K. E., D. E. Andersen, J. Meunier, E. Oppelt, R. S. Lutz, and J. G. Bruggink. 2010. Foraging location quality as a predictor of fidelity to a diurnal site for adult female American woodcock. Wildlife Biology Vol.16: In Press.

Epstein, E., E. Judziewicz, and E. Spencer. 2002. Wisconsin natural heritage inventory natural community description. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA.

Greeley, F. 1953. Sex and age studies in fall-shot woodcock (*Philohela minor*) from southern Wisconsin. Journal of Wildlife Management 17: 29–32.

Gregg, L. 1984. Population ecology of woodcock in Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin 144, Madison, Wisconsin, USA.

Hale, C. M., L. E. Frelich, and P. B. Reich. 2004. Allometric equations for estimation of ash-free dry mass from length measurements for selected European earthworm species (*Lumbricidae*) in the western Great Lakes region. American Midland Naturalist 151: 179–185.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61: 65–71.

Kroll, J. C., and R. M. Whiting. 1977. Discriminate function analysis of woodcock winter habitat in east Texas. Pages 63–71 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Lawrence, A. P., and M. A. Bowers. 2002. A test of the ‘hot’ mustard extraction method of sampling earthworms. Soil Biology and Biochemistry 34: 549–552.

Liscinsky, S. A. 1972. The Pennsylvania woodcock management study. Pennsylvania Game Commission Final Report. Pittman-Robertson Project. W-50-R.

Martin, F. W. 1964. Woodcock age and sex determination from wings. Journal of Wildlife Management 28: 287–293.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993. Techniques for research into woodcocks: experiences and recommendations. U.S. Fish and Wildlife Service Biological Report 16: 5–11.

McAuley, D. G., J. R. Longcore, G. F. Sepik, and G. W. Pendleton. 1996. Habitat characteristics of American woodcock nest sites on a managed area in Maine. Journal of Wildlife Management 60: 138–148.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit, University of Maine, Orono, Maine, USA.

Meunier, J., R. Song, R. S. Lutz, D. E. Andersen, K. E. Doherty, J. G. Bruggink, and E. Oppelt. 2008. Proximate cues for a short-distance migratory species: an application of survival analysis. Journal of Wildlife Management 72: 440–448.

Minitab, Incorporated. 1999. MINITAB Release 12.23 User’s guide. State College, Pennsylvania, USA.

Parris, R. W. 1986. Forest vegetation, earthworm, and woodcock relationships. Thesis, State University of New York, Syracuse, New York, USA.

Penfound, W. T., and E. L. Rice. 1957. An evaluation of the arms-length rectangle method in forest sampling. Ecology 38: 660–661.

Reynolds, J. W., W. B. Krohn, and G. A. Jordan. 1977. Earthworm populations as related to woodcock habitat usage in central Maine. Pages 135–146 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Rieffenberger, J. C., and R. C. Kletzly. 1967. Woodcock night lighting techniques and equipment. U.S. Bureau of Sport Fisheries and Wildlife Special, Scientific Report—Wildlife 101: 33–35.

Sepik, G. F., R. B. Owen, Jr., and T. J. Dwyer. 1983. The effect of drought on a local woodcock population. Transactions of the Northeast Fish and Wildlife Conference 40: 1–8.

Sheldon, W. G. 1960. A method of mist netting woodcocks in summer. Bird-Banding 31: 130–135.

Systat. 2000. Systat 10 Statistics II. SPSS Inc., Chicago, Illinois, USA.

Wishart, R. A., and J. R. Bider. 1976. Habitat preferences of woodcock in southwestern Quebec. Journal of Wildlife Management 40: 523–531.

Woehr, J. R. 1999. Declines in American woodcock populations: probable cause and management recommendations. Report of the American Woodcock Task Force to International Association of Fish and Wildlife Agencies.

Jed Meunier is an ecologist whose work relates to the conservation and sustainable management of natural resources. Currently a Ph.D. candidate at Colorado State University, his work includes fire ecology research in northern Mexico, which aims to guide restoration efforts and forest management in northern Mexico and the U.S. southwest. Jed received his M.S. in wildlife ecology from the University of Wisconsin-Madison after studying American woodcock migration and habitat use. He received his B.S. from Colorado State University in Natural Resource Management.

Kevin Doherty is the science coordinator for the Prairie Pothole Joint Venture (PPJV) for the U.S. Fish and Wildlife Service. He is responsible for creation and integration of applied conservation research to address migratory bird issues within the PPJV. Dr. Doherty has published 23 scientific peer-reviewed papers and book chapters on topics including: landscape ecology, sage-grouse and sagebrush ecology, and conservation planning and mitigation policy in relation to energy development. Kevin received a Ph.D. in Wildlife Biology from the University of Montana in 2008, a M.S. in Wildlife Conservation with a minor in statistics from the University of Minnesota in 2004, and a B.S. in Wildlife Science from Virginia Tech in 1997.

Eileen Oppelt is a science teacher at West Linn High School in West Linn, Oregon. She also is examining host specificity of Frankia bacteria on Alnus rubra and Alnus viridis ssp. sinuata in the Pacific Northwest at Lewis and Clark College with support from a research grant through the Murdock Charitable Trust Partners. Eileen received her B.S. in Wildlife Management from Purdue University and her M.S. in Biology from Northern Michigan University.

Scott Lutz is an Associate Professor of Forest and Wildlife Ecology at UW-Madison. Scott and his students work on a variety of bird and habitat issues in the U.S. Recently, they finished projects on several early seral woodland species including woodcock, golden-winged and blue-winged warblers.

David E. Andersen is Leader of the Minnesota Cooperative Fish and Wildlife Research Unit, located in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota in St. Paul, Minnesota. He received an M.S. in Wildlife Ecology and a Ph.D. in Wildlife Ecology and Zoology from the University of Wisconsin–Madison. His research expertise is in population ecology and conservation of wild birds, and he has conducted research on gamebirds, raptors, waterfowl, and songbirds.

John G. Bruggink received B.S. and M.A. degrees in Biology from Northern Michigan University and a Ph.D. in Zoology from Southern Illinois University. He served as the Eastern Shore and Upland Game Bird Specialist for the Office of Migratory Bird Management of the U. S. Fish and Wildlife Service from 1994 to 1998 where his duties included, among other things, coordinating the annual Woodcock Singing-ground Survey and Woodcock Wing-collection Survey, and assessing the status of woodcock populations. He currently is a professor at Northern Michigan University where he teaches wildlife and ecology courses, and has been involved with a variety of wildlife research projects.

10th American Woodcock Symposium
Roscommon, Michigan, USA

CHALLENGES TO WOODCOCK HABITAT CONSERVATION IN THE WESTERN GREAT LAKES REGION

GARY E. ZIMMER[1], Ruffed Grouse Society, *P.O. Box 116, Laona, WI 54541, USA*

RICK R. HORTON[2], Ruffed Grouse Society, *P.O. Box 657, Grand Rapids, MN 55744, USA*

Abstract: Long-term declines in American woodcock (*Scolopax minor*) populations in the western Great Lakes region have been associated with degradation and loss of suitable habitat. Recent management planning decisions by public land managers, particularly on national forests, negatively impact woodcock habitat. Projected declines in aspen/birch forests on nearly all ownerships in the region are expected to result in continuing population reductions of woodcock and associated wildlife species. As industrial forest lands are sold to private landowners or land trusts that place limitations on forest management, the resulting fragmentation of forested tracts reduces opportunities to enhance woodcock populations. The incorporation of broad-brush riparian management standards effectively eliminates early successional forest management in important riparian corridors. This seriously limits management opportunities that could positively influence woodcock populations. Private landowner forest management incentive programs, greater agency appreciation for woodcock (and associated species) habitat requirements, and more relaxed riparian forest management standards that allow for site-level diversity will all increase the likelihood of maintaining woodcock habitat into the future.

Proceedings of the American Woodcock Symposium 10: 95–104

Key words: American woodcock, habitat management, western Great Lakes region, *Scolopax minor*, riparian corridors, aspen forests, forest fragmentation.

The American woodcock (*Scolopax minor*), a popular game bird throughout eastern North America, has experienced long-term (1968–2006) population declines of 1.9 percent per year in the Eastern Region and 1.8 percent per year in the Central Region (Kelley and Rau 2006). The U.S. Fish and Wildlife Service (USFWS) strategic plan for migratory bird management identifies American woodcock as a "bird of management concern" and a "game bird below desired condition" (USFWS 2004). Recently developed Wildlife Action Plans identify the woodcock as a "Species of Greatest Conservation Need" in the western Great Lakes states (Michigan, Minnesota, and Wisconsin) (Eagle et al. 2005, Minnesota Department of Natural Resources 2006, and Wisconsin Department of Natural Resources 2005), despite relatively stable populations over the past 10 years. These were the top 3 states, respectively, in woodcock harvest during the 2005–06 hunting season, and together accounted for 62.8 percent of the nation's estimated harvest (Kelley and Rau 2006).

Habitat loss and degradation are the predominant factors influencing woodcock population trends (Dessecker and McAuley 2001, Woehr 1999). Habitats used by woodcock vary with activity, time of day, and season, but they are primarily an early successional forest species (Dessecker and McAuley 2001). Throughout the breeding range, woodcock prefer habitats characterized by high densities of woody stems (Sepik and Dwyer 1982), like recently regenerated forest stands or shrub-dominated retired agricultural lands. Dense young forest or shrub-dominated habitats on moist soils are ideal (Keppie and Whiting 1994). Earthworms comprise nearly 80 percent of woodcock diet (Sperry 1940). Moist soils keep worms at or near the soil surface and available to foraging birds. Reynolds et al. (1977) reported that both woodcock and earthworms used alder and aspen habitats the most, whereas conifers were rarely used. Leaf palatability, soil moisture, and soil temperature influenced earthworm numbers and helped determine woodcock habitat use.

Some studies have indicated that vegetative structure may be even more important than food availability in determining woodcock habitat use (Gregg 1984). When clearcut, aspen frequently regenerates into very dense young forests ideal for woodcock, ruffed grouse,

---

[1] E-mail: rgszimm@newnorth.net

[2] Present address: 37305 Deer Lake Way, Grand Rapids, MN 55744

golden-winged warbler, and other species adapted to dramatic forest disturbance (Thompson and Dessecker 1997). Aspen forests are the only deciduous species routinely managed through clearcutting; therefore they offer one of the few opportunities to easily create quality woodcock habitat.

Aspen in the western Great Lakes states are fast growing, short-lived trees that begin to decline at 55 to 70 years of age (Perala 1977). Many aspen forests in the region are currently overmature and highly susceptible to death and conversion (USDA Forest Service 2006*a*, 2006*b*). Half (54,000 acres) of the existing 106,789 acres of aspen forest communities on the Hiawatha National Forest are currently considered overmature (USDA Forest Service 2006*a*). Shade tolerant forests frequently replace aspens that are allowed to naturally succeed. Conversions in Wisconsin and Michigan typically become northern hardwoods, which are already the most abundant forest type in the western Great Lakes states (Cleland et al. 2001).

The importance of habitat in migration corridors is often overlooked in bird conservation strategies (Rich et al. 2004). Habitat use during migration has profound consequences for birds' ability to satisfy energy requirements, vulnerability to predators, and exposure to environmental stress (Moore et al. 1993). Early successional scrub-shrub habitat is preferred by migrating songbirds, as evidenced by these habitats holding the greatest number of species, the highest species diversity, and the largest number of individual birds of all habitats analyzed (Moore et al. 1993). Riparian or riverine areas also provided abundant suitable migration habitat for woodcock, as well as for a wide array of migrating birds. Factors that limit or reduce the ability to provide quality woodcock habitat on the breeding grounds or migratory stopover sites hinder conservation efforts for this species in this region. Several recent habitat management changes occurring in the western Great Lakes region may limit the ability to maintain or restore woodcock populations.

Early Successional Habitat Decline

Many disturbance-dependent ecosystems across the United States, including early successional forests, have declined in recent years (Cleland et al. 2001). Aspen/birch types declined by 1.3 million acres between the last 2 forest inventory cycles in the western Great Lakes states (Cleland et al. 2001). These declines are due in part to nearly a century of fire suppression, land conversion, rural development, and forest maturation (Trani et al. 2001). Aspen and aspen/birch forests comprise the majority of early successional deciduous forest communities in the western Great Lakes states, covering 12.9 million acres (Cleland et al. 2001). This accounts for 79 percent of the aspen-birch forest acreage in the eastern United States. Over a 58-year period in Michigan (1935 to 1993, and a 61-year period in Wisconsin (1935 to 1996), aspen/birch acreage declined by 37 percent and 36 percent, respectively. However, between 1935 and 1990, aspen/birch acreage declined by only 6 percent in Minnesota (Cleland et al. 2001), largely due to the westward progression of initial logging that delayed development of the second-growth forest. This allowed it to be regenerated in Minnesota before it could succeed to the next seral stage.

Forest Inventory and Analysis (FIA) data that classify forest stands as seedling/sapling (≤ 20 years old) can be used to identify gross trends in woodcock habitat (Woehr 1999). Twenty-eight percent of the forested land in the western Great Lakes states exists as seedling-sapling stands, with stand-size class distribution relatively even within the region (Trani et al. 2001). The majority of this young forest is aspen/birch type, because it is typically managed with even-aged techniques, as opposed to northern hardwoods types that are rarely found as young forests. The acreage of aspen seedling-sapling stands has increased in Minnesota and Wisconsin, but decreased in Michigan over the fourth and fifth forest inventory cycles (1977 to 1990 in Minnesota, 1983 to 1996 in Wisconsin and 1980 to 1993 in Michigan) (Cleland et al. 2001).

While 62 percent of forested lands in the western Great Lakes states are in private ownership, (Cleland et al. 2001), FIA data shows that non-industrial private landowners control only 41 percent of the aspen forests. Public lands (federal, state, county) account for 45 percent of the aspen forests and corporate and tribal entities own 14 percent. The rate of loss of aspen habitats on non-industrial private forestlands greatly exceeds the rate of loss on public lands (Leatherberry 2001).

The gross amount of preferred aspen/birch forest in the western Great Lakes is declining, but the amount in a young condition has increased in Wisconsin and Minnesota due in part to an active timber industry. Public lands contain a disproportionately high amount of aspen forests, and are therefore very important for woodcock management. Woodcock populations in the area are experiencing long-term declines, but in the short-term (10 years) they show signs of stabilizing (Kelley and Rau 2006). Loss of other habitats, including old fields, forest openings, lowland hardwood forests (Straw et al. 1994), wintering habitat (Krementz and Jackson 1999) and young riparian forests may still limit woodcock populations. Habitat loss is considered the biggest threat to woodcock populations, but other factors (e.g., migration stress, predation, weather events, and man-made obstacles) can contribute to mortality.

Table 1. Future changes in aspen acreage in western Great Lakes region national forest plans.

Period	Chippewa (MN)	Superior (MN)	Cheq./Nicolet (WI)	Hiawatha (MI)	Ottawa (MI)
Existing	144,700	609,400	336,100	106,789	119,000
First decade	Unknown	Unknown	330,000	85,000	109,000
Second decade	73,500	442,300	Unknown	Unknown	Unknown
Difference at end of first or second decade	–71,200 (–49.2%)	–167,100 (–27.4%)	–6,100 (–1.8%)	–21,789 (–20.4%)	–10,000 (–8.4%)
100 years	60,800	256,100	216,200	76,400	Unknown
Difference in 100 years	–83,900 (–58.0%)	–353,300 (–58.0%)	–119,900 (–35.7%)	–30,389 (–28.5%)	Unknown

Management Changes in National Forests

Five USDA National Forests in the western Great Lakes region recently revised their forest plans (Table 1). The plans will dictate forest management for the next 10–15 years on over 5.7 million acres. Due to the large amount of aspen in national forests relative to private lands (Cleland et al. 2001), national forests have the potential to significantly impact the future level of early successional forests in the region, and consequently impact future woodcock populations. Together these plans project declines of 276,189 acres in aspen forest habitat (4.8 percent of the total acreage) on these 5 forests by the second decade following plan implementation (USDA Forest Service 2004*a*, *b*, and *c*, 2006*a* and *b*). Four of the revised plans show 28.5 to 58 percent decreases in aspen levels by the tenth decade.

National forests have demonstrated an inability or unwillingness to meet aspen regeneration goals. The Chequamegon/Nicolet National Forest failed to achieve the 1986 forest plan aspen regeneration goals in 15 of the 18 years that the plan was in effect (Figure 1). During that period, the forest regenerated an average of 2,258 acres of aspen annually, only 51 percent of the plan's acreage goal. Contributing factors included reduced budgets and staff, other forest health concerns, lengthy environmental assessment processes, conflicting standards and guidelines, project appeals, and litigation. The land management decisions of the USDA Forest Service have been challenged and appealed frequently in federal court, and the agency believes such litigation constrains its professional expertise and limits effective forest management (Keele 2006). Currently 100 million board feet (MMBF) of timber scheduled for harvest on the Chequamegon/Nicolet National Forest are being delayed due to litigation (M. Theisen, U.S. Forest Service, personal communication). This litigation situation

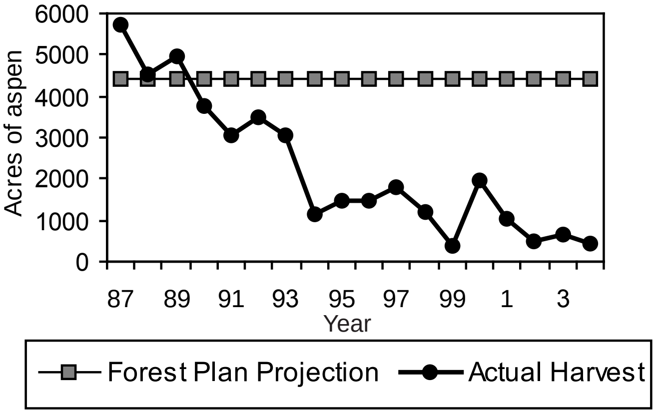


Figure 1. Chequamegon/Nicolet National Forest aspen harvest projected under the 1986 forest plan, compared to actual harvest.

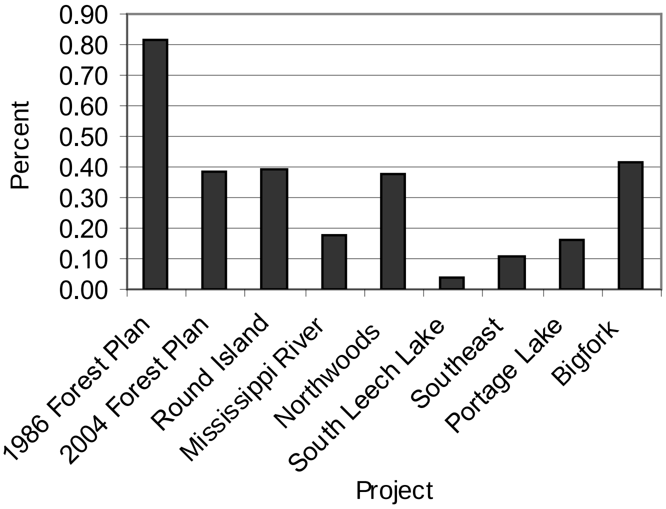


Figure 2. Percent of clearcut vegetation treatments on Chippewa National Forest projects 2 years after plan revision.

Table 2. Minnesota DNR Subsection Forest Resource Management Plan (SFRMP) scheduled aspen conversions.

Subsection plan	Current aspen acres	Aspen acres being converted to other forest types	Percent change
Agassiz Lowlands	268,500	13,545	–5
Border Lakes	130,318	43,000	–33
Mille Lacs Uplands	98,946	4,947	–5
North Shore Highlands	67,453	14,868	–22

is similar on most other western Great Lakes national forests (N. Weiland, U.S. Forest Service, personal communication).

National forests are also unwilling or unable to follow forest plan direction regarding forest management methods and procedures. Two years after implementation of the revised Chippewa Forest Plan, only 3 of 7 vegetation projects had met the plan's percentage of clearcut treatments (Figure 2). Although this goal is not necessarily intended to be met on each individual project, it will not be possible to attain planned acreage of young forest habitat across the forest unless some projects clearcut more than the planned level to make up for those where clearcutting is only a minor component.

There has been a dramatic reduction in woodcock habitat quality as well as quantity on national forests in the region in recent years, as few true clearcuts have been prescribed in aspen stands. Rather, "clearcuts with reserves" have been implemented, a prescription that specifies leaving a number of standing live trees after harvest. Initially these were unmerchantable trees and clumps of the parent stand intended to serve as visual buffers, wildlife habitat and seed sources. However, an increasing number of management prescriptions specify retaining all non-merchantable trees, all conifer regeneration, all oaks, and 10–15 dominant and co-dominant aspens per acre. The shade from this level of residual basal area can inhibit aspen suckering, reducing stem density in the new stand (Perala 1977). The auxin hormone production from live standing aspens further reduces sucker density (Farmer 1962). Aspen are being retained in a conscious effort to create thin stands, thereby reducing competition for conifer underplantings or advanced regeneration. Together these effects create lower quality habitat for woodcock, ruffed grouse, golden-winged warblers, and other associated wildlife.

Management Changes in State Forests

It is difficult to ascertain the future impact of changing forest management on state lands upon early successional wildlife in the western Great Lakes region. Current statewide forest plans for the western Great Lakes states provide frameworks for common goals and objectives but do not specify overall habitat or forest type levels (Michigan Department of Natural Resources 2006, Wisconsin Department of Natural Resources 2004). The Michigan plan, for example, sets objectives of balancing the age class distribution of the aspen cover type and minimizing the loss of the aspen cover type over the next 10 years, but without setting acreage targets for Michigan forests (Michigan Department of Natural Resources 2006). Implementing the state plan is left up to individual state forest or regional planning teams operating over varying time periods.

The Minnesota Department of Natural Resources performs forest planning based on landscape ecosystems at the subsection level. Not all subsection plans are complete, but those that are all plan to convert thousands of acres from aspen to another forest type (Table 2). This is largely driven by a desire to manage closer toward a range of natural variation, or historical condition based on pre-European settlement estimates. Many conversions will be accomplished by allowing stands to mature into the next growth stage, increasing the conifer component in mixed stands, or by re-typing stands that have already succeeded. The result will be a gross loss of early successional forest type, however the impacts of lost aspen acreage to wildlife may be offset by plans to harvest aspen closer to rotation age, resulting in more young forest at any given time (Minnesota Department of Natural Resources 2004).

FIA data shows aspen levels on forestland under state ownership in each of the states in the western Great Lakes region continuing to decrease as forest maturation continues (down 3.8% in Michigan from 1980 to 2003, down 2.8% in Minnesota from 1977 to 2003, and down 1.0 % in Wisconsin from 1983 to 2003). However, the decrease in aspen acreage has appeared to stabilize within the last decade in each of the states, with a slight increase in aspen acreage on state forestland in Wisconsin. Much of this increase is related to the acquisition of former forest industry land by the state through the

Knowles-Nelson Stewardship Fund rather than an increase in management activities (Wisconsin Department of Natural Resources 2006).

Management Changes on Private Land

The extent and age class distribution of aspen forests are important, but the future of early successional forests also depends greatly on which harvest techniques are used in the western Great Lakes region (Trani et al. 2001). Timber harvest methods like clearcut or shelterwood harvesting create sufficient disturbance to allow regeneration of early successional forests. Selective harvesting methods (e.g., thinning, patch selection) do little to change the successional stage. The small tracts found in present land-use patterns provide little opportunity for forest management or natural disturbance adequate to create the abundant, dense early successional habitat required by woodcock.

Land ownership patterns may also provide important insights and challenges to management options. Private properties are being fragmented into increasingly smaller parcels (Kilgore and Mackay 2007). Over 50 percent of private landowners in the U.S. have less than 20 acres of timberland (Birch 1996). In Wisconsin, slightly more than one-third of 248,000 forest landowners own less than 10 acres of forestland (Leatherberry 2001), and every year an average of 3,385 new parcels are created in Wisconsin's forestlands (Wisconsin Department of Natural Resources 2003). In Minnesota, mean parcel size in forest land transactions decreased from 79 acres in 1989 to 57 acres in 2002 (Kilgore and Mackay 2007). Over the same period the proportion of 20- to 40-acre tracts in sales increased from 51 to 63 percent. While non-industrial private landowners play an important role in managing the area's forests, they face increasingly difficult challenges in holding and managing forestland. Rising costs of holding land and other pressures contribute to increased land sales and subdivision. Nearly 29 percent of new landowners in St. Louis County, Minnesota stated an intention to resell the land within 5 years, and 42 percent of those respondents planned to subdivide the property (Donnay et al. 2005).

As forest tract size decreases, so does the likelihood that the landowners will perform any active forest management (Roberts et al. 1986). The intensive management or disturbance required to maintain aspen acreage may not be practical or readily accepted by private landowners. Private individuals own nearly 9 million acres in Wisconsin, but a majority of these landowners (54 percent) have not harvested timber, and thus have declining opportunities to perpetuate aspen habitats (Leatherberry 2001). Reasons for not harvesting timber include the beliefs that cutting will reduce the beauty of their land, that their timber is not of a size or quantity to warrant a harvest, and that the holding is too small to manage. Sixteen percent of landowners surveyed in Wisconsin were opposed to any harvesting (Leatherberry 2001). Private landowners control management of nearly a half million forested acres in the state. An additional concern is that there is rarely management cooperation among small landowners, and adjacent landowners can have very different goals and beliefs about timber cutting, leading to increased fragmentation. Therefore, as tracts become smaller, we can expect fewer, and smaller, early successional forest patches on the landscape.

Industrial forestlands have also recently undergone extensive ownership changes. Over 23 million acres of industrial timberland in the United States changed ownership between 1999 and 2004 (Wilent 2004). In Minnesota, 309,000 acres of former Boise Cascade Corporation holdings were sold to a corporation interested primarily in its real estate value. Choice accessible parcels are being logged and then sold as recreational properties, while conservation easements are sought for remote, productive timberlands. Other large industrial landowners are following suit. These lands were historically open to public access, but are often posted by the new recreational owners. As stated earlier, smaller recreational landowners are less likely to manage their forests in a manner that will benefit woodcock. Conservation easements counter some of the loss of forested lands across the nation by protecting large acreages from development and ensuring public access. However, while most specify that forests must be sustainably managed, few insist upon active management, and yet others place restrictions upon even-aged harvest methods (Huff 2004). One of the largest such transactions was conducted on more than 1.1 million acres of former forest industry land in the Upper Peninsula of Michigan in 2005.

Management Changes in Riparian Areas

Riparian areas are among the most important and diverse parts of forest ecosystems (Wisconsin Department of Natural Resources 2003). They support high soil moisture and a variety of associated vegetation and wildlife. Riparian areas are extremely important to woodcock populations because they feed primarily on earthworms and other invertebrates. Site factors that affect woodcock food supply, like soil moisture, soil fertility, slope, aspect, and other characteristics must be considered in their management (Sepik et al. 1981). As an example, habitat management in valleys and lower slopes is more beneficial to woodcock than management on dry upper and middle slopes (Liscinsky 1972).

A wide range of measures are in place across the western Great Lakes states to ensure that forestry operations do not negatively affect water quality. Several

Table 3. Riparian zone management on western Great Lakes region National Forests, according to revised forest plans.

	Chippewa National Forest	Superior National Forest	Chequamegon/ Nicolet National Forest	Hiawatha National Forest	Ottawa National Forest
Desired condition of riparian forests	Favor long-lived species	Favor long-lived species	Favor long-lived species	Consists of older, late seral species	Favor long-lived species but recognize need to manage aspen
1986 Plan aspen regeneration restrictions along trout streams	NA	NA	200 ft. on Nicolet 300 ft. on Chequamegon	200 ft.	200 ft.
Revised Plan aspen regeneration restrictions along trout streams	150 ft. for even-aged, 200 ft. for un-even aged.	150 ft. for even-aged, 200 ft. for un-even aged.	450 ft. on selected streams and tributaries, 300 ft. on remainder	500 ft. on designated streams and tributaries	Restriction dropped to provide management flexibility
Amount of riparian aspen not regenerated under revised plan	Unknown	Unknown	Between 12,340 and 19,870 acres	7,159 acres	NA

of these measures can have important ramifications to woodcock habitat and populations. Voluntary Best Management Practices (BMPs) are identified for riparian management zones (RMZs) in each of the western Great Lakes states. These BMPs vary by state, but in general promote long-lived tree species within 100 feet of most perennial streams, and favor the use of selective harvesting rather than even-aged harvesting. Riparian management guidelines that preclude removal of substantial overstory vegetation may unnecessarily limit development of early successional habitat that could provide important resources for woodcock and other early successional species (Dessecker and McAuley 2001).

All revised national forest plans except the Ottawa National Forest prescribe desired future conditions for riparian forests that may reduce woodcock habitat by favoring long-lived trees (Table 3). The Ottawa Plan recognized a need to maintain aspen in and adjacent to riparian environments. It provides flexibility to adjust and vary riparian area widths across the landscape based on site-specific conditions including soil, hydrology, and vegetative characteristics (USDA Forest Service 2006B).

The Chippewa and Superior National Forests did not explicitly establish more stringent riparian management zones for trout streams (USDA Forest Service 2004*b*, USDA Forest Service 2004*c*). However, a USDA Forest Service representative was appointed to the Minnesota Forest Resources Council and aided in the development of Minnesota's Voluntary Site-level Forest Management Guidelines (VSLFMG). The revised forest plans state that the forests, "…will use, as a minimum, the Council's Voluntary Site-level Guidelines for forest management." The VSLFMG specify a 50- to 100-foot buffer for even-aged forest management (25–80 ft^2/acre residual) along non-trout streams, but a 150-foot buffer for even-aged management (60 ft^2/acre residual) along trout streams.

The Chequamegon/Nicolet and Hiawatha National Forests incorporated state BMPs into their revised forest plans, but then placed additional aspen regeneration restrictions for 450 and 500 feet, respectively, on each side of selected streams and their tributaries (USDA Forest Service 2004*a*, USDA Forest Service 2006A). These increased widths were ostensibly imposed to reduce the risk of future beaver activity on streams used by brook trout or salmon (USDA Forest Service 2006A). There appears to be little justification for this amended restriction on aspen management. Allen (1983) reports most of the trees utilized by beaver in a Massachusetts study were within 98.4 feet of the water's edge. Another study referred to by Allen (Hall 1970) stated that 90 percent of all cutting of material was within 98.4 feet of the water's edge. These onerous and short-sighted restrictions ignore the fact that beaver activities are natural, and that they create warm-water wetland habitats used by several other species, such as moose, ducks, wading birds, etc.

It is doubtful whether implementing these broad-brush measures will reduce beaver populations. Howard and Larson (1985) noted that the availability of woody vegetation is of secondary importance in habitat suitability for beaver. Jenkins (1981) reported that the types of food species present might be less important in determining habitat quality for beavers than physiographic and hydrologic factors affecting the site. Stream width, stream gradient, soil drainage class and watershed size are all factors that determine beaver colony locations on streams (Howard and Larson 1985).

CONCLUSION AND IMPLICATIONS

Aspen and other early successional forests are critically important to the American woodcock and a vast array of other wildlife species. Ninety-five of 187 species (51 percent) of neotropical migratory songbirds that breed in the Midwest use shrub-sapling young forest habitats to some degree during the breeding season (Probst and Thompson 1996). The Fish and Wildlife Service's Partners in Flight program listed the golden-winged warbler as one of its songbird species of continental importance in Bird Conservation Region 12 (the western Great Lakes region) (Rich et al. 2004). About 78 percent of the continent's golden-winged warbler population, identified by the U.S. Fish and Wildlife Service as a National Watch List species, is in this region. Its habitat requirements are almost identical to the woodcock. The highest breeding densities of golden-winged warblers occur in 1- to 4-year old aspen stands, with densities dropping quickly after stands are 10 years old (Roth 2001). It is clear that the western Great Lakes region forests are the main source of golden-winged warbler populations in the entire U. S., and provide one of the last opportunities to halt the bird's downward decline. The future of this already imperiled species could be seriously threatened if aspen or other young forest habitat continues to decline at significant levels.

All 5 new National Forest Plans call for reductions in early successional habitats (276,189 acres in 2 decades), and incorporate specific management restrictions that could further reduce woodcock habitat. The cumulative effects of these actions, along with declining management for early successional species on other public and private lands, could negatively impact future woodcock populations and other associated wildlife species.

Management on state lands in the western Great Lakes region continues to show declining aspen levels but has appeared to stabilize within the last decade. Statewide management plans display awareness for minimizing the loss of the aspen cover type in the near future, but it is unclear how this strategy will be accomplished in the individual state forests. Wisconsin and Michigan have shown significant declines in aspen levels to succession in the past few decades. Minnesota has managed to maintain aspen levels due to a viable timber industry and older second growth forest. However, current forest management planning in Minnesota calls for extensive aspen/birch conversion (Table 2). The loss in aspen/birch acres may be offset by shorter rotations leading to a net increase in young forests.

Limited forest management on private lands may contribute to the declines in woodcock populations. Changes in ownership and/or management direction of private forested tracts could have long-term impacts on the ability to manage woodcock habitat. Private forest landowners must have a better understanding of the wildlife habitat implications of not managing their lands. Improved communication with private forest landowners on management resources is essential, but techniques must be developed to engage a majority of landowners. Programs that target and educate private landowners, like the Wisconsin Woodland Stewards Program or the Ruffed Grouse Society's Coverts Project, are having a positive effect. In the past 13 years, the Wisconsin Coverts Project has directly or indirectly impacted 540,000 acres of private lands (Nack 2005).

As the number of landowners increases and parcel sizes become smaller, forest management will become more difficult and less cost effective (Leatherberry 2001). Landowner incentive programs must be broader ranging and more effectively targeted (Baughman et al. 1989). However, tax rebates and monetary payments seem to be a poor incentive for landowners (Kilgore et al. 2007). Without incentive or easement programs it is highly likely that the average size of individual private forest lands will continue to decrease.

The growing trend of conservation easements is a costly, but potentially necessary method, to insure that large forestland holdings remain intact and open to public access. However, easements should not be overly restrictive regarding limits on forest management methods and strategies, and should clearly specify public access routes and restrictions (Huff 2004).

Reductions in young forest habitats along riparian systems will have a significant negative effect on migratory bird populations. Forest Service researchers found that management approaches for riparian forests often ignore their natural variability by using conventional, one-size-fits-all approaches (Palik et al. 1999). Riparian management standards should allow resource managers sufficient flexibility to make site-specific decisions. It is essential that we maintain a full range of habitat conditions used by a diversity of riparian-dependent species, including the American woodcock. Standards should not be so rigid that they effectively eliminate early successional forest management options in riparian corridors. No-cut buffers simply limit management opportunities and ignore the fact that disturbance is a natural part of riparian systems.

Due to their locations, many of the western Great Lakes region national forests provide key stopover sites for migratory birds, including woodcock, which allow them to rapidly replenish their depleted fat reserves. These habitats should be recognized and addressed in comprehensive conservation strategies and management plans for migratory birds (Moore et al. 2005).

The western Great Lakes states are one of the few remaining areas in the Eastern U.S. with abundant public land, a culture of forest management, and the timber industry infrastructure necessary to maintain young forests. As others have also concluded, declines in early successional wildlife species can best be arrested in this region (Askins 1993, Hagen 1993, Smith et al. 1993, Probst and Thompson 1996, Franzreb and Rosenberg 1997, and Roth 2001). It is imperative that land managers look more closely at the area's important early successional habitat and the wildlife species that use it.

LITERATURE CITED

Allen, A. W. 1983. Habitat suitability index models: beaver. U.S. Fish and Wildlife Service. FWS/OBS-82/10.30. Revised.

Askins, R. A. 1993. Population trends in grassland, shrubland, and forest birds in eastern North America. Pages 1–34 *in* D. M. Power, editor. Current Ornithology, Volume 11. Plenum Press, New York, New York, USA.

Baughman, M. J., J. C. Cervantes, and D. M. Rathke. 1989. Reaching Minnesota's non-industrial private forest landowners. University of Minnesota Project MN-42-089. St. Paul, Minnesota, USA.

Birch, T. W. 1996. Private forest landowners of the northern United States. 1994. U.S. Forest Service, Northeast Forest and Experiment Station Resource Bulletin NE-136, Radnor, Pennsylvania, USA.

Cleland, D. T., L. A. Leefers, and D. I. Dickmann. 2001. Ecology and management of aspen: a Lake States perspective. Proceedings of Sustaining Aspen in Western Landscapes Conference GTR RMRS-P-18.

Dessecker, D. R., and D. G. McAuley. 2001. Importance of early successional habitat to ruffed grouse and American woodcock. Wildlife Society Bulletin. 29(2): 456–465.

Donnay, J. S., M. A. Kilgore, and S. A. Snyder. 2005. A look at past and present forest landowner preferences and intentions in northern Minnesota. University of Minnesota Staff Paper Series Number 184. St. Paul, Minnesota, USA.

Eagle, A. C., E. M. Hay-Chmielewski, K. T. Cleveland, A. L. Derosier, M. E. Herbert, and R. A. Rustem, editors. 2005. Michigan's Wildlife Action Plan. Michigan Department of Natural Resources. Lansing, Michigan, USA. <http://www.michigan.gov/dnrwildlifeactionplan>.

Farmer, R. E., Jr. 1962. Aspen root sucker formation and apical dominance. Forestry Science 8: 403–410.

Franzreb, K. E., and K. V. Rosenberg. 1997. Are forest songbirds declining? Status assessment from the southern Appalachians and northeastern forests. Transactions of North American Wildlife and Natural Resources Conference 62: 264–279.

Gregg, L. E. 1984. Population ecology of woodcock in Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin No. 144. Madison, Wisconsin, USA.

Hagen, J. M. 1993. Declines of the rufous-sided towhee in the eastern United States. Auk 110: 863–874.

Hall, J. G. 1970. Willow and aspen in the ecology of beaver in Sagehen Creek, California. Ecology 41(3): 484–494.

Howard, R. J., and J. S. Larson. 1985. A stream habitat classification system for beaver. Journal of Wildlife Management 49(1): 19–25.

Huff, J. S. 2004. A survey of conservation easement restrictions on private forest land to determine their effects on forest management and timber supply. M.S. Thesis. Virginia Polytechnic Institute, Blacksburg, Virginia. USA.

Jenkins, S. H. 1981. Problems, progress, and prospects in studies of food selection by beavers. Pages 559–579 *in* J. A. Chapman and D. Purssley, editors. Volume 1. Proceedings of Worldwide Furbearer Conference.

Keele, D. M., R. W. Malmsheimer, D. W. Floyd, and J. E. Perez. 2006. Forest Service Land Management Litigation 1989–2002. Journal of Forestry 104(4): 196–202.

Kelley, J. R., Jr., and R. D. Rau. 2006. American woodcock population status, 2006. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Keppie, D. M., and R. M. Whiting, Jr. 1994. American Woodcock (*Scolopax minor*). Pages 1–27 *in* A. Poole and F. Gill, editors. The Birds of North America, No. 100. The Academy of Natural Sciences, Philadelphia, Pennsylvania and The American Ornithologists' Union, Washington, D.C., USA.

Kilgore, M. A., and D. G. Mackay. 2007. Trends in Minnesota's forestland real estate market: potential implications for forestland uses. Northern Journal of Applied Forestry. 24(1): 37–42.

Kilgore, M. A., J. M. Schertz, S. A. Snyder, and S. J. Taff. 2007. Family forest owner perceptions and attitudes: Minnesota's Sustainable Forest Incentives Act. Blandin Foundation Report, Grand Rapids, Minnesota, USA.

Krementz, D. G., and J. J. Jackson. 1999. Woodcock in the Southeast: natural history and management for landowners. Bulletin 1183. University of Georgia College of Agricultural and Environmental Sciences, Athens, Georgia, USA.

Leatherberry, E. C. 2001. A profile of Wisconsin's private forest landowners. Woodland Management. 22(1): 16–18.

Liscinsky, S. A. 1972. The Pennsylvania woodcock management study. Pennsylvania Game Commission Research Bulletin No. 171, Harrisburg, Pennsylvania, USA.

Michigan Department of Natural Resources. 2006. State Forest Management Plan. Lansing, Michigan, USA. <http://www.michigan.gov/dnr/0,1607,7-153-30301_30505_30506-144977–,00.html>.

Minnesota Department of Natural Resources. 2004. North Shore Highlands, Toimi Uplands and Laurentian Uplands Subsection Forest Management Plans. St. Paul, Minnesota, USA.

Minnesota Department of Natural Resources. 2006. Tomorrow's Habitat for the Wild and Rare: An Action Plan for Minnesota Wildlife, Minnesota's Comprehensive Wildlife Conservation Strategy. Division of Ecological Services, Minnesota Department of Natural Resources, St. Paul, Minnesota, USA.

Moore, F. R., S. A. Gauthreaux, P. Kerlinger, and T. R. Simons. 1993. Stopover habitat: management implications and guidelines *in* D. M. Finch and P. W. Stangel, editors. A multi-scale assessment of the geographic and ecological distribution of midwestern neotropical migratory birds. U. S. Forest Service General Technical Report NC-187. St. Paul, Minnesota, USA.

Moore, F. R., M. S. Woodrey, J. J. Buler, S. Woltmann, and T. R. Simons. 2005. Understanding the stopover of migratory birds: A scale dependent approach, in C. J. Ralph and T. D. Rich, editors. Bird conservation implementation and integration in the Americas: Proceedings of the Third International Partners in Flight Conference 2002. U. S. Forest Service General Technical Report PSW-191, Albany, California, USA.

Nack, J. 2005. The 2005 Progress Report for the Wisconsin Coverts Project. University of Wisconsin, Madison, Wisconsin, USA.

Palik, B., J. Zasada, and C. Hedman. 1999. Ecological considerations for riparian silviculture. Pages 233–254 *in* E. Verry, J. W. Hornbeck, and C. A. Dolloff, editors. Riparian management in riparian forests of the continental eastern United States. Lewis Press, New York, New York, USA.

Perala, D. A. 1977. General Technical Report NC-36. Manager's handbook for aspen in the north central states. U.S. Forest Service North Central Forest and Experiment Station, St. Paul, Minnesota, USA.

Probst, J. R., and F. R. Thompson. 1996. A multi-scale assessment of the geographic and ecological distribution of midwestern neotropical migratory birds. U.S. Forest Service General Technical Report NC-187. St. Paul, Minnesota, USA.

Reynolds, J. W., W. B. Kohn, and G. A. Jordan. 1977. Earthworm populations as related to woodcock habitat usage in central Maine. Pages 135–46 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Wooscock Symposium, Fredericton, New Brunswick, Canada.

Rich, T. D., C. J. Beardmore, H. Belanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Inigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendt, and T. C. Will. 2004. Partners in Flight American Landbird Conservation Plan. Cornell Laboratory of Ornithology, Ithaca, New York, USA.

Roberts, J. C., W. G. Tlusty, and H. C. Jordahl, Jr. 1986. The Wisconsin private non-industrial woodland owner, a profile. University of Wisconsin Cooperative Extension Service. Madison, Wisconsin, USA.

Roth, A. M. 2001. Impact of forest succession on shrubland-dependent birds in aspen forests managed with traditional and alternative clearcutting systems in Northern Wisconsin. M.S.Thesis. University of Wisconsin, Madison, Wisconsin, USA.

Sepik, G. R., B. Owen Jr., and M. W. Coultier. 1981. A landowner's guide to woodcock management in the northeast. Maine Agricultural Experiment Station, University of Maine Miscellaneous Report 253. Orono, Maine, USA.

Sepik, G. R., and T. J. Dwyer. 1982. Woodcock response to habitat management in Maine. Pages 106–113 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service Research Report 14.

Smith, C. R., D. M. Pence, and R. J. O'Connor. 1993. Status of neotropical migratory birds in the northeast: a preliminary assessment. Pages 172–188 *in* D. M. Finch and P. W. Stangel, editors. Status and management of neotropical migratory birds. U.S. Forest Service General Technical Report RM-229. Fort Collins, Colorado, USA.

Sperry, C. C. 1940. Food habits of a group of shorebirds: woodcock, snipe, knot, and dowitcher. United States Biological Survey, Wildlife Research Bulletin 1, Washington, D.C., USA.

Straw, J. A., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Thompson, F. R. III, and D. R. Dessecker. 1997. Management of early-successional communities in central hardwoods forests. USDA Forest Service North Central Forest Experiment Station General Technical Report NC-195. St. Paul, Minnesota, USA.

Trani, M. K., R. T. Brooks, T. L. Schmidt, V. A. Rudis, and C. M. Gabbard. 2001. Patterns and trends of early successional forests in the eastern United States. Wildlife Society Bulletin 29: 413–424.

USDA Forest Service. 2004*a*. Chequamegon/Nicolet National Forest plan and final environmental impact statement. Eastern Region. Milwaukee, Wisconsin, USA.

USDA Forest Service. 2004*b*. Chippewa National Forest plan and final environmental impact statement. Eastern Region. Milwaukee, Wisconsin, USA.

USDA Forest Service. 2004*c*. Superior National Forest plan and final environmental impact statement. Eastern Region. Milwaukee, Wisconsin, USA.

USDA Forest Service. 2006*a*. Hiawatha National Forest plan and final environmental impact statement. Eastern Region. Milwaukee, Wisconsin, USA.

USDA Forest Service. 2006*b*. Ottawa National Forest plan and final environmental impact statement. Eastern Region. Milwaukee, Wisconsin, USA.

U.S. Fish and Wildlife Service. 2004. A blueprint for the future of migratory birds: migratory bird program strategic plan 2004–2014. United States Fish and Wildlife Service, Washington, D.C., USA.

Wilent, S. 2004. Investors increase timberland holdings. The Forestry Source (December 2004): 1–4.

Wisconsin Department of Natural Resources. 2003. Wisconsin forest management guidelines. Pub-FR-226. Madison, Wisconsin, USA.

Wisconsin Department of Natural Resources. 2004. Wisconsin statewide forest plan. Madison, Wisconsin, USA. <http://dnr.state.wi.us/forestry/assessment/>.

Wisconsin Department of Natural Resources. 2005. Wisconsin's strategy for wildlife species of greatest conservation need. Madison, Wisconsin, USA.

Wisconsin Department of Natural Resources. 2006. Knowles-Nelson Stewardship Fund. Madison, Wisconsin, USA. <http://dnr.wi.gov/org/caer/cfa/lr/stewardship/dnrprojects.html>.

Woehr, J. R. 1999. Declines in American woodcock populations: probable cause and management recommendations. The report of the woodcock task force to the Migratory Shore & Upland Game Bird Subcommittee, International Association of Fish and Wildlife Agencies.

Gary Zimmer is currently a Senior Regional Biologist for the Ruffed Grouse Society and resides in Northeastern Wisconsin. Gary joined the Ruffed Grouse Society in December of 2000 after 18 years with the U.S. Forest Service, the majority of the time working as a District Wildlife Biologist. He received his B.S. in Wildlife Management and M.S. in Natural Resources from the University of Wisconsin–Stevens Point. Following graduation, Gary worked in waterfowl research for the Wisconsin Department of Natural Resources for three years. Gary is a Certified Wildlife Biologist and a past board member of the Wisconsin Chapter of the Wildlife Society.

Rick R. Horton received his B.S. (1992) and M.S. (1995) in Wildlife Ecology from the University of Wisconsin–Madison. He served as a regional wildlife biologist for the Florida Game & Freshwater Fish Commission from 1995 to 1999, as a Forest Wildlife Biologist in Minnesota for the Ruffed Grouse Society from 1999 to 2006, and as a Forest Wildlife Coordinator for the Minnesota Department of Natural Resources from 2006 to 2009. He is currently taking a hiatus from wildlife work, but retains his TWS Certified Wildlife Biologist status.

FALL MIGRATION RATES, ROUTES, AND HABITAT USE OF AMERICAN WOODCOCK IN THE CENTRAL REGION

10th American Woodcock Symposium
Roscommon, Michigan, USA

NICK A. MYATT[1]**,** Arkansas Cooperative Fish & Wildlife Research Unit, Department of Biological Sciences, *University of Arkansas, Fayetteville, AR 72701, USA*

DAVID G. KREMENTZ, U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit, Department of Biological Sciences, *University of Arkansas, Fayetteville, AR 72701, USA*

Abstract: American woodcock (*Scolopax minor*) ecology has been extensively studied on the breeding grounds and to a lesser extent on the wintering grounds, but little research has been conducted on the migration ecology of this declining species. In Fall 2001 we began a 3-year study to document woodcock fall migration routes, rates, and habitat use in the Central Region of the U.S. From 2001–2003, 582 radio-marked woodcock initiated migration from 3 study sites in Minnesota, Wisconsin, and Michigan. Aerial searches were conducted from fixed-wing aircraft during each fall migration period in the Central Region. During 224 hours of aerial telemetry, we located 42 radio-marked woodcock in 6 states. Radio-marked birds were located in upland habitats more frequently than bottomland habitats (66.6% vs. 33.3%, respectively). Migrating woodcock used a higher proportion of mature forest than expected. Stopover duration often exceeded 4 days, with some birds stopping longer than a week. Using locations of radio-marked birds, we speculated woodcock migration routes in the central U.S. GIS was used to map potential woodcock habitat in the Central Region. Based on our results, we identified priority areas for future woodcock management in the Central Region.

Proceedings of the American Woodcock Symposium 10: 105

Key words: American woodcock, fall migration, habitat use, radio telemetry, stopover duration.

Printed with permission of The Wildlife Society and Allen Press Publishing Services. The abstract and manuscript were published here:

Myatt, N. A., and D. G. Krementz. 2007. Fall migration rates, and habitat use of American woodcock in the Central United States. Journal of Wildlife Management. 71: 1197-1205.

Nick Myatt received a B.S. in Natural Resources Management from Northland College in 2002 and a M.S. in Biology from University of Arkansas in 2004. Nick's thesis at the Arkansas Cooperative Fish and Wildlife Research Unit focused on the fall migration ecology of American woodcock. After completing his masters degree, he served as Program Coordinator of the "Access and Habitat Program" for the Oregon Department of Fish and Wildlife (ODFW) from 2004-2007. Currently, Nick is the District Wildlife Biologist for ODFW in Baker City, OR.

David Krementz David received a B.S. in Wildlife Management and Conservation, a M.S. in Zoology and Physiology from University of Wyoming in 1977 and 1980, respectively, and a Ph.D. in Zoology from University of Western Ontario in 1984. After completing his doctorate, he served as a wildlife biologist for the U.S. Fish and Wildlife Service and then the U.S. Geological Survey at the Patuxent Wildlife Research Center from 1986–1999 where he studied waterfowl, woodcock and songbird population biology and habitat use. Currently, David is the Unit Leader of the U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit which he has held since 1999. David is a Past-President of the Arkansas State Chapter of the Wildlife Society.

---

[1] Present address: Baker District Wildlife Biologist, Oregon Department of Fish and Wildlife, 2995 Hughes Lane, Baker City, OR 97814 USA

FALL SURVIVAL OF AMERICAN WOODCOCK IN THE WESTERN GREAT LAKES REGION

EILEEN OPPELT, Department of Biology, Northern Michigan University,
1401 Presque Isle Avenue, Marquette, MI 49855 USA

JOHN G. BRUGGINK[1], Department of Biology, Northern Michigan University,
1401 Presque Isle Avenue, Marquette, MI 49855 USA

KEVIN E. DOHERTY, Minnesota Cooperative Fish and Wildlife Research Unit, Department of Fisheries,
Wildlife, and Conservation Biology, University of Minnesota, *St. Paul, MN 55108 USA*

DAVID E. ANDERSEN, U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit,
Department of Fisheries, Wildlife, and Conservation Biology, University of Minnesota,
St. Paul, MN 55108 USA

JED MEUNIER, Department of Wildlife Ecology, University of Wisconsin–Madison,
226 Russell Labs, 1630 Linden Drive, Madison, Wisconsin 53711, USA

R. SCOTT LUTZ, Department of Wildlife Ecology, University of Wisconsin–Madison,
226 Russell Labs, 1630 Linden Drive, Madison, Wisconsin 53711, USA

Abstract: Concern about the status of woodcock populations has highlighted the need for information on the role of hunting mortality in woodcock population dynamics. We radio-marked 1,171 woodcock during a 4-year study in Minnesota (2001–2004), and Michigan and Wisconsin (2002–2004), to assess the magnitude and causes of woodcock mortality during fall. In all three states, woodcock were radio-marked in paired study areas, one of which was open to woodcock hunting and one of which was closed to woodcock hunting or had limited access for woodcock hunting. We used program MARK to estimate fall survival rates and hunting mortality rates, and to construct a set of candidate models to examine the effects of hunting and the effects of covariates (year, state, sex, age, size) on survival. Survival rates of woodcock were 11.6% (95% CI = 4.5–18.7) higher in non-hunted areas than in hunted areas. Hunting accounted for 71 of the 147 (48%) woodcock deaths in the hunted areas; 47 (32%) were killed by predators and 29 (20%) died of various other causes. In the non-hunted and lightly-hunted areas, 38 of the 66 deaths (58%) were caused by predators; 16 birds (24%) died of various other causes (24%) and 12 birds (18%) were shot. Akaike's Information Criterion model selection indicated that fall survival varied by treatment (i.e., hunted versus non-hunted) and year. Fall survival did not vary by age, sex or size. The overall hunting mortality rate estimate in hunted areas was 14.5%. We found weak evidence that hunting mortality was higher for female woodcock than for males. Our results should be useful to biologists and administrators involved with making decisions about woodcock harvest management.

Proceedings of the American Woodcock Symposium 10: 107–108
Key words: American woodcock, hunting, mortality, *Scolopax minor*, survival, western Great Lakes region.

---

[1] E-mail: jbruggin@nmu.edu

Eileen Oppelt is a science teacher at West Linn High School in West Linn, Oregon. She also is examining host specificity of Frankia bacteria on Alnus rubra and Alnus viridis ssp. sinuata in the Pacific Northwest at Lewis and Clark College with support from a research grant through the Murdock Charitable Trust Partners. Eileen received her B.S. in Wildlife Management from Purdue University and her M.S. in Biology from Northern Michigan University.

Kevin Doherty is the science coordinator for the Prairie Pothole Joint Venture (PPJV) for the U.S. Fish and Wildlife Service. He is responsible for creation and integration of applied conservation research to address migratory bird issues within the PPJV. Dr. Doherty has published 23 scientific peer-reviewed papers and book chapters on topics including: landscape ecology, sage-grouse and sagebrush ecology, and conservation planning and mitigation policy in relation to energy development. Kevin received a Ph.D. in Wildlife Biology from the University of Montana in 2008, a M.S. in Wildlife Conservation with a minor in statistics from the University of Minnesota in 2004, and a B.S. in Wildlife Science from Virginia Tech in 1997.

Jed Meunier is an ecologist whose work relates to the conservation and sustainable management of natural resources. Currently a Ph.D. candidate at Colorado State University, his work includes fire ecology research in northern Mexico, which aims to guide restoration efforts and forest management in northern Mexico and the U.S. southwest. Jed received his M.S. in wildlife ecology from the University of Wisconsin-Madison after studying American woodcock migration and habitat use. He received his B.S. from Colorado State University in Natural Resource Management.

John G. Bruggink received B.S. and M.A. degrees in Biology from Northern Michigan University and a Ph.D. in Zoology from Southern Illinois University. He served as the Eastern Shore and Upland Game Bird Specialist for the Office of Migratory Bird Management of the U. S. Fish and Wildlife Service from 1994 to 1998 where his duties included, among other things, coordinating the annual Woodcock Singing-ground Survey and Woodcock Wing-collection Survey, and assessing the status of woodcock populations. He currently is a professor at Northern Michigan University where he teaches wildlife and ecology courses, and has been involved with a variety of wildlife research projects.

David E. Andersen is Leader of the Minnesota Cooperative Fish and Wildlife Research Unit, located in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota in St. Paul, Minnesota. He received an M.S. in Wildlife Ecology and a Ph.D. in Wildlife Ecology and Zoology from the University of Wisconsin–Madison. His research expertise is in population ecology and conservation of wild birds, and he has conducted research on gamebirds, raptors, waterfowl, and songbirds.

Scott Lutz is an Associate Professor of Forest and Wildlife Ecology at UW-Madison. Scott and his students work on a variety of bird and habitat issues in the U.S. Recently, they finished projects on several early seral woodland species including woodcock, golden-winged and blue-winged warblers.

DETECTING PASSAGE OF MIGRANT RADIO-TAGGED WOODCOCK USING SEMI-AUTOMATED RECEIVER RECORDING EQUIPMENT FROM FIRE TOWERS

10th American Woodcock Symposium
Roscommon, Michigan, USA

G. MICHAEL HARAMIS[1], U.S. Geological Survey, Patuxent Wildlife Research Center,
c/o BARC-EAST Bldg 308 Rm 114, Beltsville, MD 20705, USA

DANIEL G. MCAULEY[2], U.S. Geological Survey, Patuxent Wildlife Research Center,
5768 South Annex A, Orono, ME 04469-5768, USA

Abstract: We devised a semi-automated receiver recording system to detect the passage of migrant woodcock at Cape May, New Jersey. Woodcock were originally instrumented with conventional VHF radio transmitters at 2 sites in Maine (Moosehorn National Wildlife Refuge, near Calais, and commercial timberland near Milford) and 1 site in Vermont (Ethan Allen firing Range in Underhill). Commercially available video cassette recorders (VCR) and long-play tapes were used to record both video of the receiver scanner, as well as the receiver audio. Tandem recorders with built-in daily program facilitated full night-time (16 hr max) recording. Detection of passing woodcock was maximized by mounting the receiving system in fire towers that provided line-of-site view to the horizon above the forest canopy. Preliminary findings from 1999 recordings indicated a detection range of between 20 and 25 miles. Twenty-one woodcock were detected in two distinct waves of migration: 5 birds over two nights, 6–7 November, and 16 birds over 4 nights, 27–30 November. Woodcock were recorded on 25 instances with detection durations ranging from 7 to 73 minutes. Most woodcock (20 of 25) were detected in the late night segment from 8 p.m. to 4 a.m. Woodcock took between 8 and 18 days to travel the approximately 600 miles from Moosehorn Refuge to Cape May.

Proceedings of the American Woodcock Symposium 10: 109

Key words: American woodcock, Cape May, NJ, migration, *Scolopax minor*, telemetry.

Dan McAuley is the Station Leader and Research Wildlife Biologist with the U.S. Geological Survey's Patuxent Wildlife Research Center, Orono, Maine field station. He has worked for Patuxent since 1978. Primary responsibility is to conduct field research on migratory bird issues identified by the U.S. Fish and Wildlife Service and other Department of Interior agencies. He has worked on American woodcock population ecology and conservation for the past 30 years, addressing issues related to population dynamics; ecology; spring, summer, and fall survival and habitat use; habitat change along woodcock Singing-ground Surveys routes; and the effects of hunting pressure on American survival of woodcock in Maine, New Hampshire, Vermont, and Pennsylvania. He is the Assessment and Research Coordinator for the American Woodcock Initiative and has helped to develop Best Management Practices for woodcock for the 4 regional woodcock initiatives. Current research includes studies on adaptive habitat management and habitat use of American woodcock in the Northeast, survival of American woodcock during fall migration using radio telemetry, as well as studies on survival and recruitment of common eiders using mark-recapture methods and band recovery analyses, and evaluating use of fixed-wing aircraft to survey red-necked phalaropes in the Bay of Fundy.

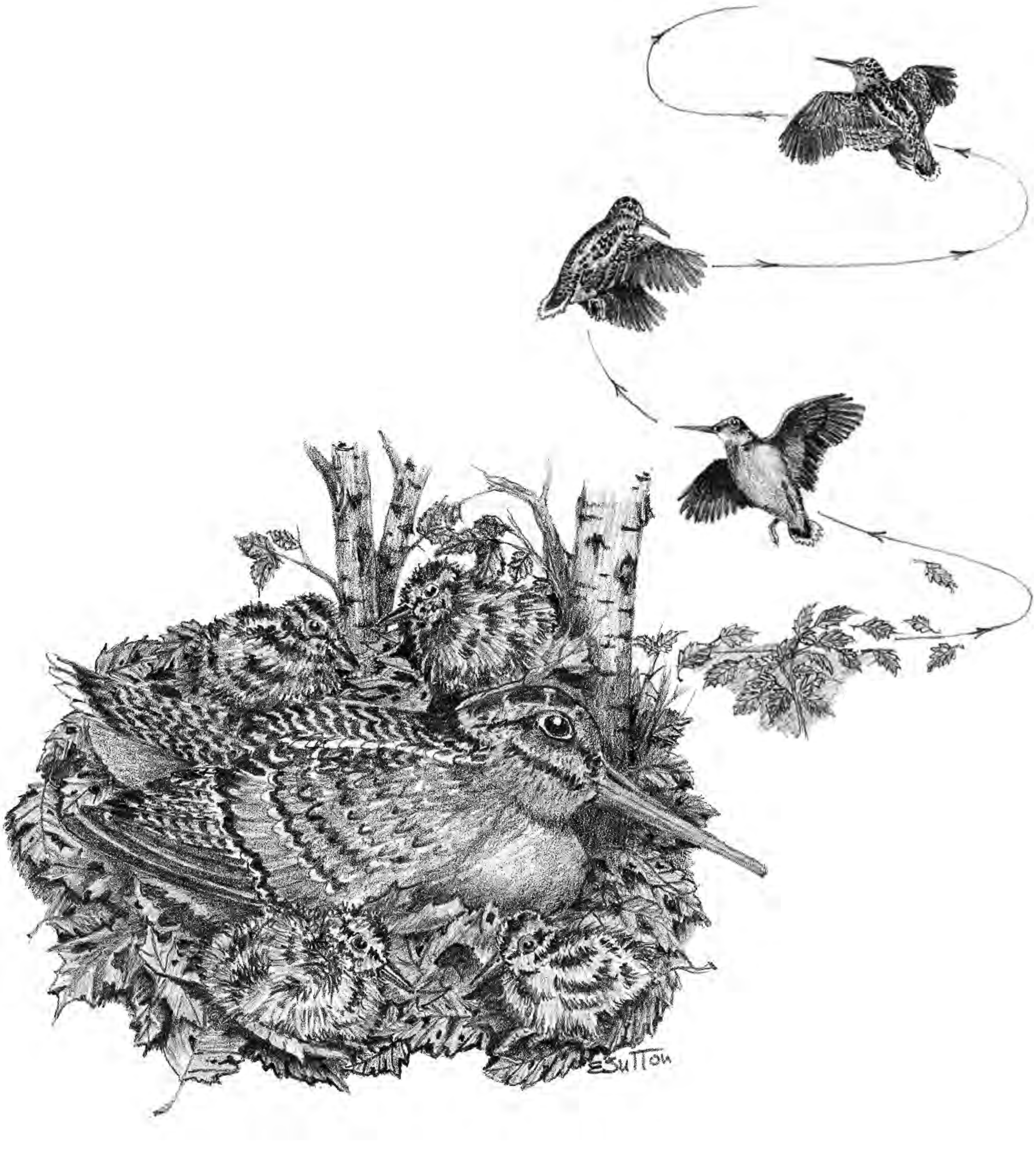
---

[1] E-mail: mharamis@usgs.gov

[2] E-mail: dan_mcauley@usgs.gov

Chapter III

Population Dynamics



INFERENCES ABOUT THE MATING SYSTEM OF AMERICAN WOODCOCK (*SCOLOPAX MINOR*) BASED ON PATERNITY ANALYSIS

10th American Woodcock Symposium
Roscommon, Michigan, USA

HEATHER L. ZIEL[1], Department of Wildlife Ecology, University of Maine,
Orono, ME 04469-5755, USA

DANIEL G. MCAULEY, USGS Patuxent Wildlife Research Center,
5768 South Annex A, Orono, ME 04469-5768

JUDITH M. RHYMER[2], Department of Wildlife Ecology, University of Maine,
Orono, ME 04469-5755, USA

Abstract: The mating system of American woodcock (*Scolopax minor*) has variously been described as promiscuous with a dispersed lek, resource-based polygyny, or monogamy. We sampled territorial males at their display sites, non-territorial males, and females with their broods on a study site in eastern Maine to characterize the mating system based on DNA analysis of microsatellite loci. We extracted DNA from blood samples from 90 males and 21 females and their broods. Genetic analysis indicated that there was no evidence for multiple paternity within broods. Possible fathers were only identified for 10 of 21 broods; 3 of these were found at the singing site of the probable father, 5 were found near the singing site of a neighboring male to the putative fathers, and 2 broods, for which there was less certainty, were found far from the singing site of the possible fathers. These limited data suggest that females may be monogamous, but resources near the territory of the father are not critical to their decision to mate with him, providing some evidence that the social structure is best described as a dispersed lek. Our data were not sufficient to determine if males are promiscuous. If male woodcock mate with >1 female, then Singing-ground Surveys which count only males would not be an accurate reflection of population trends of both males and females.

Proceedings of the American Woodcock Symposium 10: 113–122

Key words: dispersed lek, resource defense polygyny, multiple paternity, microsatellite loci, social and genetic monogamy, American woodcock (*Scolopax minor*).

Mating systems often are distinguished by the spatial and temporal distribution of resources and the degree to which mates can be monopolized (Emlen and Oring 1977). Lack (1968) concluded that over 90% of avian species are monogamous, however polygamy is likely to occur when resources or mates are economically defendable. Monogamy is expected to occur if neither sex can monopolize multiple members of the opposite sex (Emlen and Oring 1977). In addition to the spatial clustering of resources and mates, the amount of parental care that each sex provides has a strong effect on mating systems (Ligon 1999). Polygamy is more likely to occur in species where one sex provides most of the parental care (Emlen and Oring 1977). If one parent contributes only gametes and does not invest time or energy in helping to provision and raise offspring, then that parent can seek multiple mates.

In birds, several types of polygamy occur (Emlen and Oring 1977, Davies 1991, Ligon 1999). In polygynous systems, a male forms a mating association with multiple females. The social relationship between the male and several females extends past simply copulating, and the male often provides parental care for at least some of his offspring (Davies 1991, Ligon 1999). In polyandrous systems, a female mates with multiple males, either sequentially or simultaneously, during a single breeding season. Males in these systems also have an extended social relationship with a female and provide much or all of the parental care (Davies 1991, Ligon 1999). If there is no pair bond or lasting social

---

[1] Present address: Alaska Fisheries Science Center, NOAA, 7600 Sand Point Way N.E., Building 4, Seattle, Washington 98115

[2] E-mail: judith.rhymer@umit.maine.edu

relationship between the sexes, the mating system is considered promiscuous. Males and females both may copulate with multiple mates but do not associate after mating, and females provide all of the parental care (Davies 1991, Ligon 1999).

Several aspects of the American woodcock (*Scolopax minor*) mating system suggest that they are promiscuous and may use a type of lek. Leks can vary in the degree of male aggregation; in classical leks, males display in dense groups with small territories (a few meters in diameter), and in exploded or dispersed leks, males are more dispersed with larger territories, but they are still clustered in suitable display habitat (Hoglund and Alatalo 1995, Ligon 1999). Woodcock are one of the earliest returning migrants to the north and begin breeding as soon as they arrive in the spring (Sheldon 1967). Males establish and defend individual display areas (singing-ground sites) in open habitat, which are spaced at intervals of about 100–400 meters (Ellingwood et al. 1993, this study). Dominant males compete and hold display territories by performing elaborate mating displays at dusk and dawn that include conspicuous visual and vocal elements (rather than colorful plumage) to attract females to their display sites (Sheldon 1967). Courtship behavior involves repeated flights, interspersed with ground displays (Pettingill 1936, Mendall and Aldous 1943). During flights, males make a loud "twittering" sound, produced by air flowing through the outer three primaries, and on the ground, they turn in circles and utter loud calls known as "peents" (Sheldon 1967). Males interact aggressively by making cackling flights that can be heard clearly at neighboring singing sites, and chasing away males that invade their display site territories (Pitelka 1943, Sheldon 1967). A surplus of subdominant males that do not hold display territories, typically occurs in woodcock populations (McAuley et al. 1993). Without a singing-site territory, subdominant males likely do not mate, however, they will replace dominant males if the latter are removed from their display sites (Sheldon 1967, Owen et al. 1977, Ellingwood et al. 1993).

Characteristics of exploded leks that are relevant to American woodcock behavior are: 1) males are separated by considerable distances and generally cannot see each other, so they interact primarily by vocalizations, 2) males are dispersed, but females can still visit several males in a brief period of time, and 3) male parental investment and contribution to offspring ends with mating. Female woodcock provide all parental care (Sheldon 1967), and males must rely on their ability to attract females by their displays to obtain reproductive success. Behavioral observations also indicate that female woodcock visit multiple males at their display sites during the pre-nesting and nesting periods (McAuley et al. 1993), presumably assessing the fitness of potential mates based on their displays.

These characteristics suggest that the woodcock mating system is promiscuous with a type of dispersed or exploded lek (Davies 1991), as suggested by Hirons and Owen (1982) and Ellingwood et al. (1993). Previous studies have also described the mating system of woodcock as monogamous (Mendall and Aldous 1943) or resource-based polygyny, in which males defend singing sites surrounded by good nesting habitat, an essential resource for females (Dwyer et al. 1988, McAuley et al. 1993). These latter two mating systems, however, imply a social relationship (*sensu* Davies 1991) that does not pertain to American woodcock.

If the woodcock mating system is promiscuous with an exploded or dispersed lek, there may be little or no correlation between display sites of individual males and nest sites of broods they fathered. Although resources are not thought to be a distinguishing aspect of leks, males are widely dispersed in exploded leks and females may potentially forage or nest near a male's display territory. We expected that dominant males would likely father one or more broods, while subdominant, non-territorial males would not father any offspring. Whether females mate with more than one male is difficult to predict. Based on observations of their pre-nesting behavior, females may mate with more than one of the males that they visit resulting in multiple paternity of their broods, or restrict mating to one dominant male as in some species of lekking grouse (Lebigre et al. 2007).

With the application of DNA techniques to natural populations of birds (Burke and Bruford 1987), it became possible to determine whether extra-pair copulations resulted in extra-pair fertilizations, contributing to variability in reproductive success of individuals in a population. Studies showing the true relationships among parents and offspring indicate that many apparently socially monogamous avian species have high levels of extra-pair paternity in their mating system (Westneat and Stewart 2003). Therefore, observations of social interactions alone are no longer sufficient to determine mating systems and reproductive success. Species that appear to be monogamous, but are revealed as having engaged in extra-pair copulations and fertilizations, are described as being socially monogamous (but not genetically monogamous) (Gowaty 1996, Wallander et al. 2001, Bennett and Owens 2002). DNA studies have also shown that the mating system may be flexible in some species (Jiguet et al. 2000).

To examine the American woodcock mating system and determine whether male and female woodcock engage in multiple matings, we analyzed paternity using microsatellite loci by genotyping females and their offspring, dominant males on display site territories, and subdominant males in the study area.

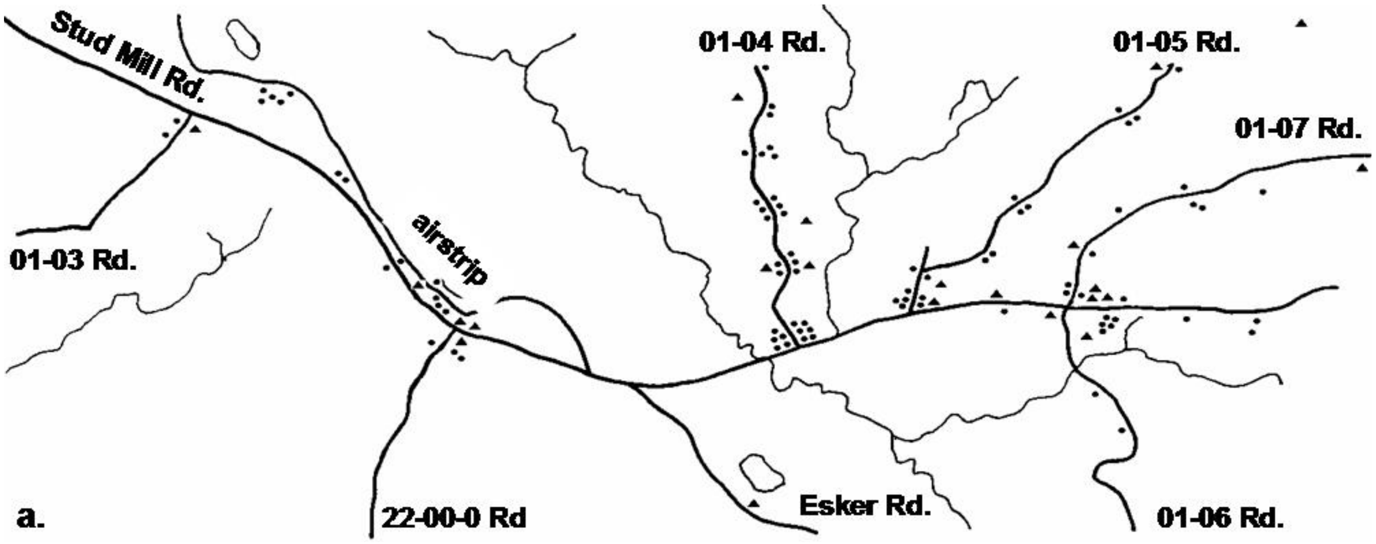


Figure 1a. Study site and locations of males, females, and broods (1997–1999) from which blood samples were collected. Filled circles represent males at display sites and triangles designate locations of females and their broods. Multiple males at a display site represent dominant and subdominant individuals over several years and/or males that appeared briefly at the study site and then disappeared.

STUDY AREA

The 2,100-ha study site was located in Hancock County, in eastern Maine [T32 MD (44º95' N; 68º63' W)] in regenerating, mixed deciduous–conifer forest land owned by Champion International Corporation (Figure 1a). Woodcock males typically establish display site territories in forest openings. In our study area, they also establish display sites on tertiary logging access roads and on an abandoned airstrip, and females nest in the nearby wooded habitat. Females use the same habitat for nesting and diurnal cover throughout the season (McAuley et al. 1993).

METHODS

Field methods

Observations of displaying males began as soon as they arrived in late March over three seasons (1997–1999). We set up mist nets around singing sites to catch dominant males observed displaying at those sites, plus any non-territorial subdominant males in the area. Some of the dominant males were marked with individual color bands in addition to standard U.S. Geological Survey (USGS) bands, so we could quantify their display behavior (Ziel 2000). Female behavior is cryptic and difficult to observe, as they remain in wooded cover as much as possible. If we happened to catch a female in the mist nets, we attached a 3.5–4.0-g radio transmitter to the back of the bird with livestock-tag cement and a single-loop wire harness that was secured with a metal crimp (McAuley et al. 1993). We radio-tracked these females until their broods hatched. To catch the majority of females and their chicks, we used trained English setters to find them about the time when we estimated that broods should be hatching. We relied on the availability of the dogs and were unfortunately not always able to sample broods as soon after hatch as would be ideal. When disturbed, females and chicks respond by freezing, so it is relatively easy to catch the female by dropping a hand net over her, and to reach down and pick up her chicks (Ammann 1974, 1977). We generally looked for 4 chicks with each female because they are determinate layers (always lay 4 eggs); however, if it was a renest or some nest predation had occurred, there were commonly 3 or fewer young. All females and chicks were banded with USGS bands.

Weight, age (hatch year [HY], second year [SY], after second year [ASY]), and location of capture were recorded for all birds. We determined age from primaries 15–18 (Martin 1964). We used a 23-gauge needle to collect small blood samples from the brachial or femoral vein of each individual. Blood was stored in lysis buffer at –20° C.

Laboratory methods

DNA was extracted from blood samples using standard phenol/chloroform extractions (Sambrook et al. 1989), and DNA concentrations of each sample were estimated with a Hoefer DyNA Quant Fluorometer, which uses fluorescence to quantify DNA concentrations. We obtained primers for 17 tetranucleotide micro-

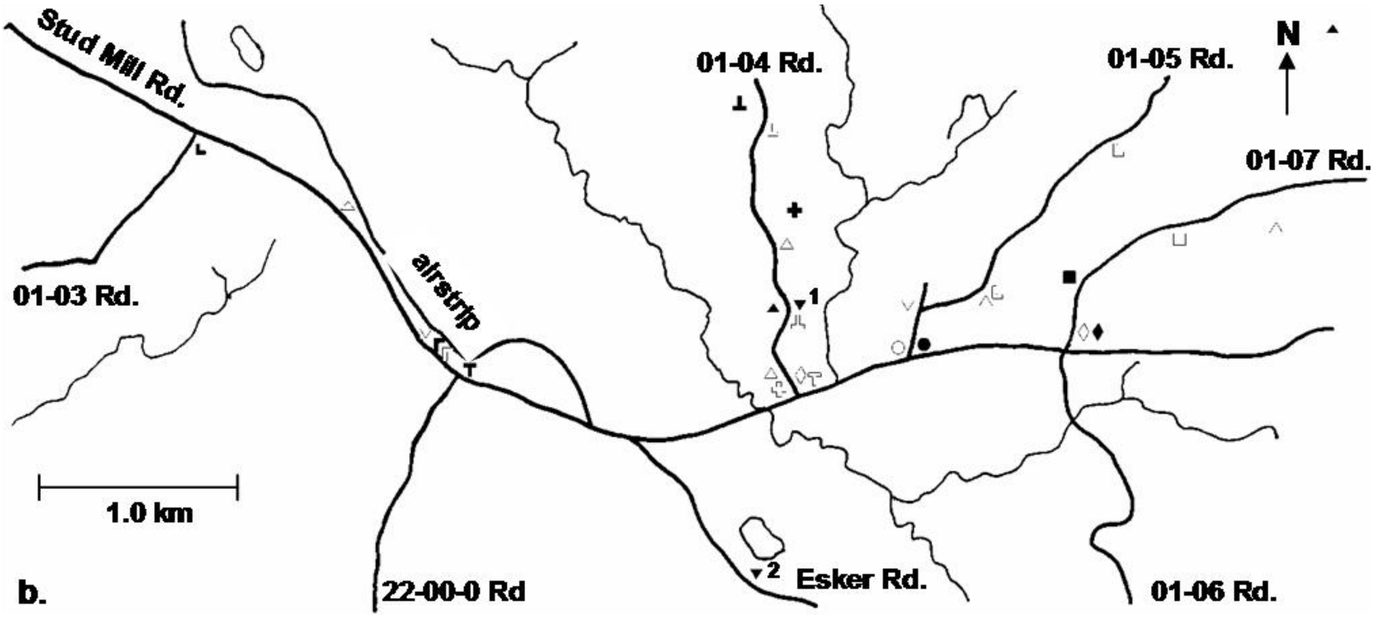


Figure 1b. Locations of females and their broods (solid symbols) and the males (open symbols) whose genotypes matched those of potential fathers of each brood. Similar symbols represent broods and males that may have fathered them. The two solid inverted triangles represent both nests of a female that renested (first nest = 1, second nest = 2).

satellite loci developed by S. Piertney (University of Aberdeen) for the ruff (*Philomachus pugnax*), 9 of which are published (Thuman et al. 2002). Five loci amplified in American woodcock, but only 2 loci (*Ruff* 6, *Ruff* 8) were polymorphic and could be used to assess paternity. We used an MJ PTC-100 programmable thermal cycler to amplify microsatellite loci in 20-µl reactions. Polymerase chain reaction (PCR) reactions contained 10x buffer (pH 8.0), 1.5 mM $MgCl_2$, 0.2 µM of each forward and reverse primer, 1.25 units Taq polymerase (Perkin-Elmer), 10 ng of DNA, 0.2 mM dNTPs, and 0.25 µM fluorescent dNTPs (R6G). The PCR program used to amplify *Ruff* 6 was 94° C for 2 minutes, followed by 29 cycles of 94° C for 30 seconds, annealing at 50° C for 30 seconds, and extension at 72° C for 30 seconds, with a final extension of 2 minutes at 72° C. We used the same program to amplify *Ruff* 8 except the annealing temperature was 48° C. After amplification, we ran samples on a 3.5% Nusieve GTG (FMC BioProducts) gel to visualize PCR products. Samples were purified in CENTRI-SEP (Princeton Separations, Inc.) columns to remove unincorporated fluorescent dNTPs, and genotyping was done on an ABI 377 automatic sequencer.

Data analysis

Alleles were scored and analyzed with GeneScan™ and Genotyper™ (Applied Biosystems Inc.) software using the size standards TAMRA350 or TAMRA500 (ABI). We determined genotypes of all males, females, and chicks with locus *Ruff* 6 and verified that the female with each brood was likely the maternal parent. Genotypes of males were compared to those of females and their chicks to determine if they were possible fathers. These comparisons excluded males that could not have sired broods. We compared genotypes of all sampled males with all chicks because males often return to the same display areas in consecutive years (Dwyer et al. 1988), so it is possible that males were in the area even if not caught each year. All females and broods were also genotyped with locus *Ruff* 8, but only those males that could have fathered broods based on results of locus *Ruff* 6 were genotyped with it. We determined the genotypes of potential fathers for each chick manually and determined whether paternity of all chicks in each brood could be explained by one male, or if >1 male was required to account for the number of different alleles among offspring in a brood. Multiple paternity would be assumed if the number of paternal alleles at a locus required to explain genetic variation in a brood was greater than 2. Allele frequencies were tested for Hardy-Weinberg equilibrium at locus *Ruff* 6 using ARLEQUIN 1.1 (Schneider et al. 1997). We did not attempt to calculate the probability that another male in the population had the same genotype as a probable father of specific broods, because we only had data for one autosomal locus (*Ruff* 6) and one sex-linked (Z) locus (*Ruff* 8) (Thuman et al. 2002).

Table 1. Genotypes of females, chicks, and potential fathers based on loci *Ruff* 6 (first line) and *Ruff* 8 (second line). Genotypes of fathers are inferred from genotypes of chicks and mothers. Locations indicate where broods were found relative to display sites of potential fathers, and symbols represent females and their broods (as illustrated in Figure 1b).

Year	Location of broods	Female genotypes	Chick genotypes	Probable genotype(s) of father	Potential father(s)	Year/Age (location of potential father)
1999	01-05-1	401 152/160 104/	416 156/160 148/	156/156 or 156/? 112/148	132 156/156 112/148	1998/ASY (01-05-1)
		●	417 152/156 112/			
			423 152/156 148/			
			424 152/156 112/			
1999	01-07-2	415 160/164 128/	430 152/160 124/128	144/152 124/124 or 124/?	403 144/152 124/124	1999/ASY (01-07-3)
		■	431 152/160 124/128			
			432 152/164 124/128			
			433 144/164 124/128			
1998	Esker Rd.	150 152/160 140/	142 156/160 136/	156/156 or 156/? 112/136	005 156/156 112/136	1999/ASY (01-05-2)
		▼	143 156/160 112/		028 144/156 112/136	1997/ASY (E. airstrip)
			144 156/160 136/			
1998	01-04-2	165 164/176 124/	152 156/176 120/124	156/156 or 156/? 120/120 or 120/?	152 156/164 120/120	
		▲	leg 156/176 120/			
1998	01-07-1	177 148/160 100/	178 148/156 100/112	156/172 112/112 or 112/?	154 156/172 112/116	
		◆	179 160/172 112/			
			180 160/172 112/			
1998	west of 01-04-5	181 160/164 140/	182 156/164 116/	156/160 or 156/164 116/132	156 156/160 116/132	
		⊥	183 156/164 132/140			
			184 160/164 116/			

Table 1. Continued.

Year	Location of broods	Female genotypes	Chick genotypes	Probable genotype(s) of father	Potential father(s)	Year/Age (location of potential father)
1997	01-04; middle of road	015 160/164 120/ +	016 160/164 124/ 017 160/164 120/128 018 160/164 124	160/164 or 160/160 or 160/? or 164/164 or 164/? 124/128	002 144/160 124/128	1997/SY (01-04-1)
1997	E. airstrip	031 152/156 120/ Γ	032 144/152 120/136 033 144/152 112/120 034 152/156 120/136 035 144/152 112/	144/152 or 144/156 112/136	028 144/156 112/136	1997/ASY (E. airstrip)
1997	01-03Stud Mill Rd.	051 156/160 120/ L	048 148/160 120/ 049 148/156 120/	148/148 or 148/? 120/120 or 120/?	004 148/152 120/120 131 144/148 120/120	1997/SY (01-04-5) 1998/ASY (01-05-3)
1997	Stud Mill Rd/ 22-00-0	029 144/164 160/ T	030 144/164 104/160	144/164 or 144/144 or 144/? or 164/164 or 164/? 104/104 or 104/?	287 144/156 104/120	1999/ASY (01-04-1)

RESULTS

We collected blood samples from 90 males, and 21 females and their broods over 3 years. In 1997, 5 females, 15 chicks, and 19 males were sampled; in 1998, 8 females, 25 chicks, and 22 males were sampled; and in 1999, 8 females, 28 chicks, and 49 males were sampled for a total of 169 birds. Both microsatellite loci were highly polymorphic; 10 alleles were scored for *Ruff* 6 and 17 alleles *Ruff* 8. All females were hemizygous at *Ruff* 8 (females birds have ZW sex chromosomes rather than XX as in mammals), and most males (ZZ) were heterozygous. Chicks that were homozygous at *Ruff* 8 were assumed to be either females or homozygous males. Allele frequencies of the breeding population were within expectations of Hardy-Weinberg equilibrium at *Ruff* 6 ($P > 0.05$). Allele frequencies of males and females were examined separately at each locus; they were normally distributed for both sexes at *Ruff* 6 and for males at *Ruff* 8.

There was no evidence to support multiple paternity within any of the 21 broods we sampled. No broods had more than 2 paternal alleles per locus, thus, the most parsimonious explanation based on these limited data is a single father for each brood (Table 1). When genotypes of inferred fathers of broods were compared with males we sampled in the field, candidate fathers were identified for 10 of the 21 broods (Table 1). In those cases where we identified a potential father, 3 broods were found at the singing site of the possible father and 5 broods were found near the singing site of a neighboring male to the possible father. Paternity of the other 2 broods (denoted L and T, Table 1) was more equivocal—they were found far from the singing sites of the possible fathers (Figure 1b). We do not have sufficient data to determine whether any males fathered multiple broods.

DISCUSSION

Based on our limited data, evidence for multiple paternity was not detected in any American woodcock brood we sampled; parentage of all 21 broods could be explained by a single mother and father. Thus, genetic analyses to date suggest that female woodcock are genetically monogamous. These results are not consistent with behavioral observations, which indicate that females visit multiple males during the pre-nesting and nesting periods of the breeding season (McAuley et al. 1993, Ziel 2000). Females visit several males, however all visits do not result in copulations; in fact, female behavior is so cryptic that it is often difficult to determine if copulation has occurred. Unfortunately, we could not capture all nesting females on the study site to address the question of males fathering multiple broods. More detailed analyses with more loci are necessary to determine paternal genotypes more accurately before drawing conclusions about male reproductive success. Woodcock are likely promiscuous—females only mate with a single male, while males possibly mate with multiple females. We have observed a single male copulate with >3 different females during an evening courtship period (DGM personal observation).

Most of the broods we found were located near a male singing site (Figure 1b), which supports previous evidence that females nest close to male display areas (Mendall and Aldous 1943, Sheldon 1967, Caldwell and Lindzey 1974, Gregg 1984, Dwyer et al. 1988). Of those broods for which we were able to identify a possible father, three were captured next to the putative father's singing site, and five were found closer to a neighbor's singing site. Woodcock chicks are precocial and can move from the nest on the day they hatch, but they are still fed by the female for the first 8–10 days. It is possible that broods found next to neighboring males' singing sites moved there after hatching, as nesting and brood rearing habitat is uniform and continuous near most of the displaying males at our study site. Broods ranged in age from 1–14 days, and both 1-day old and 14-day old broods were found at a neighbor's site. However, one 14-day old brood was found at the site of the potential father, so they do not necessarily move long distances from the nest site. McAuley et al. (1993) found that females tend to stay near nest sites with their broods in wet years, while in drier years they move to damper areas to forage for earthworms to feed chicks. These data are suggestive that resources near the display territory of the potential father are not critical to the female's decision to mate with him, and that woodcock have a dispersed lek mating system. The 2 broods found far from the candidate fathers may have belonged to females that renested (McAuley et al. 1993), or we may not have sampled the actual father.

In lek mating systems, behavioral studies have shown that male reproductive success is highly variable and often skewed toward a few males that obtain most of the copulations (Hoglund and Alatalo 1995), although low variance in reproductive success occurs in some lekking shorebird species (e.g., buff-breasted sandpipers, *Tryngites subruficollis*, Lanctot et al. 1997). Behavioral observations of male woodcock during their display periods indicated that the frequency of flights, frequency of vocalizations, duration of flights, number of male-male interactions, and number of female visits were significantly different among males (Ziel 2000). Significant variation in displays among males could contribute to variation in reproductive success. Unfortunately, our brood sampling scheme depended on which ones the trained dogs found on any given day and we only had behavioral data for one territorial male for which we also had some evidence that they potentially sired a brood that we sampled.

While lekking males are expected to mate with multiple females, female behavior is less predictable; in some species they mate with only one male, but in others, with multiple males (Ligon 1999). Based on our limited dataset, we did not find evidence for multiple paternity in any woodcock broods, suggesting that females may mate with only one male. This is unusual compared to some other species of lekking shorebirds such as buff-breasted sandpipers (Lanctot et al. 1997) and ruffs (Lank et al. 2002, Thuman and Griffith 2005), which have high rates of multiple paternity; however, lack of multiple paternity within broods is not an unusual result in lekking species, such as grouse (e.g. sage grouse, *Centrocercus urophasianus*, Semple et al. 2001; black grouse, *Tetrao tetrix*, Alatalo et al. 1996, Lebigre et al. 2007).

One possible reason why females visit multiple males, though they appear to be genetically monogamous, is to encourage males to continue to display in case they need to renest (Dwyer et al. 1988, McAuley et al. 1993). Female woodcock commonly renest if they lose a nest or a brood; they may move 1–15 km to renest, but where they choose to mate before renesting is unknown (McAuley et al. 1990). If females visit males to encourage them to display in the vicinity of their first nest, they may choose to mate with males in that area because they have observed them displaying and know where they are. One brood that matched with a potential father was the second brood for the female (Figure 1b, symbol ▼). Her first nest, located about 0.8 km from where the potential father displayed, was destroyed before the eggs hatched, and her second nest was about 2 km from where the male displayed. If this male fathered her brood, it suggests that females mate with males near their first nest and then move farther away to renest.

In summary, behavioral observations (McAuley et al. 1993, Ziel 2000) and genetic data (this study) suggest that the mating system of American woodcock is similar to a promiscuous, dispersed lek, as has been observed for another lekking shorebird, the great snipe (*Gallinago media*) (Hoglund and Lundberg 1987). However, our genetic results were obtained using only 2 microsatellite loci (one of which was sex-linked) and more data are required to fully characterize the mating system. A larger sample of females and chicks is also necessary to further address the question of males fathering multiple broods and differential reproductive success among males. We sampled males intensively each spring, but were still only able to capture potential fathers of fewer than half of the broods we sampled. Despite these limitations, we have provided some insights into the mating system of a species that is notoriously difficult to study. To more definitively address these questions it would be necessary to capture and obtain blood from all males (dominant and subdominant) that displayed within our study area and most of the females and their broods.

MANAGEMENT IMPLICATIONS

Based on these limited data, results suggest that females may be genetically monogamous, despite the socially promiscuous behavior of males observed copulating with several females (DGM personal observation). The annual Singing-ground Survey counts the number of displaying males along established road-routes (Kelley and Rau 2006, Keppie and Whiting 1994), providing an estimate of the number of breeding males each year. However, females are difficult to census during the early breeding season because their behavior is cryptic. If woodcock mated in a 1:1 ratio, then the Singing-ground Survey could provide information about population trends of both males and females. This could have important implications for management because it is not known how female numbers have been affected by population declines. It has been assumed that both female and male woodcock are declining, but this assumption is based on the Singing-ground Survey of males (Kelley 2000). We have shown that females may be monogamous, but in order to use Singing-ground Surveys to estimate the number of breeding females in a population, it would be necessary to determine the proportion of surveyed males that father multiple broods and what proportion, if any, do not father any.

ACKNOWLEDGMENTS

We would like to thank D. Clugston, A. Weik, D. Nein, K. Dunham, B. Moynihan, B. Chase, E. Chipman, and E. Fenichel for field assistance. The enthusiastic field assistance of English Setters Sadie, Xena, and Butch was crucial to the success in capturing female woodcock and their broods. S. Piertney, University of Aberdeen generously provided the ruff microsatellite primers prior to publication of their data. C. Maher, University of Southern Maine, provided insight on the behavioral ecology of mating systems. Funding for this project was provided by the Department of Wildlife Ecology, University of Maine, USGS Patuxent Wildlife Research Center, and the Penobscot County Conservation Association. This is article 3106 of the Maine Agricultural and Forest Research Station.

LITERATURE CITED

Alatalo, R. V., T. Burke, J. Dann, O. Hanotte, J. Hoglund, A. Lundberg, R. Moss, and P. T. Rintamaki. 1996. Paternity, copulation disturbance and female choice in lekking black grouse. Animal Behaviour 52: 861–873.

Ammann, G. A. 1974. Methods of capturing American woodcock broods. Pages 593–605 *in* S. Lundstrom, editor. Eleventh International Congress of Game Biology.

Ammann, G. A. 1977. Finding and banding woodcock broods using pointing dogs. Michigan Department of Natural Resources, Wildlife Division Report 2780, Lansing, Michigan, USA.

Bennett, P. M., and I. P. F. Owens. 2002. Evolutionary ecology of birds: life histories, mating systems and extinction. Oxford University Press, New York, New York, USA.

Burke, T., and M. W. Bruford. 1987. DNA fingerprinting in birds. Nature 327: 149–152.

Caldwell, P. D., and J. S. Lindzey. 1974. The behavior of adult female woodcock in central Pennsylvania. Proceedings of the Fifth American Woodcock Workshop, University of Georgia, Athens, Georgia, USA.

Davies, N. B. 1991. Mating systems. Pages 163–294 *in* J. R. Krebs and N. B. Davies, editors. Behavioral ecology: an evolutionary approach. Blackwell Scientific Publications, London, England.

Dwyer, T. J., G. F. Sepik, E. L. Derleth, and D. G. McAuley. 1988. Demographic characteristics of a Maine woodcock population and effects of habitat management. U.S. Fish and Wildlife Service Research Report 4, Washington D.C., USA.

Ellingwood, M. R., B. P. Shissler, and D. E. Samuel. 1993. Evidence of leks in the mating strategy of the American Woodcock. Pages 109–115 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Emlen, S. T., and L. W. Oring. 1977. Ecology, sexual selection, and the evolution of mating systems. Science 197: 215–223.

Gowaty, P. A. 1996. Battles of the sexes and origins of monogamy. Pages 21–52 *in* J. M. Black, editor. Partnerships in Birds. Oxford University Press, New York, New York, USA.

Gregg, L. 1984. Population ecology of woodcock in Wisconsin. Technical bulletin, Wisconsin Department of Natural Resources, No. 144, Madison, Wisconsin, USA.

Hirons, G., and R. B. Owen, Jr. 1982. Comparative breeding behavior of European and American woodcock. Pages 179–186 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service Wildlife Research Report 14.

Hoglund, J., and R. V. Alatalo. 1995. Leks. Princeton University Press.

Hoglund, J., and A. Lundberg. 1987. Sexual selection in a monomorphic lek-breeding bird: correlates of male mating success in the great snipe (*Gallinago media*). Behavioral Ecology and Sociobiology 21: 211–216.

Jiguet, F., B. Arroyo, and V. Bretagnolle. 2000. Lek mating systems: a case study in the little bustard *Tetrax tetrax*. Behavioral Processes 51: 63–82.

Kelley, J. R., Jr. 2000. American woodcock population status, 2000. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Kelley, J. R., and R. D. Rau. 2006. American woodcock population status. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Keppie, D. M., and R. M. Whiting, Jr. 1994. American woodcock (*Scolopax minor*). Pages 1–27 *in* A. Poole and F. Gill, editors. The Birds of North America, No. 100. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union, Washington, D.C., USA.

Lack, D. 1968. Ecological adaptations for breeding in birds. Methuen Press, London, England.

Lanctot, R. B., K. T. Scribner, B. Kempenaers, and P. J. Weatherhead. 1997. Lekking without a paradox in the buff-breasted sandpiper. The American Naturalist 149: 1050–1070.

Lank, D. B. Lank, C. M. Smith, O. Hanotte, A. Ohtonen, S. Bailey, and T. Burke. 2002. High frequency of polyandry in a lek mating system. Behavioral Ecology 13: 209–215.

Lebigre, C., R. V. Alatalo, H. Siitari, and S. Parri. 2007. Restrictive mating by females on black grouse leks. Molecular Ecology 16: 4380–4389.

Ligon, J. D. 1999. The evolution of avian breeding systems. Oxford University Press, New York, USA.

McAuley, D. G, J. R. Longcore, and G. F. Sepik. 1990. Renesting by American woodcocks (*Scolopax minor*). Auk 107: 407–410.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993. Behavior of radio-marked breeding American woodcock. Pages 116–125 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit, University of Maine, Orono, Maine, USA.

Owen, R. B., J. M. Anderson, J. W. Artmann, E. R. Clark, T. G. Dilworth, L. E. Gregg, F. W. Martin, J. D. Newsom, S. R. J. Pursglove. 1977. American woodcock (*Philohela minor* = *Scolopax minor* of Edwards 1974). Pages 149–186 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Pettingill, O. S. 1936. The American woodcock *Philohela minor* (Gmelin). Memoirs Boston Society of Natural History 9: 169–391.

Pitelka, F. A. 1943. Territoriality, display, and certain ecological relations of the American woodcock. The Wilson Bulletin 55: 88–114.

Sambrook, J., E. F. Fritsch, and T. Maniatis. 1989. Molecular cloning: a laboratory manual. Cold Spring Harbor Laboratory Press, New York, USA.

Schneider, S., J. Kueffer, D. Roessli, and L. Excoffier. 1997. ARLEQUIN, Version 1.1; a Software for Population Genetic Data Analysis. Genetics and Biometry Laboratory, University of Geneva, Switzerland.

Semple, K., R. K. Wayne, and R. M. Gibson. 2001. Microsatellite analysis of female mating behaviour in lek-breeding sage grouse. Molecular Ecology 10: 2043–2048.

Sheldon, W. G. 1967. The book of the American woodcock. University of Massachusetts Press, Amherst, Massachusetts, USA.

Thuman, K. A., F. Widemo, and S. B. Piertney. 2002. Characterization of polymorphic microsatellite DNA markers in the ruff (*Philomachus pugnax*). Molecular Ecology Notes 2: 276–277.

Thuman, K. A., and S. C. Griffith. 2005. Genetic similarity and the nonrandom distribution of paternity in a genetically highly polyandrous shorebird. Animal Behaviour 69: 765–770.

Trail, P. W., and E. S. Adams. 1989. Active mate choice at cock-of-the-rock leks: tactics of sampling and comparison. Behavioral Ecology and Sociobiology 25: 283–292.

Wallander, J., D. Blomqvist, and J. T. Lifjeld. 2001. Genetic and social monogamy—does it occur without male guarding in the ringed plover? Ethology 107: 561–572.

Westneat, D. F. , and I. R. K. Stewart. 2003. Extra-pair paternity in birds: causes, correlates, and conflict. Annual Review of Ecology Systematics 34: 365–396.

Ziel, H. L. 2000. Phylogeography and mating system of American woodcock (*Scolopax minor*). Thesis, University of Maine, Orono, Maine, USA.

Heather Ziel received her M.S. in Ecology and Environmental Science from the University of Maine, where she studied the mating system and population structure of American woodcock in eastern Maine. Heather is currently working for the National Marine Mammal Laboratory at NOAA, where she is part of the Polar Ecosystems Program. She works on ecology and population assessment studies of ribbon, spotted, and bearded seals in the Bering Sea and harbor seals in Alaska.

Judith M. Rhymer received a B.S. and M.S. in Zoology from the University of Manitoba, and a Ph.D. in Biological Sciences from Florida State University. She was a postdoctoral fellow at the Smithsonian Institution and Research Assistant Professor at Clemson University prior to accepting her position in the Department of Wildlife Ecology at the University of Maine in 1996. She is currently an Associate Professor with a research program in Conservation Genetics. As such, her research has gradually changed from waterfowl ecology and avian population biology to genetic studies of a variety of rare species, including small mammals, freshwater mussels and butterflies.

Dan McAuley is the Station Leader and Research Wildlife Biologist with the U.S. Geological Survey's Patuxent Wildlife Research Center, Orono, Maine field station. He has worked for Patuxent since 1978. Primary responsibility is to conduct field research on migratory bird issues identified by the U.S. Fish and Wildlife Service and other Department of Interior agencies. He has worked on American woodcock population ecology and conservation for the past 30 years, addressing issues related to population dynamics; ecology; spring, summer, and fall survival and habitat use; habitat change along woodcock Singing-ground Surveys routes; and the effects of hunting pressure on American survival of woodcock in Maine, New Hampshire, Vermont, and Pennsylvania. He is the Assessment and Research Coordinator for the American Woodcock Initiative and has helped to develop Best Management Practices for woodcock for the 4 regional woodcock initiatives. Current research includes studies on adaptive habitat management and habitat use of American woodcock in the Northeast, survival of American woodcock during fall migration using radio telemetry, as well as studies on survival and recruitment of common eiders using mark-recapture methods and band recovery analyses, and evaluating use of fixed-wing aircraft to survey red-necked phalaropes in the Bay of Fundy.

GENETIC SEX DETERMINATION IN WOODCOCK CHICKS

10th American Woodcock Symposium
Roscommon, Michigan, USA

JEAN S. FIERKE[1], Michigan Department of Natural Resources, Wildlife Division,
Wildlife Disease Lab, 4125 Beaumont Road, Room 250, Lansing, MI 48910-8106

KRISTINE A. BROWN, Michigan Department of Natural Resources, Wildlife Division,
Wildlife Disease Lab, 4125 Beaumont Road, Room 250, Lansing, MI 48910-8106

DAVID R. LUUKKONEN, Michigan Department of Natural Resources, Wildlife Division,
8562 E. Stoll Rd., East Lansing, MI 48823

C. ALAN STEWART, Michigan Department of Natural Resources, Wildlife Division,
P.O. Box 30444, Lansing, MI 48909-7944

Abstract: Knowledge of the sex of adults and young birds in natural populations can enhance our understanding of behavior and survival and can have a variety of wildlife management applications. The need for a genetic method of sex determination is based on the findings that adults in an estimated 50% of all bird species are morphologically identical and the percentage is even greater in chicks. This is particularly true for American woodcock (*Scolopax minor*) chicks. A recently developed genetic technique uses the polymerase chain reaction (PCR) to determine bird gender from feather pulp samples. This DNA-based system uses 2 conserved CHD1 (chromo-helicase-binding) genes that are located on the avian sex chromosomes in all birds, with the possible exception of the ratites (Struthioniformes). This study attempts to determine the feasibility of using this noninvasive approach when collecting woodcock chick feathers in the field. We ran DNA analysis on a total of 172 samples from 126 individual chicks and on 19 known-sex juvenile and adult carcasses submitted during the winter and summer of 2005 for controls. Of the 126 chicks processed, 98 samples provided distinguishable results. Of the 19 known-sex individuals, 15 had expected results and there were no results for 7 samples.

Proceedings of the American Woodcock Symposium 10: 123-127

Key words: American woodcock, CHD1, DNA, feather pulp, genetic analysis, *Scolopax minor*, Michigan, chick, sex determination.

The American woodcock (*Scolopax minor*) is fairly common throughout Michigan and the state is one of the more important breeding and harvest areas for woodcock in the U.S. However, significant long-term (1968–2008) declines in the number of woodcock singing males in Michigan and the Central Region were detected using Singing-ground Survey data (SGS). The Central and Eastern Regions have experienced average long-term declines in singing males heard per route of 1.2% and 1.1% per year, respectively, since 1968 (Cooper 2008). The decline seen in Michigan was 1.3% per year.

Threats to woodcock populations as listed in the 18 April 2005 Species of Greatest Conservation Need (Michigan Department of Natural Resources 2006) include conversion of habitat to agriculture lands; fire regime; grazing and mowing patterns; forest maturation; industrial, residential, and recreational development; and urban, municipal, and industrial pollution. Woodcock is an important game species in the state and an indicator of early successional habitat; it also has value to nonhunters. Hunters harvested an estimated 113,000 woodcock during 2007, compared to 390,000 harvested in 1976 (Frawley and Stewart 2009). The declining availability of quality habitat is believed to be a primary cause for the decline in the population (Dessecker and McAuley 2001). Approximately 20.8 million acres (8.4 million ha) of new woodcock habitat needs to be created across the woodcock range in order to return woodcock population densities to those observed during the early 1970s (Kelly 2008).

---

[1] E-mail: fierkej@michigan.gov

The need for a genetic method of sex determination is based on the findings that adults in an estimated 50% of all bird species are morphologically identical and the percentage is even greater in chicks. This is particularly true for American woodcock chicks. Examination of the wing feathers of adult woodcock has traditionally been used to determine sex (Martin 1964). There currently exists no practical method to determine the sex of live woodcock chicks using visual examination.

The purpose of the study is to determine if a recently developed molecular genetic technique that uses polymerase chain reaction (PCR) to identify bird gender from DNA samples is applicable for use with woodcock chick feather samples. The chicks could be sexed with minimal disturbance or injury by collecting a feather sample during routine annual banding.

Molecular genetics studies in woodcock could enhance our ability to draw ecological inferences related to issues of gene flow, mating behavior not detectable through direct observation, and our understanding of the sex ratio of chicks and of the survival and dispersal of sexes from hatching to adulthood. Knowledge obtained could ultimately be applied in population analysis and management activities. Sex determination using feathers could also be used to check the accuracy of biologist data used to determine sex from wing and beak measurements in adults.

METHODS

Sample Collection

Initial instruction sheets and 1,000 sample collection envelopes were distributed to those interested at the April 2005 spring training session for woodcock banders held by the Michigan Department of Natural Resources (DNR) Wildlife Division. The DNR provided banders with quail (*Colinus virginianus*) chicks approximately 10 days old for banding and feather collection practice. Banders were asked to pluck (not cut) 2 or 3 breast or shoulder feathers of each woodcock chick at least 3 days old. In the field, chicks are banded from age one hour to age 12 days, when they are beginning to fly; age is determined by bill length (Ammann 1994) or actual observation.

Michigan woodcock banders collected feathers from 6 May through 8 June 2005. Immediately after plucking, banders inserted the feathers into a small paper envelope and labeled the envelope with the chick's federal band number, date, and collector information. Banders then either mailed the feathers or delivered them by hand to the Michigan DNR Wildlife Disease Laboratory (WDL). The WDL kept most samples at –70° C until extraction. After the season, we contacted a number of banders and asked for their comments and suggestions regarding feather collection procedures. We also received samples from the Minnesota DNR.

During the fall hunting season, hunters collected woodcock carcasses, holding the carcasses on ice for ≤3 days. Immediately upon their arrival at WDL, we necropsied most of the carcasses, collected breast, primary, and tail feathers separately, and inspected sex organs. We processed feathers from these known-sex woodcock carcasses as control samples. In addition, banders and the Minnesota DNR collected and submitted feathers from 12 nesting hens.

DNA Extraction

A 0.5-cm segment was cut from the rachis end of feathers and placed in a 1.5-ml tube. The rachis was cut longitudinally once or twice on some of the larger feathers. We extracted genomic DNA using the Qiagen DNeasy extraction kit (Qiagen, 27220 Turnberry Ln. Ste. 200, Santa Clarita, CA 91355) following the procedures for purification of total DNA from animal tissues in the DNeasy Tissue Handbook (March 2004 edition) with one modification: in step 8 of the handbook , we used 75 µl AE buffer instead of 200µl. Non-latex nitrile gloves were worn throughout the procedure and instruments and working surfaces were rinsed with ethyl alcohol and flamed between samples.

DNA Amplification and Visualization of Bands

The method for DNA analysis is based on the genetic amplification of the chromo-helicase-DNA-binding 1 (CHD1) gene found in the sex chromosomes of most birds (ratites are the exception) and was successfully established in the mid-1990s by Ellegren and Sheldon (1997), Griffiths et al. (1998), and Whittingham and Dunn (2000).

We amplified these genes (genetic markers) with specific primers and separated the products on a polyacrylamide or agarose gel. Several published sets of primers aid in determining bird sex. The first set designed was the P8/P2 (Griffiths et al 1998). A second published set of primers is 2250F/2718R (Fridolfsson and Ellegren 1999). This study used the P2 and P8 primers to amplify the region of the CHD1 gene by PCR from feathers. We performed PCR reactions using 5 µl DNA, 2.5µl 10X LGL, 2.5 µl 2mM dNTP, 2.5 µl P2 primer, 2.5 µl P8 primer, 0.5 µl 24 mM $MgCl_2$, 0.5 µl TAQ, and 9 µl H_20 for a total reaction of 25 µl. We performed the PCR reaction in a Robocycler Gradient 96 Stratagene thermal cycler at 94° C for two minutes, then 40 cycles of the following: 94° C for 30 seconds, 50° C for one minute, and 72° C for five minutes. For all samples, visualization of PCR product used vertical 6% polyacrylamide gels run at 60 watts. We scanned the polyacrylamide gels on an FM-BIO II machine made by Hitachi, the fluorescence arising from a HEX dye attached to the 5' end of one of the primers. In preparing reagents and following PCR reaction protocol, we used procedures established by Michigan State University's Molecular Ecology Laboratory. Two personnel scored gels independently for quality control purposes.

RESULTS

Banders throughout Michigan collected breast feathers from 153 chicks 6 May through 8 June 2005, and Earl Johnson (Minnesota DNR) submitted breast feathers from 19 chicks in June of 2004. In addition, the Michigan banders and Earl Johnson (Minnesota DNR) collected and submitted 12 feather samples from nesting hens. Woodcock hunters submitted 58 carcasses for known-sex controls in the fall of 2004. We received 21 carcasses from other sources. We ran DNA analysis on 140 samples from the 126 individual chick samples and on 32 samples from 19 individuals of the adult known-sex controls.

The analysis of gelled DNA product yielded patterns of bands by which males and females could be differentiated (Figure 1). Visualization on acrylamide gels showed 3 banding patterns similar to those seen in auklets (Dawson 2001). We observed 2 different-sized DNA fragments for the Z chromosome. Dawson found 3 forms for the Z chromosome (365, 373, and 377 base pairs) and 2 for the W (388 and 391 base pairs), which they determined to be polymorphisms. The banding patterns were strong for samples of breast, primary, and tail feathers from known-sex controls.

Of the 126 chick samples processed, 98 samples provided distinguishable results with 48 indicating male and 50 indicating female. Of the 15 known sex control samples with distinguishable results, 100 percent were in agreement with the anatomically determined sex.

Adherence to Expected Sex Ratio

The male:female ratio for all individual chicks sampled was 48:50, close to the expected 50:50 ratio. The results for the sex ratio for chicks identified to broods were also very close to the expected 50:50 ratio. Three of the four 4-chick broods were 50:50, and one had 2 males, 1 female, and 1 individual with no clear result. Of the five 3-chick broods, 2 broods had 1 male and 2 females, 2 broods had 2 males and 1 female, and 1 brood had 2 females and 1 individual with no clear results. There were 2 broods with 2 chicks, and both had 1 male and 1 female.

DISCUSSION

DNA Analysis

The P2/P8 primer technique yielded expected results for both the known sex control samples and for the expected sex ratio of chicks in broods. We obtained results for 105 of the 140 chick feather samples analyzed (75% usable) and for 25 of the 32 control samples (78% usable). Success rates of 75% and 78%, respectively, indicate that laboratory and field handling procedures were adequate.

The polymorphism of the Z chromosome may have complicated scoring as compared to using the 2550F/2718R primers. In addition, the smaller DNA fragment size with the P2/P8 primer set ruled out the use of agarose gels.

Due to budget and time constraints, we re-amplified and gelled only 7 of the 39 chick samples that had no results on the first run. We were also unable to test the use of the 2550F/2718R primer set (Fridolfsson and Ellergren 1999) as suggested by Dawson (2001) and Dr. Kennedy (Albion College, MI, personal communication) and Dr. York (Hillsdale College, MI, personal communication). These primers amplify PCR products of 2 distinct bands of 130 base pair size difference (430 and 600) and are readily visualized on an agarose gel.

Field Collection

One to 2 feathers from the woodcock chicks appears to be an adequate size sample for DNA sexing (Table 1) even if the feathers are very small. Because banders at the training session were concerned about plucking feathers from some of the younger chicks, it was agreed that they would try to collect from chicks >3 days old and pluck only shoulder or breast feathers.

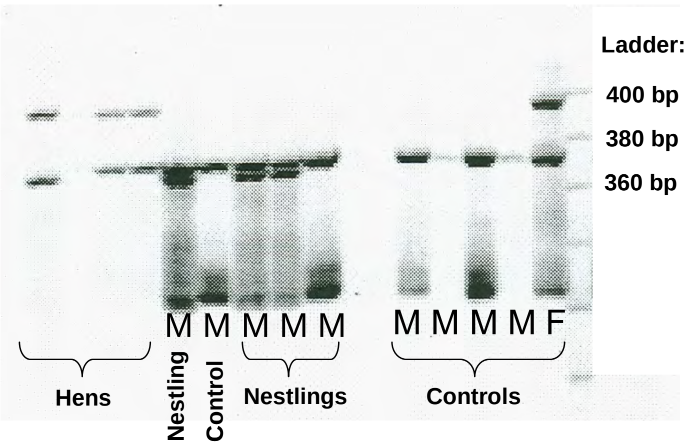


Figure 1. Patterns of amplified DNA on polyacrylamide gel using P2 and P8 primers. M = male, F = female, bp = base pairs.

Table 1. Number of feathers in the sample and samples with no results.

Number of feathers in sample	Total number of samples	Samples with no results
1	23	6
2	90	22
3	7	0
4	2	0
5	4	3[a]
10[b]	1	1

[a] Two of the samples with no results were from the same brood taken on the same day.

[b] This was a different sample consisting of very tiny down feathers.

It was noted that wing and shoulder feathers emerge first, and the shoulder feathers should provide more material (feather pulp) for DNA analysis than breast feathers. Comments from banders regarding chick safety indicated that shoulder feather removal would cause less potential damage to the chick skin or muscle. Feathers will immediately begin to grow back at pluck sites (Earl Johnson, Minnesota DNR, personal communication). There was also a concern that if the ambient temperature is less than 15° C the chicks might not be returned to the hen for warming as soon as needed. It was noted that there was some difficulty placing the very small feathers into the envelope.

CONCLUSION

This relatively non-invasive molecular sexing technique is convenient for field collectors, simple to perform in the laboratory, and rather inexpensive in labor and supplies. DNA analysis appears to be an effective way to distinguish sex in woodcock adults and chicks using feather pulp. This technique may serve to verify the phenotypic parameters currently in use to determine woodcock sex, such as the measurement of adult bill length and wing feathers. Additional verification of this method could be undertaken by collecting data on the sex of banded chicks when they are taken as adults in the fall harvest.

ACKNOWLEDGMENTS

We thank K. Scribner, S. Libants and K. Bennett-Filcek with the Molecular Ecology Laboratory in the Department of Fisheries and Wildlife at Michigan State University for their instruction, many hours of assistance, and use of their laboratory facilities. We also acknowledge D. Kennedy of Albion College, MI and D. York of Hillsdale College, MI for sharing their bird DNA protocols, and D. York for shipping primers; T. Cooley, Z. Cooley, M. Cosgrove, T. Lyon, and J. Rose, Michigan DNR WLD personnel, for help with carcass necropsy, feather collection and extraction, and database creation and data entry. The project would not have been possible without the chick feather samples provided by the Michigan woodcock banders and E. Johnson of Minnesota DNR, and carcasses submitted by the Michigan woodcock hunters, in particular C. Riley and R. Strouse.

LITERATURE CITED

Ammann, A. 1994. A guide to capturing and banding American woodcock using pointing dogs. The Ruffed Grouse Society, Coraopolis, Pennsylvania, USA.

Cooper, T. R., K. Parker, and R. D. Rau. 2008. American woodcock population status, 2008. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Dawson, D. A., S. Darby, F. M. Hunter, P. Krupa, I. L. Jones, and T. Burke. 2001. A critique of avian CHD-based molecular sexing protocols illustrated by a Z-chromosome polymorphism detected in auklets. Molecular Ecology Notes 1: 2001–204.

Dessecker, D. R., and D. G. McAuley. 2001. Importance of early successional habitat to ruffed grouse and American woodcock. Wildlife Society Bulletin 29: 456-465.

Eagle, A., E. Hay-Chmielewski, K. Cleveland, A. Derosier, M. Herbert, and R. Rustem, editors. 2005. Michigan's Wildlife Action Plan. Michigan Department of Natural Resources. Lansing, Michigan, USA. <http://www.michigan.gov/dnrwildlifeactionplan>.

Ellegren, H., and B. Sheldon. 1997. New tools for sex identification and the study of sex allocation in birds. Trends in Ecology and Evolution 12 (7): 225–259.

Frawley, V. R., and C. A. Stewart. 2009. Ruffed grouse and American woodcock status in Michigan, 2009. Michigan Department of Natural Resources Wildlife Report No. 3504, Lansing, Michigan, USA.

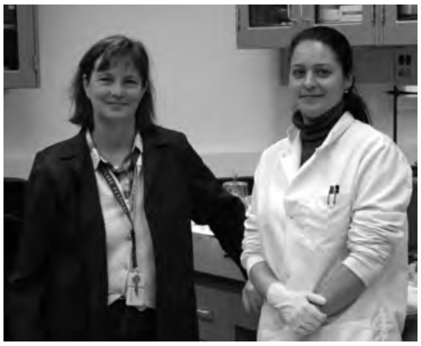
Fridolfsson, A. K., and H. Ellegren. 1999. A simple and universal method for molecular sexing of non-ratite birds. Journal of Avian Biology 30: 116–121.

Kelley, J., S. Williamson, and T. R. Cooper. 2008. American woodcock conservation plan: a summary of and recommendations for woodcock conservation in North America. Woodcock Task Force Migratory Shore and Upland Game Bird Working Group, Association of Fish and Wildlife Agencies. <*http://www.timberdoodle.org*>.

Griffiths, R., M. Double, K. Orr, and R. Dawson. 1998. A DNA test to sex most birds. Molecular Ecology 7: 1071–1075.

Martin, F. W. 1964. Woodcock age and sex determination from wings. The Journal of Wildlife Management 28 (2): 287–293.

Whittingham, L. A., and P. O. Dunn. 2000. Offspring sex ratios in tree swallows: females in better condition produce more sons. Molecular Ecology 9: 1123–1129.



Jean Fierke (left) works as a lab scientist for the MDNR Wildlife Health Section. She holds a Bachelor's degree in Animal Science from Michigan State University. She began work at the Wildlife Disease Lab in 1993 and has been a part of many of the disease surveillance programs in addition to participation in population health studies.

Kristine Brown (right) is a lab assistant for the MDNR Wildlife Health Section and has a Bachelor's degree in Fisheries & Wildlife Management from Michigan State University.

Al Stewart is the Upland Game Bird Specialist and Program Leader with the Michigan Department of Natural Resources and is responsible for statewide conservation and management programs for American woodcock, ruffed grouse, sharp-tailed grouse, quail, pheasants, and wild turkeys. He banded his first woodcock in 1971 with Andy Ammann and is the administrator of the Michigan woodcock banding program. He has pursued American woodcock in North America and Eurasian woodcock in Russia. He first participated in the woodcock wingbee in the early 1970s and continues to attend. He has contributed to national management activities for American woodcock and provided input to the American Woodcock Conservation Plan.

David R. Luukkonen is a Wildlife Research Specialist with the Michigan Department of Natural Resources; he is also an adjunct faculty member of the Department of Fisheries and Wildlife at Michigan State University. His primary interest is research to improve management decisions for migratory and resident game birds.

GENETIC VARIATION AMONG GRAVID FEMALE AMERICAN WOODCOCK IN EASTERN TEXAS DURING WINTER

10th American Woodcock Symposium
Roscommon, Michigan, USA

R. MONTAGUE WHITING, JR., Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, *Box 6109 SFA Station, Nacogdoches, TX 75962, USA*

DEAN RANSOM, JR.[1] , Department of Wildlife and Fisheries Sciences, Texas A&M University, *2258 TAMU, 210 Nagle Hall, College Station, TX 77843, USA*

CHRISTOPHER E. COMER[2], Arthur Temple College of Forestry and Agriculture, Stephen F. Austin State University, *Box 6109 SFA Station, Nacogdoches, TX 75962, USA*

KATHRYN A. CONNELL, Department of Wildlife and Fisheries Sciences, Texas A&M University, 2258 TAMU, *210 Nagle Hall, College Station, TX 77843, USA*

RODNEY L. HONEYCUTT[3], Department of Wildlife and Fisheries Sciences, Texas A&M University, *2258 TAMU, 210 Nagle Hall, College Station, TX 77843, USA*

Abstract: We investigated genetic variability in gravid female American woodcock (*Scolopax minor*) from 2 eastern Texas counties during late January 1997–1999. We amplified and sequenced a 750-base-pair fragment of the mitochondrial cytochrome *b* gene for 20 gravid females collected on winter range. We observed 13 unique haplotypes among the 20 individuals with an average haplotype divergence of 0.63%. The high level of haplotype diversity ($h = 0.009474$) and low nucleotide diversity ($\pi = 0.00509$) are consistent with genetic variation in woodcock collected on the traditional summer nesting range. A possible explanation of our results is that admixture occurs among woodcock populations on wintering grounds. If winter breeding is common, it may provide a mechanism for preventing genetic differentiation of woodcock populations from different flyways, and this lack of differentiation has implications for the designation of management units for woodcock.

Proceedings of the American Woodcock Symposium 10: 129–134

Key words: American woodcock, genetics, management units, mitochondrial DNA, *Scolopax minor*, Texas, winter breeding.

The range of the American woodcock (*Scolopax minor*) includes most of the forested areas of the eastern United States and Canada. Woodcock normally winter in the Piedmont and Coastal Plains of the southern United States from Texas to South Carolina. The breeding range includes most of the wintering range and extends northward into southern Canada (Straw et al. 1994). During most winters, males begin regular courtship flights by early January and reach reproductive readiness between mid-January and early February (Whiting and Boggus 1982, Mason 1986). Clutch initiation on the southern range occurs between late January and mid-March (Causey et al. 1974, Stamps and Doerr 1977, Whiting and Boggus 1982). Relatively warm and wet weather in January may increase the frequency of nesting on southern portions of the range (Causey et al. 1987). Studies of breeding on the southern range have consistently shown high variability in breeding rates with occasional years of significant southern breeding. In Alabama, the proportion of females nesting locally varied from 4% to 38% in January and February over 2 years (Walker and Causey 1982). In eastern Texas, 17 years of January harvest data for female woodcock likewise showed considerable annual variability and potentially high breeding rates in some years (0–29%; Whiting et

---

[1] Current address: Texas Agricultural Experiment Station, P.O. Box 1658, Vernon, TX 76384, USA.

[2] E-mail: comerce@sfasu.edu

[3] Current address: Natural Sciences Division, Pepperdine University, 24255 Pacific Coast Highway, Malibu, CA 90263, USA.

al. 2005). In February, 35% of adult female woodcock in eastern Texas were gravid over a 6-year period (Whiting et al. 1985).

Banding data for woodcock populations from Central and Eastern Regions suggest limited exchange between these 2 regions (Krohn 1972). Traditionally, populations of woodcock from these 2 regions have been managed separately (Coon et al. 1977). Band recovery data have shown that woodcock have a high degree of fidelity to breeding grounds in Maine (Krohn and Clark 1977) and Pennsylvania (Coon et al. 1976). Females apparently have high fidelity to specific nest sites (Straw et al. 1994) and there is little crossover between management units (Coon et al. 1977). These observations support the management unit designations and would suggest that Central and Eastern populations are reproductively separate.

Recent assessments of management units have employed population genetics for the identification of geographically and presumably genetically distinct populations of game species (Gay et al. 2004) as well as breeding populations in both neotropical migrants (Kimura et al. 2002) and shorebirds (Wenink et al. 1996). Existing genetic data from the northern breeding range of the American woodcock indicate limited demographic isolation of the Eastern and Central Regions (Rhymer et al. 2005). These results suggest substantial gene flow among the management units, along with overall high levels of genetic diversity among woodcock. The mechanism for gene flow between regions is not clear; however, mixing of birds on the wintering ground is one possible explanation, particularly if breeding on the wintering ground is extensive. The objective of this study was to assess the genetic characteristics of female woodcock breeding on winter range in eastern Texas.

METHODS

During late January, we obtained tissue samples from gravid female woodcock harvested by hunters either on or adjacent to the Davy Crockett National Forest in Houston and Trinity counties in eastern Texas. We collected brain tissue samples from all gravid females and maintained them in a –80° C ultra-cold freezer until final processing. We followed the procedure of Sambrook et al. (1989) to extract total genomic DNA from the tissue samples. We used the polymerase chain reaction (PCR; Saiki et al. 1988) to amplify a 750-base-pair fragment of the mitochondrial cytochrome *b* (mtDNA, Cyt *b*) gene. Reaction protocols and primers used to amplify and sequence the fragment were those reported by Ransom et al. (2001). We performed amplification in a Perkin Elmer/Cetus DNA thermal cycler, and sequenced amplification products using an ABI PRISM™ (Applied Biosystems, Perkin-Elmer Cetus, Norfolk, CT) dye-terminator cycle-sequencing kit. Prior to sequencing, we removed excess dye and primers from the samples on G-50 Sephadex spin columns. We then loaded PCR products on an Applied Biosystems 377 automated sequencer (Foster City, CA). We sequenced all fragments on both strands. We aligned overlapping sequences using the program Sequencher 3.1.1 (Gene Codes Corporation, Ann Arbor, MI), and examined each composite sequence for an open reading frame. We performed final alignment of all mitochondrial DNA (mtDNA) haplotypes using Clustal W (Thompson et al. 1992). We submitted all sequences to GenBank® (Benson et al. 2000) for assignment of accession numbers.

We obtained estimates of Tamura and Nei (1993) distances for all pair-wise comparisons of unique mtDNA haplotypes, and we estimated relationships among haplotypes using both neighbor-joining and maximum parsimony methods in PAUP*4.0b (Swofford 1999). We calculated haplotype diversity (*h*) and nucleotide diversity (π) using the methods of Nei (1987) and Tajima (1983), respectively, as implemented in the program ARLEQUIN (Schneider et al. 2000).

RESULTS

Between 25 January and 31 January in the years 1997–1999, we collected tissue samples from 20 gravid female woodcock. The proportion of adult females that were gravid during this time period varied among years, with 17/31 (55%) in 1997, 4/20 (20%) in 1998, and 1/4 (25%) in 1999. We were unable to obtain genetic data for 2 birds; further details about harvested birds in these years can be found in Whiting et al. (2005). Among the 20 birds from which we collected genetic information, we identified 13 unique mtDNA haplotypes. Four haplotypes were shared among birds, including: 4810cons (3 birds; 15%), 4815cons (3 birds; 15%), 1.7cons (2 birds; 10%), and 4821cons (3 birds; 15%). The remaining 9 haplotypes were unique to a single bird.

Haplotype divergence ranged from 0.159% to 1.444% and averaged 0.630%. Distances between haplotypes ranged from 0.00159 to 0.01111 (Table 1). The dendrogram based on neighbor-joining did not show significant clustering of haplotypes; instead, it suggested a large number of haplotypes that are only weakly and evenly differentiated (Figure 1). We did not observe clustering by year of harvest, and 2 haplotypes (4810cons and 1.7cons) were found in both 1997 and 1998. Haplotype diversity was high ($h = 0.947 \pm 0.03$) and nucleotide diversity was low ($\pi = 0.00509 \pm 0.00306$).

Table 1. Genetic distances (uncorrected *p*; Tamura and Nei 1993) among 13 mitochondrial DNA cytochrome *b* haplotypes for American woodcock collected in Trinity and Houston counties, Texas, during late January, 1997–1999.

Haplotypes	1	2	3	4	5	6	7	8	9	10	11	12
2	0.00318											
3	0.00159	0.00318										
4	0.00319	0.00478	0.00159									
5	0.00159	0.00478	0.00319	0.00480								
6	0.00319	0.00638	0.00478	0.00639	0.00159							
7	0.00319	0.00638	0.00478	0.00639	0.00159	0.00319						
8	0.00319	0.00638	0.00478	0.00639	0.00159	0.00319	0.00319					
9	0.00319	0.00478	0.00159	0.00320	0.00159	0.00318	0.00318	0.00318				
10	0.00319	0.00399	0.00639	0.00802	0.00319	0.00479	0.00479	0.00479	0.00478			
11	0.00639	0.00691	0.00799	0.00962	0.00479	0.00640	0.00640	0.00640	0.00638	0.00159		
12	0.00799	0.00639	0.00639	0.00802	0.00638	0.00798	0.00798	0.00798	0.00478	0.00318	0.00478	
13	0.00638	0.00960	0.00798	0.00959	0.00798	0.00960	0.00960	0.00960	0.00959	0.01121	0.01283	0.01444

DISCUSSION

The results of our study are similar to those of Rhymer et al. (2005) and indicate high mtDNA haplotype diversity among woodcock across their range. The high haplotype diversity may indicate extensive mixing and elevated gene flow among subpopulations of woodcock. We found that haplotype diversity (13 in 20 birds) in samples from 2 Texas counties was similar to or greater than that from 14 states and 4 Canadian provinces (32 in 114 birds for the ND6 gene) sampled by Rhymer et al. (2005). The large number of haplotypes in our small geographic area is consistent with the effects of substantial mixing on the wintering grounds. Nucleotide diversity was relatively low, suggesting recent divergence of haplotypes. As noted by Rhymer et al. (2005), the high haplotype diversity and lack of genetic structure in woodcock populations could be the result of one or more factors including either ongoing gene flow or historical demographic events. Historical demographic events that could produce the observed

Figure 1. Neighbor-joining dendrogram of *p* distances between cytochrome *b* haplotypes for American woodcock collected in Trinity and Houston counties, Texas, during late January 1997–1999.

pattern of high haplotype diversity and low nucleotide diversity include a recent and rapid population expansion or a recent population bottleneck. Due to the limited spatial scale and number of samples in our study, we cannot determine the influence of these events on current population genetic structure.

Female gene flow among geographically defined subpopulations of woodcock would also produce the observed genetic patterns in this study and that of Rhymer et al. (2005). Genetic mixing is possible wherever woodcock breeding occurs, including the traditional northern breeding grounds. However, banding studies have consistently documented high fidelity to northern natal sites, with individual woodcock often returning to the same breeding location in successive years (Coon et al. 1976, Krohn and Clark 1977, Straw et al. 1994). Thus, mixing on the traditional breeding grounds may not account for the observed variability. However, if both mixing of subpopulations and extensive breeding occur on the southern wintering range, this may provide a logical explanation of observed genetic patterns.

Evidence for breeding by woodcock on the southern wintering range is well-established and widespread (e.g., Causey et al. 1987, Whiting and Boggus 1982). The amount of southern breeding appears to be highly variable and dependent on several factors (Whiting et al. 2005); however, it can be high in some years (Walker and Causey 1982, Whiting et al. 1985). This study provides genetic evidence that is consistent with the occurrence of mixing of woodcock populations on the southern wintering range and is substantiated by evidence from limited banding studies in the Southeast. Woodcock banded in Louisiana on winter range were recovered across the northern range from Minnesota to Nova Scotia with approximately 50% recovery in the Central Region and 20% in the Eastern Region (Martin et al. 1969). East-west movement during winter may occur as well, as birds banded in Louisiana were recovered in 7 southeastern states (Ala., Ark., Ky., Mo., Miss., Tenn., Tex.; Martin et al. 1969). Data on limited numbers of banded birds (n = 24) recovered in eastern Texas showed that they were banded in 5 northern states (Ind., Me., Mich., Minn., Wis.) and in Louisiana (D. Haukos, USFWS, personal communication).

Genetic divergence among woodcock appears to be correlated with a rapid population expansion during the glacial retreat of the late Pleistocene (Rhymer et al. 2005). However, based on genetic data and other evidence, gene flow among subpopulations on the winter range provides a plausible explanation for the maintenance of genetically mixed woodcock populations in North America.

Although the data presented here are too limited to be used as a basis for changing current woodcock management practices, they suggest, in combination with other data (e.g., Rhymer et al. 2005), that mixing between current management units is not uncommon. Although currently defined management regions appear to be justified based on fidelity to breeding grounds, extensive mixing of birds on the wintering range may call into question the value of separate management units for this portion of the species' range. In any case, further genetic analyses across the winter range, along with demographic studies, will be necessary to determine the importance of winter mixing in the population genetics of woodcock and the ultimate value of the current management designations.

ACKNOWLEDGMENTS

This research was supported by the Arthur Temple College of Forestry and Agriculture at Austin State University, and by the Department of Wildlife and Fisheries Sciences, Texas A&M University. The manuscript and analysis benefited greatly from a review from W. C. Conway and from the comments of anonymous reviewers.

LITERATURE CITED

Benson D. A., Karsch-Mizrachi I., Lipman D. J., Ostell J., Rapp B. A., Wheeler D. L. 2000 GenBank. Nucleic Acids Research 28: 15–18.

Causey, M. K., J. Roboski, and G. Horton. 1974. Nesting activities of the American woodcock (*Philohela minor* Gmelin) in Alabama. Pages 5–12 *in* Proceedings of the Fifth American Woodcock Workshop, University of Georgia, Athens, Georgia, USA.

Causey, M. K., M. K. Hudson, and T. P. Mack. 1987. Breeding activity of American woodcock in Alabama as related to temperature. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 41: 373–377.

Coon, R. A., P. D. Caldwell, and G. L. Storm. 1976. Some characteristics of a fall migration of female woodcock. Journal of Wildlife Management 40: 91–95.

Coon, R. A., T. J. Dwyer, and J. W. Artmann. 1977. Identification of harvest units for the American woodcock. Pages 147–153 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium, Fredericton, New Brunswick, Canada.

Gay, L., P. Defos du Rau, J-Y. Mondain-Monval, and P-A. Crochet. 2004. Phylogeography of a game species: the red-crested pochard (*Netta rufina*) and consequences for its management. Molecular Ecology 13: 1035–1045.

Kimura, M., S. M. Clegg, I. J. Lovette, K. R. Holder, D. J. Girman, B. Mila, P. Wade, and T. B. Smith. 2002. Phylogeographical approaches to assessing demographic connectivity between breeding and overwintering regions in a nearctic-neotropical warbler (*Wilsonia pusilla*). Molecular Ecology 11: 1605–1616.

Krohn, W. B. 1972. American woodcock banding and recovery data, 1950–1970. U.S. Fish and Wildlife Service Administrative Report 213.

Krohn, W. B., and E. R. Clark. 1977. Band-recovery distribution of eastern Maine woodcock. Wildlife Society Bulletin 5: 118–122.

Martin, F. W., S. O. Williams, J. D. Newsome, and L. L. Glasgow. 1969. Analysis of records of Louisiana-banded woodcock. Proceedings of the Southeastern Association of Game and Fish Commissioners 23: 85–96.

Mason, P. J. 1986. Testicular morphology, serum testosterone concentration, courtship behavior, and the relationship of photosensitivity in the American woodcock (*Scolopax minor*). Dissertation, Auburn University, Auburn, Alabama, USA.

Nei, M. 1987. Molecular Evolutionary Genetics. Columbia University Press, New York, New York, USA.

Ransom, D., R. L. Honeycutt, and R. D. Slack. 2001. Population genetics of southeastern wood ducks. Journal of Wildlife Management 65: 745–754.

Rhymer, J. M., D. G. McAuley, and H. L. Ziel. 2005. Phylogeography of the American woodcock (*Scolopax minor*): are management units based on band recovery data reflected in genetically based management units? Auk 122: 1149–1160.

Saiki, R. R., D. H. Gelfand, S. Stoffel, S. J. Scharf, R. H. Higuchi, G. T. Horn, K. B. Mullis, and H. A. Erlich. 1988. Primer directed enzymatic amplification of DNA with a thermostable DNA polymerase. Science 239: 487–491.

Sambrook, J., E. F. Fritsch, and T. Maniatis. 1989. Molecular cloning: a laboratory manual. Cold Spring Harbor Laboratory Press, Cold Spring Harbor, New York, USA.

Schneider, S., D. Roessli, and L. Excoffier. 2000. Arlequin ver. 2.000: a software for population genetics data analysis. Genetics and Biometry Laboratory, University of Geneva, Switzerland.

Stamps, R. T., and P. D. Doerr. 1977. Reproductive maturation and breeding of woodcock in Alabama. Pages 185–190 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium, Fredericton, New Brunswick, Canada.

Straw, J. A., Jr., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American Woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. The International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Swofford, D. L. 1999. PAUP*. Phylogenetic Analysis Using Parsimony (* and other methods). Version 4. Sinauer Associates, Sunderland, Massachusetts, USA.

Tajima, F. 1983. Evolutionary relationship of DNA sequences in finite populations. Genetics 105: 437–460.

Tamura, K., and M. Nei. 1993. Estimation of the number of nucleotide substitutions in the control region of mitochondrial DNA in humans and chimpanzees. Molecular Biology and Evolution 10: 512–526.

Thompson, J. D., D. G. Higgins, and T. J. Gibson. 1992. Clustal W: Improving the sensitivity of progressive multiple sequence alignment through sequence weighting, position specific gap penalties, and weight matrix choice. Nucleic Acids Research 22: 4673–4680.

Walker, W. A., and M. K. Causey. 1982. Breeding activity of American woodcock in Alabama. Journal of Wildlife Management 46: 1054–1057.

Wenink, P. W., A. J. Baker, and M. G. J. Tilanus. 1996. Global mitochondrial DNA phylogeography of holoarctic breeding dunlins (*Calidris alpina*). Evolution 50: 318–330.

Whiting, R. M., Jr., and T. G. Boggus. 1982. Breeding biology of American woodcock in east Texas. Pages 132–138 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Woodcock ecology and management, United States Fish and Wildlife Service, Wildlife Research Report 14.

Whiting, R. M., Jr., R. R. George, M. K. Causey, and T. H. Roberts. 1985. February hunting of American woodcock: breeding implications. Pages 309–317 *in* S. L. Beasom and S. T. Roberson, editors. Game harvest management. Caesar Kleberg Wildlife Research Institute, Kingsville, Texas, USA.

Whiting, R. M., Jr., D. A. Haukos, and L. M. Smith. 2005. Factors affecting January reproduction of American woodcock in Texas. Southeastern Naturalist 4: 639–646.

R. Montague Whiting, Jr. is Professor Emeritus in the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University (SFASU) in Nacogdoches, Texas. He joined the faculty of SFASU in 1972 and completed the Ph.D. on the Texas A&M–SFASU joint program in 1978. During his academic career, he taught several forestry and numerous wildlife courses. Most of his research involved game and nongame birds, especially northern bobwhite and American woodcock. Currently, he is enjoying retirement and hunting birds as often and in as many places as possible with the objective of bagging at least one of every game bird in the continental United States.

Christopher E. Comer is an assistant professor of Forest Wildlife Management in the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University. He received his Ph.D. in Forest Resources from the University of Georgia conducting research on genetic structure in white-tailed deer and its implications for more effective management. In addition to a personal and professional interest in American woodcock, he studies the influence of savannah restoration on wildlife communities, black bears, and forest bats.

Dean Ransom, Jr., is currently a Research Scientist with the Rolling Plains Quail Research Ranch near Roby, TX, and is housed at the Texas A&M AgriLife Research and Extension Center in San Angelo, TX. He received his B.S. and Ph.D. degrees in Wildlife Ecology from Texas A&M University at College Station, TX and his M.S. degree in Wildlife Ecology from the University of Wisconsin at Madison. His research currently is directed towards northern bobwhites and associated shrub-land nongame birds in the Rolling Plains of Texas. Dean has served two terms as an Associate Editor for The Journal of Wildlife Management and is a Certified Wildlife Biologist (TWS).

Not Pictured

Kathryn A. Connell participated in this research as an undergraduate student at Texas A&M University. She is now a biology teacher in Texas.

Rodney L. Honeycutt is a University Professor and Professor of Biology in the Natural Science Division at Pepperdine University. He retired as a professor in Wildlife & Fisheries Sciences at Texas A&M University, and prior to Texas A&M, he was an associate professor at Harvard University. He received his Ph.D. from Texas Tech University and was a postdoctoral fellow at both Australian National University and the University of Michigan. His research specialty is in population genetics and phylogenetics, and he has worked extensively on endangered and threatened species of birds and mammals.

10th American Woodcock Symposium
Roscommon, Michigan, USA

STATUS OF AMERICAN WOODCOCK AND WOODCOCK SURVEYS IN NORTH AMERICA

THOMAS R. COOPER[1] **and JAMES R. KELLEY, JR.,** U.S. Fish and Wildlife Service, Division of Migratory Bird Management, *BHW Federal Building, 1 Federal Dr., Fort Snelling, MN 55111, USA*

Abstract: The U.S. Fish and Wildlife Service (USFWS), with support from numerous cooperators, coordinates 3 annual surveys to assess the population status of American woodcock (*Scolopax minor*). The surveys include the American Woodcock Singing-ground Survey (SGS), the American Woodcock Wing-collection Survey (WCS), and the Harvest Information Program (HIP). The U.S. Fish and Wildlife Service summarizes data from each survey in an annual American Woodcock Status Report. The report presents results for the 2 North American woodcock management regions (Eastern and Central). Annual woodcock banding and band recoveries provide additional information used for the management of woodcock. In this paper, we review the status of the SGS and WCS, present a summary of results from each survey, and discuss concerns and research priorities relevant to each survey. We do not cover the HIP survey because Padding et al. (2010) presented a review of the survey at the symposium. We also review banding effort over time and review how banding data have been used for woodcock management. Moving forward, stakeholders should provide direction on how to improve the current surveys and how to integrate these data into a modeling framework that enables managers to assess population response to harvest and habitat management decisions.

Proceedings of the American Woodcock Symposium 10: 135–145

Key words: American woodcock, banding, Singing-ground Survey, *Scolopax minor,* Wing-collection Survey.

The American woodcock is a popular game bird throughout eastern North America. The management objective of the U.S. Fish and Wildlife Service (USFWS) is to maintain populations of woodcock at levels consistent with the demands of consumptive and non-consumptive users (U.S. Fish and Wildlife Service 1990). Reliable population trends, harvest estimates, and information on recruitment and distribution are essential for comprehensive woodcock management. Each year, the USFWS, in cooperation with state, provincial, and private partners, coordinates three surveys to assess the population status of American woodcock. The Singing-ground Survey (SGS) provides an annual index of abundance, the Wing-collection Survey (WCS) provides an annual index of woodcock recruitment, and the Harvest Information Program (HIP) uses a sampling frame of woodcock hunters to estimate the number of hunters, harvest, and days spent afield each year. The USFWS summarizes data from these surveys in an annual report that is distributed to stakeholders (annual report available online: http://www.fws.gov/migratorybirds/NewReportsPublications/PopulationStatus.html). The USFWS, with input from stakeholders, uses the data to make annual management decisions for the Eastern and Central Management Regions (Figure 1). Several private partners and government agencies participate in annual woodcock banding activities, although there is currently no national coordination of banding effort.

Our objective for this paper is to review the status of each survey used to monitor American woodcock populations. For each survey, we present background information about the survey including survey methodology, summarize the most recent results as of the Tenth American Woodcock Symposium, and discuss current concerns and research priorities relevant to each survey. Padding et al. (2010) reviewed the Harvest Information Program (HIP), so we do not include a review of the HIP survey in our paper. We also summarize banding effort through time and review the use of banding data to date.

AMERICAN WOODCOCK SINGING-GROUND SURVEY (SGS)

SGS Background and Methodology

The SGS was developed to monitor changes in woodcock relative abundance and exploits the conspicuous courtship display of the male woodcock. Early studies demonstrated that counts of singing males provide indices to woodcock populations and could be used to monitor annual changes (Mendall and Aldous 1943, Goudy 1960, Duke 1966, and Whitcomb 1974). Before

---

[1] E-mail: tom_cooper@fws.gov

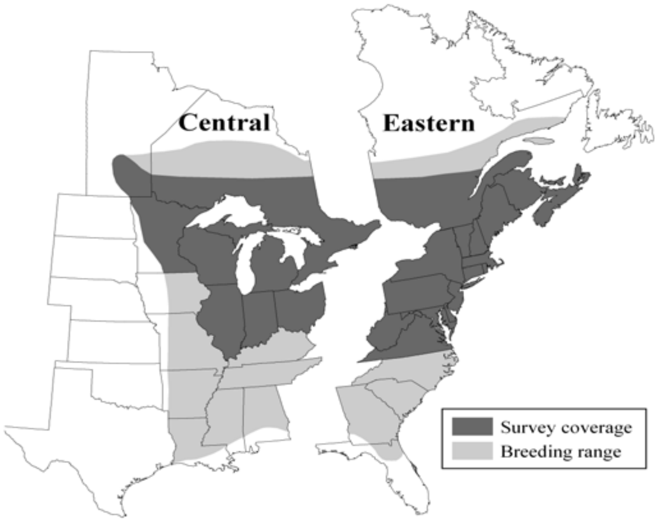


Figure 1. Woodcock management regions, breeding range, and American Woodcock Singing-ground Survey coverage.

1968, observers conducted counts along non-randomly-located routes. Beginning in 1968, the USFWS relocated routes 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 (Figure 1).

Each route is 3.6 miles (5.4 km) long and consists of 10 listening points. Observers survey the routes shortly after sunset and record the number of woodcock heard peenting over a period of two minutes at each stop (the vocalization of displaying male woodcock). Acceptable dates for conducting the survey align with latitudinal bands to coincide with peaks in courtship behavior of local woodcock (Figure 2). In most states, the peak of courtship activity (including local woodcock and woodcock still migrating) may occur earlier in the spring and local reproduction may already be underway during survey timeframes. However, designated survey dates minimize the counting of migrating woodcock. Survey protocols designate acceptable wind, precipitation, and temperature conditions to avoid adverse weather conditions that may affect courtship behavior or the ability of observers to hear woodcock (Kelley and Rau 2006).

The survey consists of approximately 1,500 routes. Routes where no woodcock are heard for 2 consecutive years enter "constant zero" status and are not run for the next 5 years to avoid expending unnecessary resources. If woodcock are heard on a constant zero route after 5 years, the route reverts back to active status. Approximately half of the survey routes are in constant zero status. For more details about the development of the SGS, consult Sauer and Bortner (1991).

Survey data analysis methodologies have become more sophisticated over time. Geissler and Noon (1981)

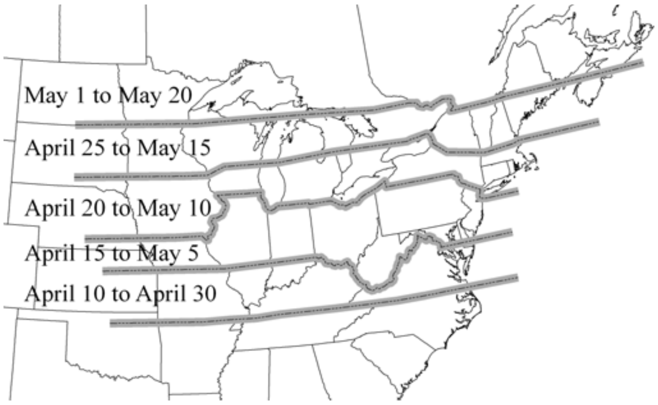


Figure 2. Survey windows for the American Woodcock Singing-ground Survey.

developed the base year method to assess change in annual indices using ratios of counts. The base year method may have resulted in biased trend estimates and biased variance estimates (Sauer and Bortner 1991). Due to the potential biases, Geissler and Sauer (1990) refined analysis using a route-regression method. Using this method, trends are estimated using the weighted averages of route-specific slopes (Sauer and Bortner 1991). The route regression method was further modified by incorporating Poisson regressions with log links for individual routes (Link and Sauer 1994).

Work is currently underway to estimate trends using hierarchical log-linear modeling methods. In practice, the hierarchical modeling approach will provide trend and annual indices that are generally comparable to the estimates provided by the previously used route regression approach. However, the hierarchical model method has a more rigorous and realistic theoretical basis than the weightings used in the route regression approach, and the indices and trends are directly comparable as the same data are used to calculate each. In addition, it allows the incorporation of model-based assumptions regarding the distribution of observer effects, stratum effects, effort, and other features over space and time

(Editors' Note: Since the symposium, the U.S. Fish and Wildlife Service in cooperation with the U.S. Geological Survey Patuxent Wildlife Research Center started using a hierarchical model to estimate indices and trends from the SGS. This change was initiated in 2008. Please consult Sauer et al. 2008 for details on using the hierarchical modeling approach).

SGS Results Summary

Each year, trends are estimated for the most recent 1-year, 10-year, and long-term (1968–present) time periods (Kelley and Rau 2006). The number of woodcock heard displaying during the 2006 Singing-ground Sur-

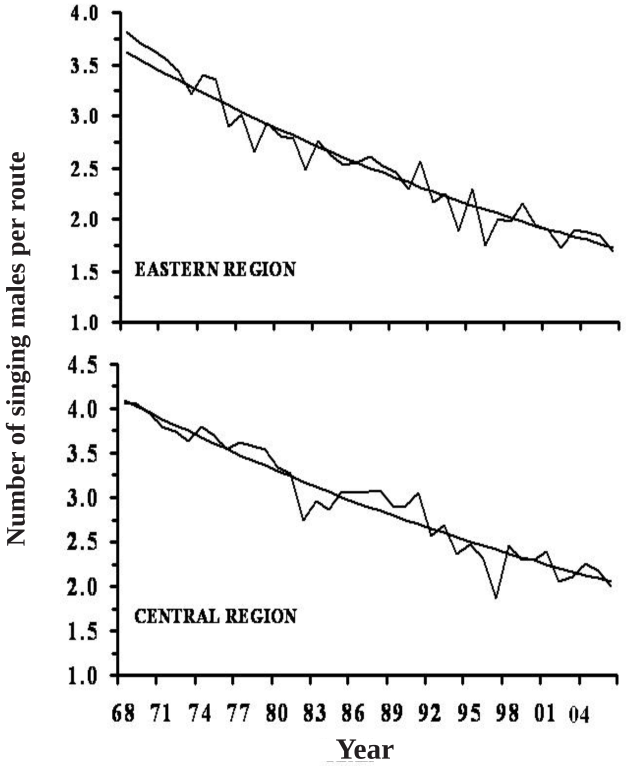


Figure 3. Long-term trends (smooth line) and annual indices of the number of woodcock heard on the American Woodcock Singing-ground Survey, 1968–2006 (Kelley and Rau 2006).

vey in the Eastern Region was not significantly different from 2005 levels; however, the Central Region experienced an 8% decline (Table 1). Ten-year trends were computed for 357 routes in the Eastern Region and 381 routes in the Central Region. Ten-year trend estimates for both regions were not significant (Table 1). Long-term (1968–2006) trends were estimated for 625 routes in the Eastern Region and 631 routes in the Central Region. Both regions show significant long-term declining trends of –1.9 and –1.8% per year for the Eastern and Central Regions, respectively (Figure 3). There were significant long-term declines in breeding population indices throughout many states and provinces in the Eastern and Central Regions (Table 1).

SGS Survey Future

The SGS continues to be an essential tool for the management of the American woodcock in North America. The survey's past and future uses include the following:

1. The survey provides a long-term data set to guide the management of woodcock in North America. The survey detected long-term population declines throughout the species' range. In response, the USFWS implemented more conservative hunting seasons in an effort to keep hunting seasons commensurate with population status.
2. The Woodcock Task Force, created by the Association of Fish and Wildlife Agencies, used data from the survey to develop explicit population and habitat goals for the American Woodcock Conservation Plan (Kelley et al 2008). Further, the task force will use data from the SGS to assess progress toward meeting the population and habitat goals outlined in the American Woodcock Conservation Plan.
3. The USFWS, in cooperation with Flyway Councils, plans to develop a harvest strategy for woodcock based on various population parameters. Data from the SGS will factor heavily into strategy formulation.
4. Researchers have used data from the SGS to build spatially explicit models showing the relationship between woodcock abundance and landscape-level variables (Thogmartin et al. 2007).

Survey cooperators have identified several concerns relating to the SGS. Future work should focus on addressing the following concerns:

1. Declining participation in the SGS – Participation in the survey has declined over recent years mainly due to funding or staff shortages of cooperating agencies. Survey cooperators should heighten awareness of the survey's importance and open a dialogue with cooperating agencies in order to improve survey participation.
2. Lack of detection probability estimates – Researchers should evaluate techniques (i.e., repeated counts, distance sampling, and removal methods) for estimating detection probabilities of woodcock along SGS routes. Determining detection probabilities would potentially allow the estimation of population size from SGS count data. Population estimates could then be incorporated into the framework for developing a harvest strategy for woodcock, used to develop improved conservation goals, and for other purposes not yet envisioned.
3. Habitat changes adjacent to routes – Because the SGS is a roadside survey, habitat changes along SGS routes may not be representative of changes to the larger landscape. Previous research (Dwyer et al. 1983) evaluated the relationship of habitat variables to indices along SGS routes; however, the relationship of habitat changes along routes to changes on the larger landscape has not been evaluated. Results from the Morrison et al. (2010) paper presented at the symposium show that habitat is increasing across the province of New Brunswick, but decreasing along SGS routes. Survey cooperators should assess if landscape changes along survey routes reflect changes to the surrounding landscape throughout the survey area.

Table 1. Trends (% change per year[a]) in the number of American woodcock heard in the Singing-ground Survey during 1968–2006, as determined by the estimating equations technique (Link and Sauer 1994).

State, province, or region	No. of routes[b]	2005–2006				1996–2006				1968–2006			
		n[c]	% change	90%CI		*n*	% change	90% CI		*n*	% change	90% CI	
CT	3	2	–26.9	–55.9	2.1	4	–13.7	–43.0	15.7	9	–10.4 ** [d]	–17.1	–3.8
DE	2	0				2	–13.4 *	–16.4	–10.4	2	2.9	–8.5	14.2
ME	43	28	13.0	–6.4	32.5	51	1.0	–0.4	2.5	66	–1.9 ***	–2.8	–1.1
MD	9	4	560.6	–862.4	1983.7	6	–27.3	–71.3	16.7	21	–9.7 **	–16.9	–2.5
MA	11	2	64.7*	49.7	79.6	9	1.9	–4.7	8.6	20	–4.6 *	–8.7	–0.5
NB	12	10	–4.3	–24.6	15.9	52	4.3***	2.1	6.6	64	–0.5	–1.5	0.6
NH	14	11	–18.7	–38.0	0.5	13	0.4	–3.1	3.8	18	1.2	–0.9	3.3
NJ	3	2	3.9	–109.7	117.5	5	–13.8	–26.0	–1.7	17	–8.9 ***	–10.9	–7.0
NY	58	37	26.5	–19.6	72.7	75	–2.5	–7.0	2.1	107	–2.5 ***	–3.5	–1.4
NS	32	16	–25.6	–51.6	0.5	43	–4.3	–14.0	5.4	60	–0.2	–1.8	1.3
PA	28	11	–30.1	–61.3	1.0	27	–0.2	–5.5	5.0	58	–3.4 ***	–5.3	–1.5
PEI	5	3	2.2	–18.5	23.0	7	–8.0	–18.3	2.3	12	–1.6	–3.3	0.1
QUE	4	0				16	7.6***	4.1	11.1	56	–1.3	–4.4	1.7
RI	1	0				0				2	–16.3	–23.9	–8.6
VT	15	11	–4.2	–29.8	21.5	17	0.9	–1.8	3.7	21	–0.7	–2.4	0.9
VA	12	4	102.1	–514.9	719.2	11	–16.9 **	–26.5	–7.3	47	–11.1 ***	–14.9	–7.3
WV	19	10	–6.2	–33.0	20.5	19	–7.2	–15.8	1.4	45	–2.7 ***	–4.1	–1.2
Eastern	271	152	4.3	–12.4	21.1	357	0.0	–1.8	1.7	625	–1.9 ***	–2.4	–1.4
IL	8	0				5	13.2	–13.2	39.6	25	24.5	–7.2	56.2
IN	16	2	–96.1***	–97.0	–95.2	7	–5.1	–22.2	12.0	39	–7.1 **	–12.1	–2.0
MB[e]	11	4	–27.4*	–46.2	–8.5	21	0.0	–4.0	4.0	22	–2.4	–5.5	0.8
MI	95	68	–7.9	–18.8	3.0	108	–1.0	–3.0	1.1	147	–1.7 ***	–2.5	–0.9
MN	74	52	–8.3	–19.3	2.6	79	0.5	–1.7	2.8	102	–1.0 *	–1.8	–0.1
OH	32	15	–12.7	–39.6	14.3	27	–6.7	–14.4	0.9	57	–6.2 ***	–9.1	–3.3
ON	31	12	–5.5	–29.6	18.5	60	3.1	–0.3	6.4	138	–1.9 ***	–2.7	–1.1
WI	68	47	–5.2	–22.5	12.2	74	0.1	–1.9	2.1	101	–1.9 ***	–2.5	–1.2
Central	335	201	–8.0**	–14.5	–1.5	381	–0.1	–1.2	1.0	631	–1.8 ***	–2.3	–1.4

[a] Mean of weighted route trends within each state, province, or region. 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.

[b] Total number of routes surveyed in 2006 for which data were received by 1 June.

[c] Number of comparable routes (2005 versus 2006) with at least 2 non-zero counts.

[d] Indicates slope is significantly different from zero: * $P < 0.10$, ** $P < 0.05$, *** $P < 0.01$; significance levels are approximate for states/provinces where $n < 10$.For purposes of this report, statistical significance was defined as $P < 0.05$, except for the 2-year comparison where $P < 0.10$ was used because of the low power of the test.

[e] Manitoba began participating in the Singing-ground Survey in 1990.

4. The survey does not cover the entire breeding range – A significant number of woodcock may breed north of the SGS area (Sauer et al. 2008). Survey cooperators should assess the number of woodcock breeding north of the current survey area. In addition, they should assess the number of woodcock breeding south of the current survey area. Biologists in Kentucky, which is south of the current survey area, are currently investigating the number of woodcock breeding in the state (John Brunjes, Kentucky Department of Fish and Wildlife Resources, personal communication).
5. Changes in migration and breeding chronology – Woodcock may be migrating and breeding earlier in response to climate change. Future research should assess the influence of climate change on the current survey timing throughout the area surveyed by the SGS.

(Editors' note: Since the symposium, research to estimate detection probabilities and compare habitat change along SGS routes with the larger landscape have been funded through the USFWS Webless Research Program. The research is being conducted through the Minnesota Cooperative Fish and Wildlife Research Unit. Additionally, the Division of Migratory Bird Management initiated an ongoing dialogue to improve Singing-ground Survey participation in 2008 with the distribution of a 2007 participation assessment that was shared with partners in state and provincial agencies and with the Canadian Wildlife Service (CWS). Gaps in participation were identified and efforts are underway to address areas of concern. Participation levels are now tracked and communicated to partner agencies on an annual basis.)

AMERICAN WOODCOCK WING-COLLECTION SURVEY (WCS)

WCS Background and Methodology

The WCS, operational since 1963, was incorporated into a national webless migratory gamebird wing-collection survey in 1997. The primary purpose of the WCS is to provide indices to reproductive success of woodcock. Wing data also provide information on the chronology and distribution of woodcock harvest since hunters report the date and location of harvest for each wing.

Woodcock hunters, the USFWS, and state wildlife agencies cooperate in the wing survey effort. Participants include hunters who either 1) participated in past surveys; 2) were a subset of hunters that indicated on the Harvest Information Program survey that they hunted woodcock; or 3) contacted the USFWS and requested to participate in the survey. The USFWS provides WCS participants with prepaid mailing envelopes and requests them to submit one wing from each woodcock harvested. Hunters record the date of the hunt along with the state and location where they harvested the bird. Participants only submit envelopes from successful hunts. State, federal, and private biologists determine the age and sex of the harvested individuals by examining plumage characteristics (Martin 1964, Sepik 1994) during the annual woodcock wingbee. Prior to examining wings, all wingbee participants must pass a test of known-age and known-sex wings.

The ratio of immature birds (male and female combined) per adult female in the harvest provides an index to recruitment of young into the population. Annual recruitment indices are calculated for each state with ≥125 submitted wings. Regional indices are calculated each year by weighting the regional index with the relative contribution of each state to the cumulative number of adult female and immature wings received since the start of the survey in 1963 (Kelley and Rau 2006).

WCS Results Summary

Over the past five hunting seasons (2001–2005), an average of 1,127 hunters per year have participated in the WCS and have submitted an average of 10,516 wings per year (Figure 4). The long-term average (1963–2004) recruitment index for the Eastern Management Region (EMR) is 1.67 juveniles per adult female, while it is 1.62 for the Central Management Region (CMR) (Figure 5, Kelley and Rau 2006). In the EMR, recruitment indices

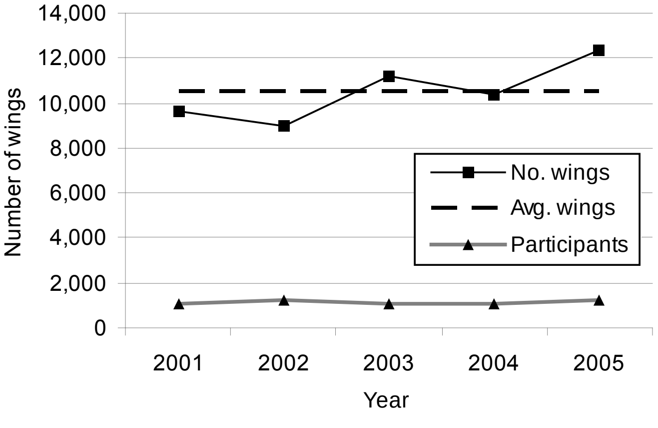


Figure 4. American woodcock wing receipts and hunter participation in the American Woodcock Wing-collection Survey, 2001–2005.

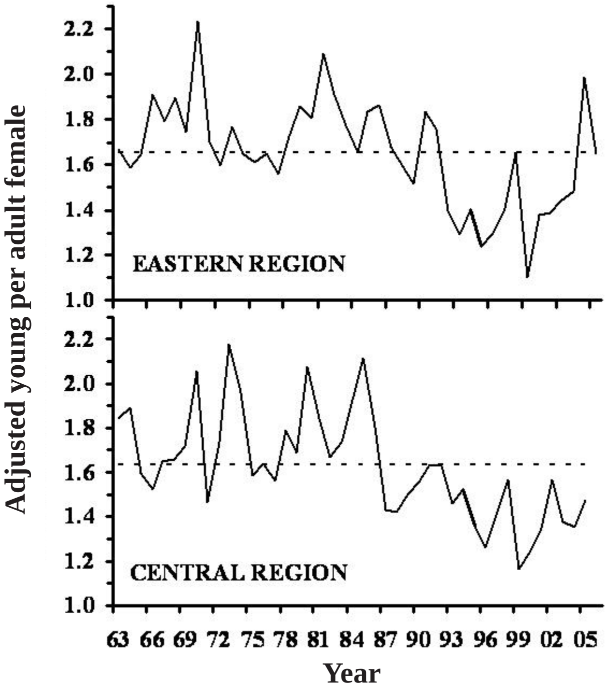


Figure 5. Weighted annual indices of recruitment from the American Woodcock Wing-collection Survey (U.S.), 1963–2005 (Kelley and Rau 2006).The dashed line represents the 1963–2004 average.

have been below the long-term average for 9 of the past 10 years, while in the CMR the indices have been below the average for the past 10 years (Figure 5).

WCS Discussion

The WCS continues to provide important information about annual woodcock recruitment but future work could improve the survey by addressing the following concerns:

1. Small sample sizes for some states where woodcock are hunted – Survey coordinators should take steps to improve participation from all states where woodcock are harvested. For example, set a goal to receive wings in proportion to the number of woodcock harvested in each state (i.e., get a certain percentage of the wings harvested in each state based on harvest estimates from the HIP survey).
2. Non-random survey design – The USFWS does not randomly select participating hunters to submit wings. The non-random survey design could bias survey results; however, unpublished data from the Canadian Harvest Survey Program indicated that age ratios did not differ between wings received randomly and non-randomly (Eric Reed, Canadian Wildlife Service, personal communication).
3. Age ratios are not adjusted for age-specific harvest vulnerabilities – Future research should assess whether age-specific harvest vulnerability exists. If vulnerability differs between age classes, analysts should adjust recruitment indices to reflect differences in harvest vulnerability.
4. Precision estimates (i.e., confidence intervals) are not calculated for recruitment indices – Data analysts should investigate techniques for estimating the precision of recruitment indices.
5. The woodcock wingbee protocol differs from other migratory gamebird wingbees (i.e. waterfowl) – At the waterfowl wingbee, an expert double-checks each wing to confirm the recorded age and sex. No one double-checks wings at the woodcock wingbee; participants must only pass a test prior to examining wings.

AMERICAN WOODCOCK BANDING

Banding Background and Methodology

There currently is no consistent, range-wide banding program for American woodcock in North America like there is for other species such as waterfowl. Most banding is completed through state-led efforts that are heavily reliant on volunteers or associated with localized research projects. For example, Minnesota and Michigan have active brood banding programs where pointing dogs are used to locate broods (Ammann 1981), while biologists in Louisiana band wintering woodcock using night-lighting techniques on roosting fields (Olinde 2007). In addition, researchers have banded numerous birds as part of long-term research efforts such as those at Moosehorn NWR in Maine. The major barrier to an operational woodcock banding program is that woodcock are not attracted to bait like other game birds (i.e., waterfowl and doves). Therefore, banders must expend a large amount of effort to band a limited number of woodcock using methods such as pointing dogs, mist netting at singing ground locations, or night-lighting at roosting fields.

Banding Summary

Banding records from the United States Geological Survey's (USGS) Bird Banding Laboratory indicate that 118,466 woodcock have been banded between 1930 and 2005. Cooperators from twenty states or provinces banded ≥500 birds during this time period (Table 2). Banding effort was not consistent over time, with effort peaking during the 1970s when >35,000 bird were banded (Table 2). Areas with the highest banding density include north-central Wisconsin, northern Michigan,

Table 2. Number of American woodcock banded by decade for each state or province where ≥499 woodcock have been banded.

State/Province	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s[a]	Total
Michigan	2	0	109	2,717	3,905	6,593	13,451	7,437	34,214
Louisiana	54	455	9,013	8,608	1,593	4	2,044	1,314	23,085
Maine	325	255	111	4,247	7,817	2,452	2,074	702	17,983
Wisconsin	1	0	6	612	9,360	1,134	264	532	11,909
New York	1	0	50	597	2,819	127	49	20	3,663
West Virginia	0	0	0	1,636	1,685	226	7	10	3,564
Minnesota	2	0	33	241	1,072	338	746	854	3,286
New Jersey	0	4	11	1,061	1,834	112	18	5	3,045
Massachusetts	7	2	1,035	188	874	75	102	18	2,301
Pennsylvania	18	18	204	231	371	292	694	24	1,852
New Brunswick	28	254	260	283	869	6	5	0	1,705
North Carolina	0	0	1	5	1,323	341	2	1	1,673
Virginia	0	0	0	15	14	795	536	41	1,401
Quebec	0	0	0	2	139	225	738	149	1,253
Indiana	0	0	0	91	221	597	32	1	942
Ontario	0	0	48	173	324	138	146	101	930
Alabama	2	0	0	10	669	229	0	0	910
Maryland	0	0	5	91	488	136	22	12	754
Ohio	0	0	4	28	154	373	120	67	746
Vermont	0	0	0	0	161	15	122	201	499
Total	440	988	10,890	20,836	35,692	14,208	21,172	11,489	115,715

[a] Records through 31 December 2005.

Table 3. Number of hunter-reported band recoveries by decade for each state or province where ≥50 American woodcock have been reported.

State/Province	1930s	1940s	1950s	1960s	1970s	1980s	1990s	2000s	Total
Michigan	0	2	55	301	237	252	455	281	1,583
Louisiana	1	8	40	90	124	38	138	172	611
Maine	6	8	9	129	327	27	26	10	542
West Virginia	0	0	1	333	136	4	0	2	476
Wisconsin	0	1	21	25	236	66	14	21	384
New Jersey	2	1	7	36	144	3	2	0	195
Pennsylvania	0	2	27	57	75	15	14	2	192
New York	3	0	8	42	112	8	1	0	174
Indiana	0	0	0	4	23	131	3	1	162
Massachusetts	2	2	11	16	69	2	5	3	110
New Brunswick	1	4	6	20	62	2	5	0	100
Minnesota	0	0	6	7	28	7	22	17	87
Mississippi	1	1	6	24	35	4	1	0	72
Quebec	0	0	1	2	14	9	36	1	63
Connecticut	0	0	2	17	32	1	0	3	55
Total	16	29	200	1,103	1,654	569	722	513	4,806

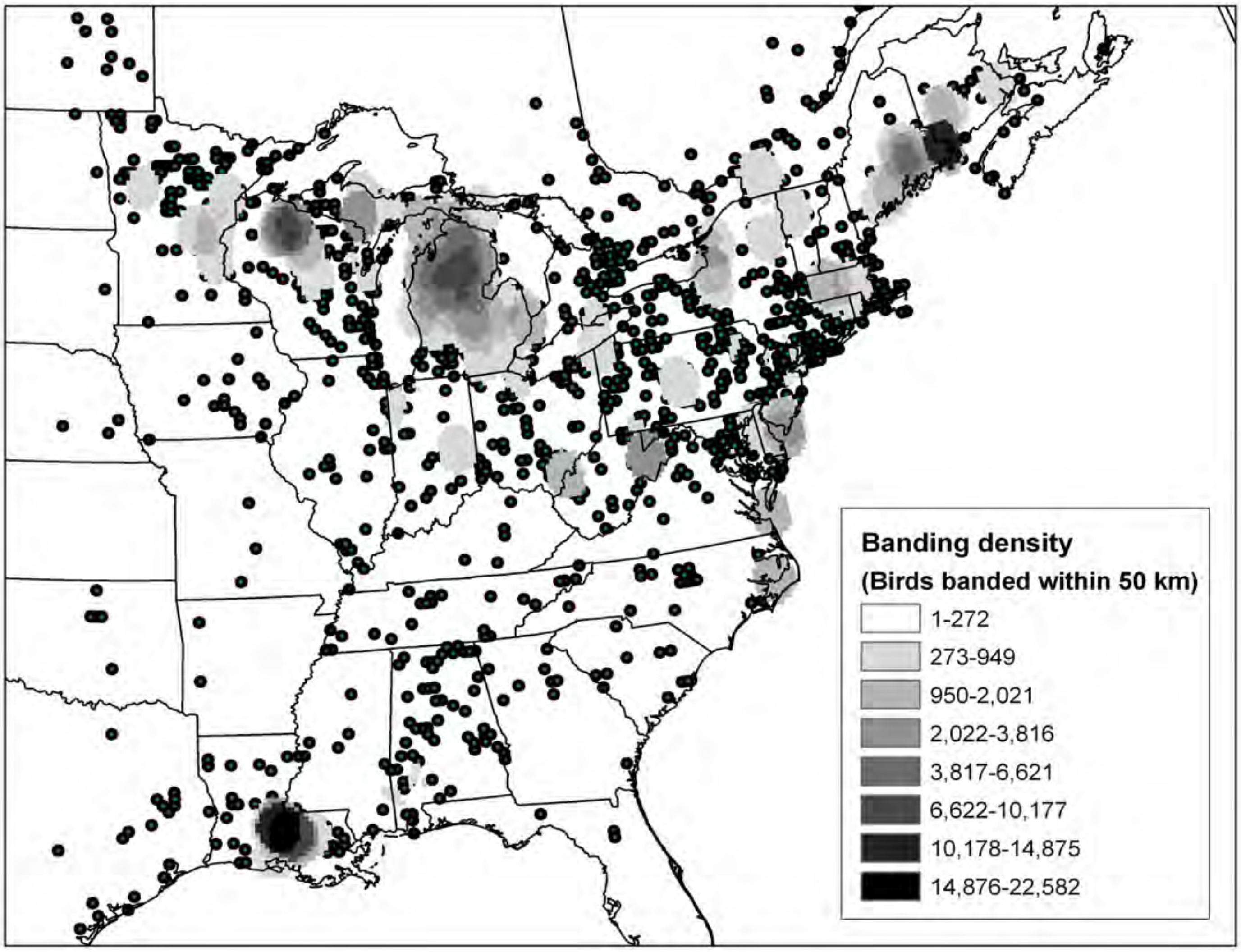


Figure 6. Banding distribution for American woodcock. Individual points represent banding locations in low-density banding areas.

eastern Maine, eastern West Virginia, and central Louisiana (Figure 6). Other states or provinces with <500 banding records include Connecticut, Delaware, District of Columbia, Florida, Georgia, Illinois, Iowa, Kentucky, Labrador, Manitoba, Mississippi, Missouri, Nebraska, New Hampshire, North Dakota, Nova Scotia, Oklahoma, Rhode Island, South Carolina, South Dakota, Tennessee, and Texas.

A total of 6,197 banded woodcock have been encountered between 1930 and the end of the 2005 hunting season. A majority of the encounters (5,303) are recoveries reported from hunter-shot birds. Fifteen states or provinces have ≥50 band recoveries during this time period (Table 3). The greatest number of recoveries came from the 1970s (Table 3), which corresponds to the decade of highest banding effort. The recovery area distribution is similar to the banding area distribution (Figure 7). Other states or provinces with band recoveries, but numbering <50 records include Alabama, Arkansas, Delaware, Florida, Georgia, Illinois, Iowa, Kansas, Kentucky, Maryland, Missouri, New Hampshire, North Carolina, Nova Scotia, Ohio, Oklahoma, Ontario, Rhode Island, South Carolina, Tennessee, Texas, Vermont, and Virginia.

Banding Discussion

Data from band recoveries have been important in the management of woodcock even though there is not a consistent, range-wide banding program. For example, the creation of the Eastern and Central Woodcock Management Regions was biologically justified through analysis of band recovery data (Martin et al. 1969, Krohn et al. 1974, Coon et al. 1977, Myatt and Krementz 2005). Banding data have also been used to examine woodcock vital rates such as annual survival and band recovery rates (e.g., Krohn et al. 1974, Dwyer and Nichols 1982, Krementz and Bruggink 2000,

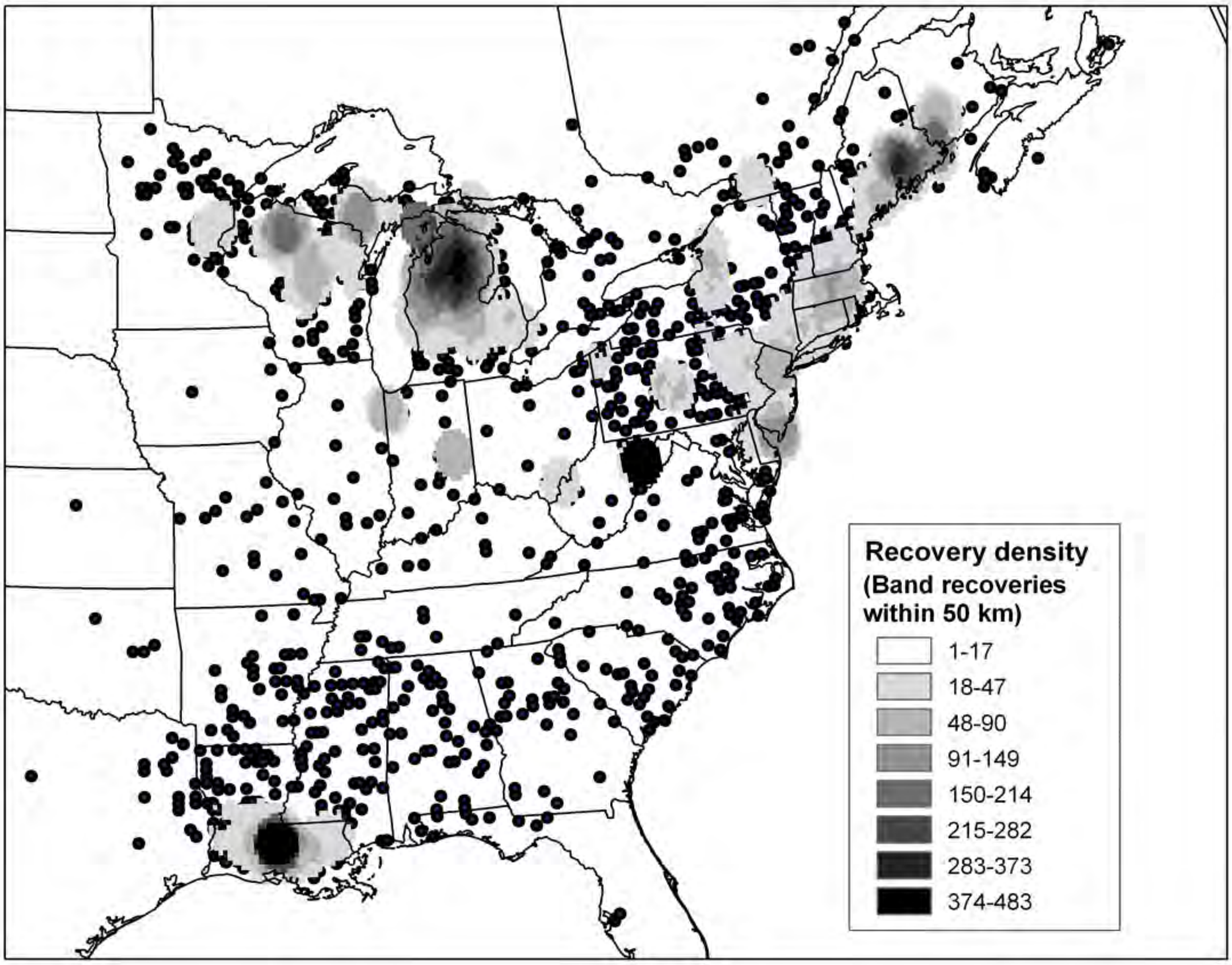


Figure 7. Recovery distribution for bands from hunter-reported American woodcock. Individual points represent recovery locations from low-density areas.

Krementz et al. 2003). Although banding data have been used to estimate vital rates, McAuley et al. (2005) indicate that estimates derived from banding data are imprecise due to the inadequate amount of banding data available. Dwyer and Nichols (1982) noted that limited banding and recovery data sets have always been a barrier to better understanding woodcock population dynamics. Although researchers have recommended increasing banding effort and banding area distribution to improve the precision of estimates (Krementz et al. 2003), others have indicated that starting an adequate banding program would be difficult and may not be the best use of limited resources (Krementz and Bruggink 2000).

At minimum, stakeholders should complete a banding needs assessment that evaluates the feasibility of implementing an operational range-wide banding program. The assessment should provide guidance on how many birds need to be banded in order to calculate precise estimates of survival, recovery, and harvest at the management region scale. Decision makers will then have to determine if the benefits of having banding data to better inform management outweigh the cost of implementing an adequate banding program. If feasible, implementing an operational banding program will require significant cooperation between federal, state, and private conservation partners.

DISCUSSION

American woodcock population management in the United States has historically relied on trend data from the SGS. Managers have not used data from the other surveys (HIP, WCS, and banding data) in any formal decision-making process to date. Moving forward, stakeholders should cooperate on developing a conceptual model that incorporates the biologically relevant periods of the annual woodcock cycle. As a first step, population modelers should assess the utility of using data sets from the current surveys in developing a demographic-based population model. Using the model as a tool, stakeholders can then begin to 1) identify gaps in our current information base; 2) prioritize additional data collection needs that will feed into a population assessment framework; and 3) begin assessing population response to harvest and habitat management decisions.

(Editors' note: Since the symposium, the USFWS released a scoping document in December 2007 that outlines the available woodcock population data and presents a method for integrating these data sources into a population modeling framework. In addition, the Migratory Shore and Upland Game Bird Support Task Force convened a workshop in August 2009 to identify the priority information needs for woodcock over the next 5–10 years. Participants determined that developing a demographic-based model was a high priority for improving management of woodcock.)

ACKNOWLEDGMENTS

We thank all the cooperators that assist with woodcock surveys including personnel from the U.S. Fish and Wildlife Service, Canadian Wildlife Service, U. S. Geological Survey, state/provincial conservation agencies, and non-government conservation organizations. We also thank the many hunters that send wings into the Wing-collection Survey and participate in the Harvest Information Program. Additionally, we thank all of the volunteers dedicated to woodcock banding efforts throughout the breeding range. R. Rau and K. Parker provided input on earlier drafts of the manuscript. Finally, we thank the anonymous reviewers for providing helpful comments to improve the manuscript.

LITERATURE CITED

Ammann, A. 1981. A guide to capturing and banding American woodcock using pointing dogs. The Ruffed Grouse Society, Coraopolis, Pennsylvania, USA.

Coon, R. A., T. J. Dwyer, and J. W. Artmann. 1977. Identification of harvest units for the American woodcock. Pages 147–153 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium, Fredericton, New Brunswick, Canada.

Duke, G. E. 1966. Reliability of censuses of singing male woodcock. Journal of Wildlife Management 30: 697–707.

Dwyer, T. J., and J. D. Nichols. 1982. Regional population inferences for the American woodcock. Pages 12–21 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14, Washington, D.C., USA.

Dwyer, T. J., D. G. McAuley, and E. L. Derleth. 1983. Woodcock singing-ground counts and habitat changes in the northeastern United States. Journal of Wildlife Management 47(3): 772–779.

Geissler, P. H., and B. R. Noon. 1981. Estimates of avian population trends from the North American Breeding Bird Survey. Pages 42–51 *in* C. J. Ralph and J. M. Scott, editors. Estimating the numbers of terrestrial birds. Studies in Avian Biology 6., Cooper Ornithological Society, Lawrence, Kansas, USA.

Geissler, P. H., and J. R. Sauer. 1990. Topics in route regression analysis. Pages 54–57 *in* J. R. Sauer and S. Droege, editors. Survey designs and statistical methods for the estimation of avian population trends. U.S. Fish and Wildlife Service, Biological Report 90(1), Washington, D.C., USA.

Goudy, W. H. 1960. Factors affecting woodcock spring population indexes in southern Michigan. Thesis, Michigan State University, East Lansing, Michigan, USA.

Kelley, J. R., Jr., and R. D. Rau. 2006. American woodcock population status, 2006. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Kelley, J., S. Williamson, and T. R. Cooper, editors. 2008. American Woodcock Conservation Plan: a summary of and recommendations for conservation in North America. Wildlife Management Institute, Washington, D.C., USA.

Kidd, J. B., and H. T. Harper. 1974. Introduction of the American Woodcock in California. Proceedings of the Fifth Woodcock Workshop, University of Georgia, Athens, Georgia, USA.

Krementz, D. G., and J. G. Bruggink. 2000. Sources of variation in survival and recovery rates of American woodcock. Pages 55–64 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Krementz, D. G., J. E. Hines, and D. R. Luukkonen. 2003. Survival and recovery rates of American woodcock banded in Michigan. Journal of Wildlife Management 67(2): 398–407.

Krohn, W. B., F. W. Martin, and K. P. Burnham. 1974. Band recovery distribution and survival estimates of Maine woodcock. Pages 1–8 *in* Proceedings of the Fifth American Woodcock Workshop, University of Georgia, Athens, Georgia, USA.

Link, W. A., and J. R. Sauer. 1994. Estimating equations estimates of trends. Bird Populations 2: 23–32.

Martin, F. W. 1964. Woodcock age and sex determination from wings. Journal of Wildlife Management 28: 287–293.

Martin, F. W., S. O. Williams III, J. D. Newsom, and L. L. Glasgow. 1969. Analysis of records of Louisiana-banded woodcock. Proceedings of the Third Annual Conference of the Southeastern Association of Game and Fish Commissioners 23: 85–96.

McAuley, D. G., J. R. Longcore, D. A. Clugston, R. B. Allen, A. Weik, S. Williamson, J. Dunn, B. Palmer, K. Evans, W. Staats, G. F. Sepik, and W. Halteman. 2005. Effects of hunting on survival of American woodcock in the Northeast. Journal of Wildlife Management 69(4): 1565–1577.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit, University of Maine, Orono, Maine, USA.

Myatt, N. A. American woodcock fall migration using Central Region band-recovery and Wing-collection Survey data. Journal of Wildlife Management 71(20): 336–344.

Olinde, M. W. 2007. Woodcock banding annual report. Louisiana Department of Wildlife and Fisheries Project #W-55-22, Baton Rouge, Louisiana, USA.

Padding, P. I., M. T. Moore, K. D. Richkus, and E. M. Martin. 2010. Estimating woodcock hunter activity and harvest in the United States. Pages 29–35 *in* C.A. Stewart, and V. R. Frawley, editors. Proceedings of the Tenth American Woodcock Symposium. Michigan Department of Natural Resources and Environment, Lansing, Michigan, USA.

Sauer, J. R., and J. B. Bortner. 1991. Population trends from the American Woodcock Singing-ground Survey, 1970–88. Journal of Wildlife Management 55: 300–312.

Sauer, J. R., W. A. Link, W. L. Kendall, J. R. Kelley, and D. K. Niven. 2008. A hierarchical model for estimating change in American woodcock populations. Journal of Wildlife Management, 72(1): 204–214.

Sepik, G. F. 1994. A woodcock in the hand. Ruffed Grouse Society, Coraopolis, Pennsylvania, USA.

Thogmartin, W. E., J. R. Sauer, and M. G. Knutson. 2007. Modeling and mapping abundance of American woodcock across the midwestern and northeastern United States. Journal of Wildlife Management 71(2): 376–382.

U.S. Fish and Wildlife Service. 1990. American Woodcock Management Plan. U.S. Fish and Wildlife Service. Washington, D.C., USA.

Whitcomb, D. A. 1974. Characteristics of an insular woodcock population. Michigan Department of Natural Resources, Wildlife Division Report 2720. Lansing, Michigan, USA.

Thomas R. Cooper (left) has been a biologist with the U.S. Fish and Wildlife Service, Division of Migratory Bird Management from 2006 to present. Since 2007, he has served as the Eastern Webless Migratory Game Bird Specialist for the Division. He was co-editor of the American Woodcock Conservation Plan and serves as the co-chair of the Woodcock Task Force under the direction of the Association of Fish and Wildlife Agencies' Migratory Shore and Upland Game Bird Working Group. Prior to working for the U.S. Fish and Wildlife Service, he worked as a habitat restoration biologist for the Minnesota Waterfowl Association. He received a B.S. in Biology (1993) from Bloomsburg University of Pennsylvania and an M.S. (1997) and Ph.D. (2005) in Wildlife and Fisheries Sciences from South Dakota State University.

James R. Kelley, Jr. (right) has been a biologist with the U.S. Fish and Wildlife Service, Division of Migratory Bird Management from 1991 to present. During 1991–2000 he served as a staff biologist focusing on waterfowl population dynamics and assessment. He served as the Eastern Webless Migratory Game Bird Specialist for the Division from 2000–2007. During this period he coordinated and was co-editor of the American Woodcock Conservation Plan. In 2007, he assumed duties as the Mississippi Flyway Representative where he serves as a liaison between the Service and the 14 state agencies within the Flyway. He received a B.S. in Wildlife Management from the University of Maine (1983) and an M.S. in Fisheries and Wildlife from the University of Missouri (1986).

10th American Woodcock Symposium
Roscommon, Michigan, USA

BREEDING EURASIAN WOODCOCK SURVEY IN BELARUS

EDWARD MONGIN[1]**,** Institute of Zoology of National Academy of Sciences of Belarus,
Academicheskaya St. 27, 220072 Minsk, Belarus

MARINA DMITRENOK, Institute of Zoology of National Academy of Sciences of Belarus,
Academicheskaya St. 27, 220072 Minsk, Belarus

YURI BOGUTSKI, Berezinsky Biosphere Reserve, Domzeritsi, *Vitebsk Region, Belarus*

NICHOLAS CHERKAS, Belovezhskaya Pushcha National Park, Kamenyuki, *Brest Region, Belarus*

SERGEY SANDAKOV, Belarusian State University, *Minsk, Belarus*

Abstract: In 2005, the Institute of Zoology of the National Academy of Science of Belarus and APB-Birdlife Belarus (NGO Akhova Ptushak Belarusi) undertook a survey of breeding Eurasian woodcock *Scolopax rusticola* to 1) develop the woodcock monitoring program in Belarus, 2) produce a baseline population index for this breeding population of woodcock, and 3) investigate the distribution and abundance of breeding woodcock in relation to woodland habitat characteristics. Our survey method was based on counts of roding males. We performed counts at 60 listening points located in 10 plots (12 x 12 km each). Observers made the counts of roding birds during May and June. Habitat data were collected within 50–100 m from the each observation point. The number of detections varied between 2 and 30 (mean 11.6 ± 6.91 SD). We found that as tree density increased, woodcock abundance declined. Additional surveys are necessary to establish population trends and to further elucidate the factors influencing woodcock abundance. With trend estimates and habitat use information, biologists will be able to better manage Eurasian woodcock in the future.

Proceedings of the American Woodcock Symposium 10: 147–151
Key words: Belarus, breeding, Eurasian woodcock, roding, survey, *Scolopax rusticola*.

While the Eurasian woodcock (*Scolopax rusticola*) is a very popular game bird in Belarus, the species is one of the less studied waders in the country. The Belarusian breeding population of woodcock has been recently estimated at 100,000–120,000 roding males (Nikiforov and Mongin 1998, Thorup 2006). However, the current estimations are based on limited or incomplete information and the trends for changes in woodcock populations are unknown. Traditionally woodcock hunting is more popular in spring than in fall, and there are only limited data concerning the impact of hunting on the species abundance (Sandakov 2004*a*). The growing hunting tourism in Belarus may pose a threat for the species both in spring and fall seasons if proper management and conservation measures are not developed.

In order to improve our knowledge of the current status and trends of the breeding population of Eurasian woodcock in Belarus, we conducted a number of studies during the 2005 breeding season. Our main objectives were to 1) initiate a woodcock monitoring program in Belarus, 2) produce a baseline population index for the breeding woodcock population there, and 3) investigate the distribution and abundance of breeding woodcock in relation to woodland habitat characteristics.

STUDY AREA

The total area of Belarus is 207,600 km^2 and woodlands occupy about 40% of the territory. Conifer and mixed forests (67%) predominate over deciduous forests (33%). We surveyed roding woodcock during the breeding season in Belarus. Surveys were made at 10 plots (12 x 12 km) where woodlands dominated (Figure 1). Two survey plots were located in the National Park of Belovezhskaya Pushcha (52°42’ N, 24°03’ E;

---

[1] E-mail: ed.mongin@mail.com

Figure 1. Plots where Eurasian woodcock were surveyed in 2005. Plots 2–3 and 8–9 were located in Berezinsky Reserve and National Park of Belovezhskaya Pushcha, respectively.

52°35' N 23°54' E), two were in the Berezinsky Reserve (54°50' N, 28°22' E; 54°42' N, 28°16' E), and the others were in non-protected areas.

METHODS

Habitat variables and classification

We classified and recorded several habitat variables, which were previously suggested to influence distribution of woodcock during the breeding season (Hirons and Johnson 1987), namely the type of woodland, the basal area of trees (m^2/ha), and the litter depth (cm). These are important variables in the context of woodcock biology. Litter depth is related to humus and activity of soil invertebrates, which determine amongst other things the abundance of earthworms (Hirons and Johnson 1987, Løfaldli et al. 1992, Duriez et al. 2005). We collected habitat variables in plots within 50–100 m from each observation point. We calculated the basal area of trees in 5 100-m^2 plots and measured the litter depth in 10 1-m^2 plots. To determine the basal area of trees we recorded to the nearest centimeter the diameters of trees at breast height in selected plots, and we calculated a mean basal area of trees in m^2 per ha. We ranked the density of trees as follows: 1) <25 m^2/ha, 2) 26–35 m^2/ha, 3) >35 m^2/ha. We classified woodlands as deciduous, mixed, pine-birchen, or conifer on the basis of the dominant tree species recorded at each site. To avoid problems with too many null proportions in the analysis, we combined deciduous and mixed woodlands into one category. We divided the age of forest into 3 classes: young (<40 years), middle-aged (41–70 years) and mature (>70 years). We measured the litter depth to the nearest 0.5 cm directly at samples dug out. We used three classes of litter depth: 1) < 3cm, 2) 3–5 cm, and 3) >5 cm.

Roding woodcock surveys

We conducted roding woodcock surveys at listening points following the method developed in France (Ferrand 1993). We established listening points in 12 x 12-km survey plots, and we divided each plot into 36 sampling units (2 x 2 km). We sampled 6 random units in each plot. Listening stations were located in the center of sampling units. We allowed observers to move toward an open area (e.g., a clearing or crossing of forest roads) to find a suitable observation point. We conducted surveys between 20 May and 30 June 2005 as the most intensive roding of woodcock takes place during this period (Sandakov 2004*b*). Surveys began approximately 15–30 minutes before sunset and continued for >2 hours. We did not conduct counts of roding males if it was raining hard or if winds exceeded 19 km/hr. For each listening station, an observer recorded all woodcocks seen and heard, as the number of roding males generally correlates well with the number of individuals and hence provides an index of male abundance (Ferrand 1993, Hoodless 2004). We defined 2 classes of abundance according to Ferrand (1993): low-abundance sites had 1–4 detections and high-abundance sites had >4 detections. Occupation rate is the proportion of listening points that were either high- or low-abundance sites.

Statistical analyses

We analyzed the number of woodcock detections per 2-hour period using a generalized linear model (GLM) and ANOVA using STATISTICA 6 (StatSoft Inc. 2001). We investigated the relationship between uncorrected counts and tree density, litter depth, age, and the type of woodland.

RESULTS

We surveyed 60 listening points across 10 plots. Roding woodcocks were detected at all listening points, and the number of contacts varied between 2 and 30 (mean 11.6 ± 6.91 SD). The occupation rates of the high- and low-abundance sites were 0.86 and 0.13 respectively.

We found no relationship between either habitat type, the age of forest or the interaction of these 2 variables and the number of woodcock detected (GLM habitat type $F_{2,51} = 0.78$, $P = 0.464$, age of forest $F_{2,51} = 0.13$, $P = 0.879$, habitat type x age of forest $F_{4,51} = 0.74$, $P = 0.566$, Figure 2). We also did not find any relationship between litter depth and the number of woodcock detected (ANOVA, $F_{2,44} = 0.89$, $P = 0.419$). We found that as tree density increased, the number of woodcock detected decreased (ANOVA, $F_{2,45} = 4.94$, $P = 0.012$, Figure 3).

DISCUSSION

We found that roding woodcocks are present at a higher proportion of survey plots in Belarus (100% in the present study) compared to surveys conducted elsewhere in western European countries. For example, occupation rates in France ranged from 19–28% (Gossmann and Ferrand 2004, Gossmann et al. 2005) and were 43% in the United Kingdom (Hoodless et al. 2006). At the same time occupation rate averaged 85–95% in Russia (Fokin et al. 2004) and 95–100% in Estonia (Elts 2002). The higher proportion of occupied sites in Belarus, Russia and Estonia is likely explained by the higher numbers of breeding woodcock compared to the western European countries (Thorup 2006) and by similar structure of natural forests in the Eastern European countries. Mean numbers of contacts at listening points were similar between western and eastern European countries: 7.3–9.8 in Russia (Fokin et al. 2004), 9.5 in the UK (Hoodless et al. 2006), 9.6–12.6 in western Switzerland (Estoppey 2004), and 15.0–20.1 in Estonia (Elts 2002).

Our preliminary analyses of the differences in various woodland habitats suggest that in Belarus male roding woodcocks occupy conifer as well as mixed and deciduous woods during the breeding season. Our results are only based on male behavior, but we assume that male habitat use reflects the habitat use of females as well (Hirons 1980, Hirons and Johnson 1987). We found no difference in the number of woodcock detections in different habitats, similar to that reported for Britain (Hoodless et al. 2006).

We found a negative relationship between tree density and number of woodcock detections, likely explained by the feeding and breeding behavior of woodcock. Woodcock prefer feeding habitats where trees are less dense and percentage cover of ground vegetation is higher (Hirons and Johnson 1987). Roding males fly over the territories, preferably relatively open habitats (Fokin and Blokhin 1999), where females breed (Hirons 1980, Hirons and Johnson 1987, Lauer et al. 2006). We did not discover a relationship between litter depth and number of woodcock detected. Nevertheless the litter depth is an indicator of humus type. Litter depth was overall thinner in mixed and deciduous woods compared to pine-birchen and conifer woods. A thin litter layer is typical for humus of mulls type and results from an active and abundant soil fauna (Duriez et al. 2005). They found that mull humus soils were preferred by woodcock to moders and mors because mulls are richer in earthworms.

Our use of a 50–100-m sampling circle for habitat measurements was probably too small, and in the future a larger sampling plot should be used. We chose this approach in order to take data comparable to data taken in the UK (Hoodless et al. 2004).

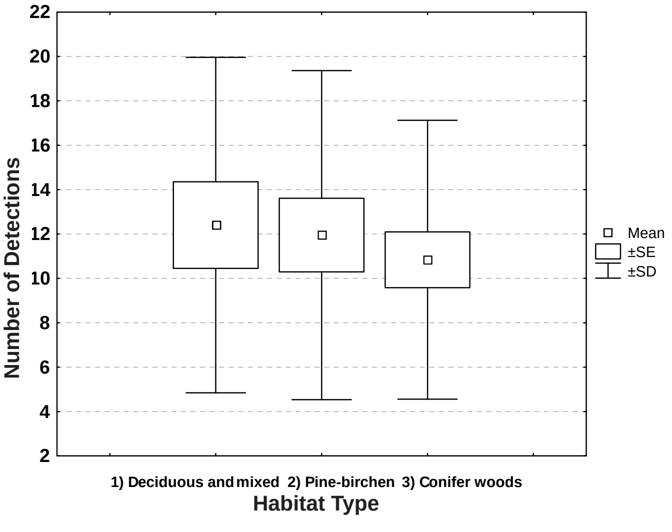


Figure 2. Box plots of roding Eurasian woodcock detected in different forest types in Belarus.

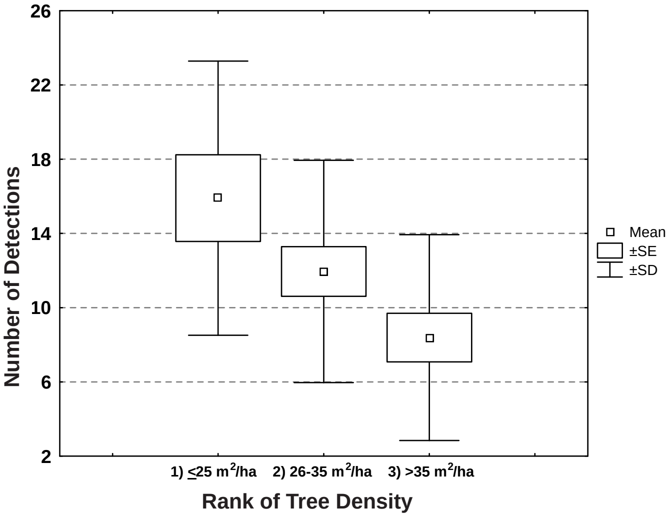


Figure 3. Box plots of roding Eurasian woodcocks detected among forests ranked by tree density in Belarus.

Our study is the first step in establishing the monitoring program for woodcock in the territory of Belarus. Similar studies have been carried on for >10 years in other European countries such as France, Russia, Estonia, Switzerland, and the UK. A common procedure should lead to better estimates of population trends and species abundance in Europe. Annual monitoring of the Eurasian woodcock should provide the hunting managers and Natural Resources Conservancy agencies with important information to maintain the population of the species at such a level that will guarantee sustainable use of woodcock. Comparison of the data on Eurasian and American woodcock (*S. minor*) should help to understand and prevent the long-term population declines of the species on both continents. In Belarus, further work is needed to establish population trends and to determine the factors influencing the species abundance in order to establish a sustainable national management policy.

ACKNOWLEDGMENTS

The study was performed by the Institute of Zoology of the National Academy of Belarus and the APB-Birdlife Belarus (NGO Akhova Ptushak Belarusi) with financial support of the ONCFS (Office National de la Chasse et de la Faune Sauvage, France). We are very grateful to O. Ostrovsky, A. Kisleyko and all the volunteers who participated in the survey. We also thank A. Kashtalian and A. Davydzionak who facilitated the work. We thank 2 anonymous reviewers for reviewing an early version of our manuscript.

LITERATURE CITED

Duriez, O., Y. Ferrand, F. Binet, E. Corda, F. Gossmann, and H. Fritz. 2005. Habitat selection of the Eurasian woodcock in winter in relation to earthworms availability. Biological Conservation 122: 479–490.

Elts, J. 2002. Monitoring of roding woodcock in Estonia. Woodcock and Snipe Specialist Group Newsletter 28: 13–16.

Estoppey, F. 2004. 2003 Western Switzerland woodcock Report. Woodcock and Snipe Specialist Group Newsletter 30: 30–33.

Gossmann, F., and Y. Ferrand. 2004. 2003–2004 French woodcock report. Woodcock and Snipe Specialist Group Newsletter 30: 36–39.

Gossmann, F., C. Bastat, M. Guenezan, and Y. Ferrand. 2005. 2004–2005 French woodcock report. Woodcock and Snipe Specialist Group Newsletter 31: 21–22.

Ferrand, Y. 1993. A census method for roding Eurasian woodcock in France. Pages 19–25 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Fokin, S., and Y. Blokhin. 1999. Roding activity, spring hunting and hunting bags of woodcock (*Scolopax rusticola*) in Russia. Fifth European Woodcock and Snipe Workshop – Proceedings of an International Symposium of the Wetlands International Woodcock and Snipe Specialist Group 3–5 May 1998, International Wader Studies 11: 19–24.

Fokin, S., Y. Blokhin, P. Zverev, M. Kozlova, and Y. Romanov. 2004. Spring migration of the woodcock, *Scolopax rusticola*, and roding in Russia in 2004. Woodcock and Snipe Specialist Group Newsletter 30: 4–8.

Hirons, G. 1980. The significance of roding by woodcock *Scolopax rusticola*: an alternative explanation based on observation of marked birds. Ibis 122: 350–354.

Hirons, G., and T. H. Johnson. 1987. A quantitative analysis of habitat preferences of woodcock, *Scolopax rusticola*, in the breeding season. Ibis 129: 371–381.

Hoodless, A. 2004. Woodcock—developing calibrations for the survey. Game Conservancy Trust Review of 2003: 76–77.

Hoodless, A., N. Aebischer, D. Lang, and R. Fuller. 2004. The 2003 breeding woodcock survey in Britain. Woodcock and Snipe Specialist Group Newsletter 30: 40–42.

Hoodless, A., D. Lang, R. J. Fuller, N. Aebischer, and J. Ewald. 2006. Development of a survey method for breeding woodcock and its application to assessing the status of the British population. Proceedings of Sixth European Woodcock and Snipe Workshop, International Wader Studies 13: 48–54.

Lauer, E., P. Sibut, B. Duterte, S. Colinon, Y. Ferrand, and C. Duchamp. 2006. Identification test of suitable woodcock breeding habitats in mountain areas. Proceedings of Sixth European Woodcock and Snipe Workshop, International Wader Studies 13: 66–70.

Løfaldli, L., J. A. Kålås, and P. Fiske. 1992. Habitat selection and diet of great snipe Gallinago media during breeding. Ibis 134: 35–43.

Nikiforov, M. E., and E. A. Mongin. 1998. Breeding waders of Belarus: number estimates and recent population trends. Pages 93–96 in P. S. Tomkovich and E. A. Lebedeva, editors. Breeding waders in Eastern Europe—2000. Russian Bird Conservation Union, Moscow. Vol. 1. [In Russian.]

Sandakov, S. 2004*a*. Hunting bags of woodcock, *Scolopax rusticola*, in Belarus: one year monitoring results. Woodcock and Snipe Specialist Group Newsletter 30: 21–22.

Sandakov, S. 2004*b*. Some results of roding woodcock, *Scolopax rusticola*, monitoring in Belarus. Woodcock and Snipe Specialist Group Newsletter 30: 19–20.

StatSoft Inc. 2001. STATISTICA 6. StatSoft Inc., Tulsa, Oklahoma, USA.

Thorup, O., compiler. 2006. Breeding waders in Europe 2000. International Wader Studies 14.

Edward Mongin received a B.S. in Zoology from the Belarusian State University in 1991 and a Ph.D. in Zoology from the Institute of Zoology of National Academy of Sciences in 2004. Edward served as a staff scientist and a senior researcher for the Institute of Zoology NAS from 1991-2009, during which time he studied waders, grey partridge, quail and corncrake and worked on migratory bird issues. He worked as a field ecologist for Emirates Center for Wildlife Propagation where he studied the houbara bustard in 2009 and 2010 on the territories of Kazakhstan and Uzbekistan. Edward is currently an environmental expert and the project supervisor on the woodcock studies for the APB-Birdlife Belarus, a position he has held since 2006.

Yuri Bogutski received a B.S. in Zoology from the Belarusian State University in 1996. He is currently a senior researcher of Berezinsky Biosphere Reserve where Yuri conducts population estimation of birds included in National Red Data Book, researches on capercaillie and birds of floodplain habitats.

Marina Dmitrenok is a staff scientist for the Institute of Zoology NAS. She received a B.S. in Zoology from the Belarusian State University in 1994. Marina has conducted researches on great bittern and raptor birds, and works on bird conservation projects.

Nicholas Cherkas received a B.S. in Zoology from the Belarusian State University in 1989. Nicholas served as a graduate research assistant for the Institute of Zoology NAS from 1988–1992. He worked after as a staff scientist for the Belovezhskaya Pushcha National Park where he has conducted researches on raptor and grouse birds in 1992–2009. Nicholas received a Ph.D. in Zoology from the Institute of Zoology in 2009. He is currently a scientific consultant for the educational project of UNDP.

Sergey Sandakov received a B.S. and a M.S. in Zoology from the Belarusian State University. For several years Sergey worked as a teacher in the University and conducted science researches. His sphere of interests is ornithology especially biology of Eurasian woodcock. He is currently preparing his materials for Ph.D. in Zoology.

AMERICAN WOODCOCK SINGING-GROUND SURVEYS: SHOULD THEY BE EXPANDED?

10th American Woodcock Symposium
Roscommon, Michigan, USA

R. MONTAGUE WHITING, JR.[1]**,** Arthur Temple College of Forestry and Agriculture,
Stephen F. Austin State University, Nacogdoches, Texas 75962

Abstract: Standardized Singing-ground Surveys have been conducted in the northern United States and southern Canada to detect trends in American woodcock (*Scolopax minor*) populations since 1968. Surveys have not been conducted in southern and some midwestern states in which woodcock are known to breed because the survey protocol was purposely designed to minimize counts of migrating males. Singing-ground Survey dates were thus established to occur after migrating males departed the survey areas. However, the frequency of singing males by survey date over a breeding season, regardless of geographic location, often takes the form of a bell-shaped curve, with the maximum number of singing males presumably corresponding to the presence of migrants. Examination of courting male counts from southern states shows bell-shaped curves similar to those from traditional Singing-ground Survey areas. This suggests that some of the males recorded during traditional surveys are migratory. The only curves that showed the desired right-skewed patterns, which would be the expected patterns if counts took place after migrants had passed through and before courtship waned, are from the northern portion of the woodcock breeding range in Quebec. Additionally, the highest counts of courting males per route tend to occur in the northern portions of the survey area. These findings suggest that existing surveys in southern portions of the survey area are recording some migrating males. Data also suggests that nesting in the South and Midwest contributes to the continental woodcock population. I contend that current Singing-ground Surveys are potentially missing an important segment of the woodcock population and may not reflect continental population trends. Hence, surveys should be expanded into southern and midwestern portions of the breeding range not currently included in the survey.

Proceedings of the American Woodcock Symposium 10: 153–159
Key words: American woodcock, population estimates, *Scolopax minor*, Singing-ground Surveys.

The American woodcock (*Scolopax minor*) is a popular migratory game bird hunted throughout much of eastern North America. In the United States, the species is managed as separate populations in 2 regions. The Eastern Region corresponds to the Atlantic Flyway for waterfowl and generally is east of the Appalachian Mountains. The Central Region is west of the Appalachians and includes all of the Mississippi Flyway and eastern portions of the Central Flyway (United States Fish and Wildlife Service [USFWS] 1990).

Population trends are monitored primarily through the Singing-ground Survey, with inferences also drawn from analysis of the parts collection survey data. The Singing-ground Survey, initiated in 1968, was developed to take advantage of the male woodcock's conspicuous courtship display at dusk. Standardized 5.4-km routes are located along secondary roads in randomly selected 10-minute blocks in central and northern portions of the species breeding range. Detailed methodology is provided by Tautin et al. (1983).

Singing-ground Surveys are conducted in 6 Canadian providences and 19 states. The southernmost states surveyed are Virginia in the Eastern Region and Ohio, Indiana, and Illinois in the Central Region; Minnesota is the only state west of the Mississippi River. Singing-ground Surveys are not conducted in many southern and midwestern states with documented woodcock nesting (Causey et al. 1974, Barclay and Smith 1977, Stamps and Doerr 1977, Roberts and Dimmick 1978, Whiting and Boggus 1982, Murphy and Thompson 1993).

Woodcock are the only polygynous migratory game bird that is surveyed using counts of courting males. Dominant males actively defend their courtship sites from other males, and there are few data that quantify the number of non-courting males that may be on such sites (Keppie and Whiting 1994). Likewise, there are no data to estimate the number of breeding females per courting male (Owen et al. 1977) or changes in these ratios over time and geographic region; however, Gregg

---

[1] Email: mwhiting@sfasu.edu

(1984) concluded a close relationship between courting males and nesting females in Wisconsin. At least one study found no correlation between singing males and actual population densities (Dwyer et al. 1988), whereas another study did (Whitcomb and Bourgeois 1974). As a result, accuracy of the Singing-ground Survey has been questioned and researchers have encouraged a more rigorous design (Owen et al. 1977, Sauer and Bortner 1991). Also, the Singing-ground Survey currently emphasizes the central portion of the breeding range. My data and observations suggest that an expansion of the survey to include the southern and western portions of woodcock breeding range, coupled with a critical evaluation of survey timing, may result in a survey design that provides more accurate population estimates. I contend that surveying the entire breeding range is important when monitoring polygynous, migratory species that are subject to potentially extreme weather events throughout that range.

COUNTING MIGRATING MALES

Singing-ground Surveys conducted in the South and southern Midwest would record migrating males, and it is likely that some males would be recounted when they reached the traditional survey area. The original survey was designed to minimize counting of migrating males. However, for a variety of potential reasons, the current survey is likely counting such males. In the current survey area, courting male woodcock are counted during 5 overlapping 21-day periods beginning 10 April in the southernmost areas and ending 20 May in the northernmost areas (Tautin et al. 1983). The dates are assigned by latitude. Although in theory the dates were selected such that the majority of migrating males have passed through, documentation on the scientific basis for how the dates were selected is lacking.

When woodcock Singing-ground Surveys were originally standardized across the assumed breeding range, the survey design was based on work in central-southern Michigan (Goudy 1960, Duke 1966) and in Massachusetts (Sheldon 1953). Using data from surveys that started in late March or early April and extended through May, Goudy (1960: 16) selected his "central period" such that it would "include the 30-day period of courtship activity with the most consistent series of counts." However, his 3 years of data showed no discernable pattern, and the numbers of birds per stop during the central periods varied widely. Duke (1966: 699) conducted counts for 2 springs; for his "stable period," the starting date was based on the cessation of territorial behavior and when "courtship activity seemed to become fairly regular." Four of the 5 counts were initiated within a week after the first courting male was heard; snow delayed the start of Duke's (1966) fifth count by a week. However, data from neither study suggest a period of high courtship activity resulting from migrants passing through. As a result, it is likely that both Goudy (1960) and Duke (1966) included migrating males in their counts. For the standardized surveys, Goudy (1960) recommended 20 April–10 May and Duke (1966) suggested 15 April–15 May.

Courtship flights in the Gulf Coastal Plain begin as early as November in warm winters (Roboski and Causey 1981). Testes recrudescence in adult males begins in early December; in subadults, enlargement begins about 2 weeks later (Stamps and Doerr 1977, Whiting and Boggus 1982, Rushing and Doerr 1984). Males begin establishing territories and performing regular courtship flights in late December and early January (Whiting and Boggus 1982, Causey et al. 1987, Tappe et al. 1989). Some males reach sexual maturity by late December and virtually all are mature by late January or early February (Stamps and Doerr 1977, Roberts 1980, Whiting and Boggus 1982, Rushing and Doerr 1984, Mason 1986).

In Oklahoma (Barclay and Smith 1977) and eastern Texas (Whiting and Boggus 1982, Tappe et al. 1989), numbers of courting males plotted against date produced bell-shaped curves with peaks in mid-February; in each study, the number of courting males rapidly declined after the peak and there were few or no actively courting males by the second week of March. In Tennessee and Missouri, numbers of courting males peaked about 10 March (Roberts and Dimmick 1978), and 17 March (Murphy and Thompson 1993), and after these dates, declines paralleled those observed in Texas and Oklahoma. The rapid declines in courtship activities after the peaks suggest that migrating males were included in the survey results. Conversely, in North Carolina, the number of courtship flights peaked in mid-March, rapidly declined initially, then slowly declined through April and into May; duration of the flights was longer in April and May than in March (Rushing and Doerr 1984). These results suggest that birds recorded in April and May were residents. Similarily, in Quebec, numbers of males on courtship sites demonstrated a bell-shaped curve which peaked in late April, declined rapidly until early May, then remained stable for the last 3 weeks of the month (Couture and Bourgeois 1977). The authors attributed the drop in density in early May to "… the end of the migrants passage."

These studies indicate that the numbers of surveyed courting males tend to show a bell-shaped curve that moves northward in an orderly manner as spring progresses. (Murphy and Thompson 1993). As the birds move north, the curve should flatten as males reach their areas of residence and thus drop out of the migrating population. To meet protocol, timing of surveys should occur after the migration peak has passed. As currently conducted, some Singing-ground Surveys probably are counting migrating males (Whitcomb and Bourgeois 1974, Dwyer et al. 1988). The magnitude of including migrating males in continental-wide population estimates has not been quantified and warrants further evaluation.

BREEDING AND NESTING OUTSIDE OF THE SURVEY AREA

In the last 40 years, numerous studies have documented widespread nesting by woodcock south of the Singing-ground Survey area. The first set of studies was by Causey and his students in Alabama (Causey et al. 1974). It is likely that those researchers were the first to purposely seek, capture, and band woodcock chicks in the southern United States. During 15 years, that group banded 360 chicks and 30 nesting/brooding hens. Their results in locating nests and broods between 1974 and 1980 were similar to early efforts by biologists on the northern breeding grounds (Causey 1981).

Researchers also have recorded woodcock nests and chicks in North Carolina (Stamps and Doerr 1977, Rushing and Doerr 1984), Tennessee (Roberts and Dimmick 1978), Kentucky (T. Edwards, Kentucky Department of Fish and Wildlife Resources, personal communication), Oklahoma (Barclay and Smith 1977), Texas (Whiting and Boggus 1982), and Missouri (Murphy and Thompson 1993). Conversely, a study in South Carolina (Pace and Wood 1979) and 2 studies in Louisiana (Olinde and Prickett 1991, Olinde 2000) showed little evidence of nesting.

Woodcock undoubtedly breed and produce young in the southern and central portions of their range. Using 6 years of data from 5 southern states, with most data from Alabama, Tennessee, and Texas, Whiting et al. (1985) found that 60 of 170 (35%) adult woodcock hens had ovaries in the rapid eruption stage during February, indicating that egg laying would occur within 9 days (Stamps and Doerr 1977, Whiting and Boggus 1982). Based on limited sample sizes, the proportions of females in breeding condition generally north of these states but south of the survey area, range 8 to 67% (Stamps and Doerr 1977, Pace and Wood 1979). In Missouri, Murphy and Thompson (1993) recorded 30 nests and 10 broods, and estimated that all clutches were initiated in March. The significance of southern and midwestern breeding activity to the continental woodcock population is unknown and warrants further investigation. If these areas are responsible for significant recruitment to the continental population, expanding the current survey routes into these regions is warranted.

FACTORS AFFECTING WOODCOCK NESTING IN THE SOUTH

Historically, woodcock may not have bred and nested north of the glacier line (*ca* latitude 40° N). All earthworm species north of that line are of European origin (Gates 1970, Reynolds 1977, Hendrix and Bohlen 2002) and may not have been present prior to colonization by Europeans. In the South, the earliest records of woodcock breeding and nesting activities can be traced to bulletins of state ornithological organizations and other state-oriented publications (e.g., Oberholser 1938, Imhoff 1962, Pitts 1978), some dating to the early 1900s. In the 1950s, Reid and Goodrum (1954) documented woodcock nests and chicks on cutover pine lands in west-central Louisiana. However, it was not until the Fifth Woodcock Symposium in 1974 that southern nesting was brought to the attention of woodcock researchers and biologists. Prior to that, nesting research had been concentrated in the northern states and Canada, and most of the limited southern research focused on wintering habitat, primarily in the Atchafalaya Basin of Louisiana.

The amount and distribution of nesting habitat in the South has changed since the original woodcock surveys were designed in the late 1950s and early 1960s. During the 1950s, forest industry purchased large quantities of retired farm land (Fickle 2004). For most companies, even-aged forest management using the clearcut regeneration system was standard procedure by the late 1960s. A widely used technique to prepare the sites for planting of pine seedlings was to shear residual vegetation (Fox et al. 2007). Shearing resulted in vigorous hardwood sprouts which produced abundant leaves, thus food for earthworms. Until canopy closure when the planted pines were 8 to 12 years old, such plantations provided excellent woodcock habitat if the soil supported earthworms and its texture and structure allowed probing. Woodcock used the young plantations for diurnal cover (Boggus and Whiting 1982), feeding (Gregory and Whiting 2000), courting (Tappe and Whiting 1989, Murphy and Thompson 1993), nesting, and brood rearing (Whiting and Boggus 1982).

Widespread use of the clearcut regeneration system in the South began about the same time as the standardized Singing-ground Surveys (Fox et al. 2007). As clearcutting use in the South expanded and quality of woodcock habitat on the northern breeding grounds declined (Owen et al. 1977), results from Singing-ground Surveys in the Eastern and Central regions showed decreasing population trends. It is possible that as breeding activity decreased in the North, it increased in the South.

Woody plant invasion also may have resulted in increased woodcock breeding activity in the South and Midwest. Historically, the southern and western peripheries of the woodcock's range were grasslands which were maintained by fire. Fire control has been a factor that allowed woody plants to invade the grasslands and produce habitat in which woodcock breed. In Texas, woodcock nests or chicks have been recorded in a Chinese tallow (*Sapium sebiferum*) thicket (Robinson and Aumann 1997) and a mixed-species shrubland (Cain et al. 1977), both in the Gulf Prairies and Marshes Ecological Region (Gould 1962), and in a pecan (*Carya illinoinensis*) bottomland in the city limits of Austin (Mosier and Martin 1980), which is in the Edwards Plateau Region (Gould 1962). All three areas were historically grasslands or surrounded by grasslands prior to fire exclusion (Gould 1962). These southern nesting records coincide with nesting records from the western periphery as detailed by Smith and Barclay (1978) and supported by Lingle (1981) and Sargeant and Sargeant (2001).

CONCLUSIONS AND RECOMMENDATIONS

Abundance indices as derived from Singing-ground Surveys suggest that woodcock populations in the Eastern and Central regions have declined in the last 37 years. However, I hypothesize the declines are not as drastic as indicated by the Singing-ground Survey results because southern and midwestern recruitment to the continental population is ignored. Habitat conditions throughout the traditional Singing-ground Survey area have deteriorated, primarily because of forest succession (Straw et al. 1994). As a result, courtship, breeding, and nesting may have increased in the South and Midwest, and spring-migrating woodcock seeking appropriate breeding habitat may have dispersed further north (Marshall 1982, Keppie et al. 1984) and/or west of the current survey area. If so, the current surveys do not reflect population trends. Surveys conducted throughout the known breeding range of the species would help address these possibilities and provide a multitude of other benefits.

Throughout its range, the intensity and timing of woodcock courtship activity (Dwyer et al. 1988, Tappe et al. 1989) and nesting (Causey 1981, Dwyer et al. 1988, Vander Haegen et al. 1993) vary among years. If habitat and climatic conditions are appropriate in the Deep South, males court intensively and nesting may be extensive. If not, courtship is subdued and there is little or no nesting. In Alabama, Causey et al. (1987) found that January temperature was positively related to nesting activity. However, Whiting et al. (2006) were unable to confirm that relationship. Other authors have hypothesized that nesting in the South is related to winter precipitation (Davis 1961, Cain, et al. 1977, Robinson and Aumann 1997). The relationship of climatic conditions to woodcock courting and breeding in the South is probably more complicated than just temperature or precipitation. Data from southern Singing-ground Surveys could be used to investigate that relationship and the relationship between courtship intensity in the South and in the current survey area. Likewise, surveys on the western periphery of the species range would aid in determining if woodcock are taking advantage of favorable weather conditions, expanding their breeding range because of improved habitat, or both.

There are numerous other questions regarding woodcock breeding and nesting in the South that need to be addressed. As others have noted (Causey et al. 1987, Keppie and Whiting 1994), the contribution of southern-nesting woodcock to the continental population is unknown. Likewise, it is unknown whether a bird hatched in February would be aged as an adult or subadult if it was bagged the following January and its wing submitted to the Wing-collection Survey. The possibility that female woodcock which nest in the South during winter may nest again in the North during spring or summer also has been raised (Causey et al. 1987).

In addition, dates when the onset of testes enlargement/recrudescence and attainment of sexual maturity occur in males on the wintering grounds are well documented. However, there are no publications that address when testes return to the quiescent stage. Such information would aid in clarifying the issue of whether males counted in southern portions of the Singing-ground Survey area are residents. If so, their testes should return to the quiescent stage earlier in the year than those counted in the northern portions of the survey area. Researchers collecting males on the northern breeding grounds should gather such data. Mason (1986) used serum testosterone concentrations to estimate gonadal maturity in male woodcock. It may be possible to expand on his techniques such that sacrificing males would not be necessary.

Clearly, southern reproduction is occurring and potentially having a significant effect on the continental woodcock population. However, data on the magnitude and consistency of this effect, in addition to a complete understanding of the geographic distribution of breeding activities, are lacking. I contend that the USFWS should consider incorporating southern and additional midwestern portions of the woodcock range into the annual singing survey. Some data are available that can guide the expansion of the current survey. Using USFWS standardized Singing-ground Survey procedures, Texas Parks and Wildlife Department conducted surveys in the Piney Woods and Post Oak Savannah regions of eastern

Texas for 5 years (George 1992). Some of these routes probably could be re-established. The routes in Oklahoma (Barclay and Smith 1977) probably could not be re-established, but standardized routes could be positioned in the same counties in which they took place. Surveys of courting males in North Carolina (Rushing and Doerr 1984) and Missouri (Murphy and Thompson 1993) appear to have been conducted differently than standardized Singing-ground Surveys, but still may serve as starting points. Regardless, if southern and midwestern surveys are not initiated, many of the questions and survey assumptions I review in this manuscript will remain unanswered and unsubstantiated because there will still be a lack of long-term data.

ACKNOWLEDGMENTS

J. G. Bruggink, C. E. Comer, W. C. Conway, D. R. Dessecker, D. A. Haukos, J. R. Kelley, M. W. Olinde, T. H. Roberts, and L. M. Smith reviewed early drafts of this manuscript; review and editing of latter drafts by G. J. Roloff is sincerely appreciated. Manuscript preparation was provided by C. R. Linebarger, S. E. Richardson, J. L. Flynn, and S. M. Leeper of the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University.

LITERATURE CITED

Barclay, J. S., and R. W. Smith. 1977. The status and distribution of woodcock in Oklahoma. Pages 39–50 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada.

Boggus, T. G., and R. M. Whiting, Jr., 1982. Effects of habitat variables on foraging of American woodcock wintering in East Texas. Pages 148–153 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Woodcock ecology and management. U.S. Fish and Wildlife Service Wildlife Research Report 14.

Cain, B. W., R. J. Whyte, and P. Micks. 1977. Southern nesting record of the American Woodcock. Bulletin of the Texas Ornithological Society 11: 46.

Causey, M. K. 1981. Alabama woodcock investigations. Final Report, P-R Project W-44-5, Study II. Alabama Department of Conservation and Natural Resources, Montgomery, Alabama, USA.

Causey, M. K., M. K. Hudson, and T. P. Mack. 1987. Breeding activity of American woodcock in Alabama as related to temperature. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 41: 373–377.

Causey, M. K., J. C. Roboski, and G. I. Horton. 1974. Nesting activities of the American woodcock (*Philohela minor* Gmelin) in Alabama. Proceedings of the Fifth Woodcock Workshop. University of Georgia, Athens, Georgia, USA.

Couture, R., and J-C. Bourgeois. 1977. American woodcock density variations during the breeding season in central Quebec. Pages 93–99 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada.

Davis, W. B. 1961. Woodcock nesting in Brazos County, Texas. Auk 78: 272–273.

Duke, G. E. 1966. Reliability of censuses of singing male woodcocks. Journal of Wildlife Management 30: 697–707.

Dwyer, T. J., G. F. Sepik, E. L. Derleth, and D. G. McAuley. 1988. Demographic characteristics of a Maine woodcock population and effects of habitat management. U.S. Fish and Wildlife Research 4, U.S. Fish and Wildlife Service, Washington, D.C., USA.

Fickle, J. E. 2004. Into the future. Pages 84–88 *in* A. P. McDonald, compiler. Arthur Temple College of Forestry: the story of forestry at SFA. Stephen F. Austin College of Forestry, Nacogdoches, Texas, USA.

Fox, T. R., E. J. Jokela, and H. L. Allen. 2007. The development of pine plantation silviculture in the southern United States. Journal of Forestry 105: 337–347.

Gates, G. E. 1970. Miscellanea megadrilogica VII. Megadrilogica 1: 1–14.

George, R. R. 1992. Woodcock density, distribution, movement, and harvest. Federal Aid Project Number W-128-R-1, Job Number 8. Texas Parks and Wildlife Department, Austin, Texas, USA.

Gregg, L. 1984. Population ecology of woodcock in Wisconsin. Wisconsin Department of Natural Resources Technical Bulletin 144, Madison, Wisconsin, USA.

Gregory, J. F., and R. M. Whiting, Jr. 2000. Food habits and preferences of American woodcock in East Texas pine plantations. Pages 23–35 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel Maryland, USA.

Goudy, W. H. 1960. Factors affecting woodcock spring population indexes in southern Michigan. Thesis, Michigan State University, East Lansing, Michigan, USA.

Gould, F. W. 1962. Texas plants—a checklist and ecological summary. Texas Agricultural Experiment Station, College Station, Texas, USA.

Hendrix, P. F., and P. J. Bohlen. 2002. Exotic earthworm invasions in North America: ecological and policy implications. BioScience 52: 801–811.

Imhoff, T. A. 1962. Alabama birds. University of Alabama Press, Tuscaloosa, Alabama, USA.

Keppie, D. M., W. R. Watt, and G. W. Redmond. 1984. Male woodcock in coniferous forests: implications for route allocations in surveys. Wildlife Society Bulletin 12: 174–178.

Keppie, D. M., and R. M. Whiting, Jr. 1994. American woodcock (*Scolopax minor*). In A. Poole and F. Gill, editors. The Birds of North America, Number 100. Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.

Lingle, G. R. 1981. Status of American woodcock in Nebraska with notes on a recent breeding record. The Prairie Naturalist 13: 47–51.

Marshall, W. H. 1982. Minnesota woodcock. Loon 54: 203–211.

Mason, P. J. 1986. Testicular morphology, serum testosterone concentration, courtship behavior, and the relationship to photosensitivity in American woodcock (*scolopax minor*). Dissertation, Auburn University, Auburn, Alabama, USA.

Mosier, D. T., and R. F. Martin, 1980. Central Texas breeding of the American woodcock. Texas Journal of Science 32: 94.

Murphy, D. W., and F. R. Thompson. 1993. Breeding chronology and habitat of the American woodcock in Missouri. Pages 12–18 *in* J. R. Longcore and G. F. Sepik, editors. Proceeding of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16, Washington, D.C., USA.

Oberholser, H. C. 1938. The bird life of Louisiana. Bulletin 28, Louisiana Department of Conservation, Baton Rouge, Louisiana, USA.

Olinde, M. W. 2000. Gonadal condition of American woodcock harvested in Louisiana during the 1986–1988 hunting seasons. Pages 84–89 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Olinde, M. W., and T. E. Prickett. 1991. Gonadal characteristics of February-harvested woodcock in Louisiana. Wildlife Society Bulletin 19: 465–469.

Owen, R. B., Jr., J. M. Anderson, J. W. Artmann, E. R. Clark, T. G. Dilworth, L. E. Gregg, F. W. Martin, J. D. Newsom, S. R. Pursglove, Jr. 1977. American woodcock (*Philohela minor* = *Scolopax minor* of Edwards 1974). Pages 149–186 *in* G. C. Sanderson, editor. Management of migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Pace, R. M., III, and G. W. Wood. 1979. Observations of woodcock wintering in coastal South Carolina. Proceedings of the Annual Conference of the Southeastern Association of Game and Fish Commissioners 33: 72–80.

Pitts, T. D. 1978. Status of the American woodcock in Tennessee. The Migrant 49: 31–35.

Reid, V. H., and P. Goodrum. 1954. Observations of woodcock breeding in certain southeastern states. Pages 17–18 *in* J. W. Aldrich, compiler. Investigations of woodcock, snipe, and rails in 1953. U.S. Fish and Wildlife Service and Canadian Wildlife Service Special Scientific Report – Wildlife 24.

Reynolds, J. W. 1977. Earthworms utilized by the American woodcock. Pages 161–169 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada.

Roberts, T. H. 1980. Sexual development during winter in male American woodcock. Auk 97: 879–881.

Roberts, T. H., and R. W. Dimmick. 1978. Distribution and breeding chronology of woodcock in Tennessee. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 32: 8–16.

Robinson, J. A., and G. Aumann. 1997. An American woodcock nest in Galveston County, Texas. Bulletin of the Texas Ornithological Society 30: 20–23.

Roboski, J. C., and M. K. Causey. 1981. Incidence, habitat use, and chonology of woodcock in Alabama. Journal of Wildlife Management 45: 793–797.

Rushing, E. L., and P. D. Doerr. 1984. Breeding biology of the American woodcock in Piedmont North Carolina. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 38: 142–152.

Sargeant, F. Y., and G. A. Sargeant. 2001. Evidence of American woodcock nesting in southeastern North Dakota. The Prairie Naturalist 33: 45–46.

Sauer, J. R., and J. B. Bortner. 1991. Population trends from the American woodcock Singing-ground Survey, 1970–88. Journal of Wildlife Management 55: 300–312.

Sheldon, W. G. 1953. Woodcock studies in Massachusetts. Transactions of the North American Wildlife Conference 18: 369–377.

Smith, R. W., and J. S. Barclay. 1978. Evidence of westward changes in the range of the American woodcock. American Birds 32: 1122–1127.

Stamps, R. T., and P. D. Doerr. 1977. Reproductive maturation and breeding chronology of woodcock in North Carolina. Pages 185–190 *in* D. M. Keppie and R. B. Owen, Jr., editors. Proceedings of the Sixth Woodcock Symposium. New Brunswick Department of Natural Resources, Fredericton, New Brunswick, Canada.

Straw, J. A., Jr., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Tappe, P. A., and R. M. Whiting, Jr. 1989. Correlation of woodcock counts with habitat types in eastern Texas. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 43: 346–349.

Tappe, P. A., R. M. Whiting, Jr., and R. R. George. 1989. Singing-ground Surveys for woodcock in east Texas. Wildlife Society Bulletin 17: 36–40.

Tautin, J., P. H. Geissler, R. E. Munro, and R. S. Pospahala. 1983. Monitoring the population status of American woodcock. Transactions of the North American Wildlife and Natural Resources Conference 48: 376–388.

United States Fish and Wildlife Service. 1990. American woodcock management plan. U.S. Fish and Wildlife Service, Washington, D.C., USA.

Vander Haegen, W. M., W. B. Krohn, and R. B. Owen, Jr. 1993. Effect of weather on earthworm abundance and foods of the American woodcock in spring. Pages 26–31 *in* J. R. Longcore and G. F. Sepik, editors. Proceeding of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16, Washington, D.C., USA.

Whitcomb, D.A., and A. Bourgeois. 1974. Studies of singing male surveys on High Island, Michigan. Proceedings of the Fifth Woodcock Workshop. University of Georgia, Athens, Georgia, USA.

Whiting, R. M., Jr., and T. G. Boggus. 1982. Breeding biology of American woodcock in east Texas. Pages 132–138 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Woodcock ecology and management. U.S. Fish and Wildlife Service Wildlife Research Report 14. Washington, D.C., USA.

Whiting, R. M., Jr., R. R. George, M. K. Causey, and T. H. Roberts. 1985. February hunting of American woodcock: breeding implications. Pages 309–317 *in* S. L. Beasom and S. F. Roberson, editors. Game harvest management. Caesar Kleberg Wildlife Research Institute, Kingsville, Texas, USA.

Whiting, R. M., Jr., D. A. Haukos, and L. M. Smith. 2006. Factors affecting January reproduction of American woodcock in Texas. Southeastern Naturalist 4: 639–646.

R. Montague Whiting, Jr. is Professor Emeritus in the Arthur Temple College of Forestry and Agriculture at Stephen F. Austin State University (SFASU) in Nacogdoches, Texas. He joined the faculty of SFASU in 1972 and completed the Ph.D. on the Texas A&M–SFASU joint program in 1978. During his academic career, he taught several forestry and numerous wildlife courses. Most of his research involved game and nongame birds, especially northern bobwhite and American woodcock. Currently, he is enjoying retirement and hunting birds as often and in as many places as possible with the objective of bagging at least one of every game bird in the continental United States.

THE MICHIGAN WOODCOCK BANDING PROGRAM

10th American Woodcock Symposium
Roscommon, Michigan, USA

C. ALAN STEWART[1], Michigan Department of Natural Resources,
PO Box 30444, Lansing, MI 48909-7944, USA

VALERIE R. FRAWLEY, Michigan Department of Natural Resources,
PO Box 30444, Lansing, MI 48909-7944, USA

Abstract: Banding of American woodcock (*Scolopax minor*) is an effective technique to monitor woodcock migration, distribution, and other aspects of woodcock life history. In the 1930s, researchers in the United States began using pointing bird dogs to locate woodcock broods for banding. Since the 1960s, the Michigan Department of Natural Resources and Environment (DNR) implemented a spring woodcock-banding program involving volunteers and the use of pointing dogs. This program has improved in recent years through mandatory bander training sessions. Using trained volunteer banders, woodcock banding programs can be improved and expanded into broader geographic areas without encumbering government agencies. This model can be adopted in other states and regions to increase the scope and distribution of banding programs. Currently, the DNR program enlists approximately 100 volunteer banders who annually spend about 1,600 hours in search of woodcock and band approximately 1,000 chicks each year.

Proceedings of the American Woodcock Symposium 10: 161–167

Key words: American woodcock, banding, Michigan, bander training, *Scolopax minor.*

The DNR has implemented a spring American woodcock (*Scolopax minor*) banding program since 1960. This program involves recruiting and training volunteer banders who use pointing dogs to find woodcock hens (adults) and chicks (locals) during April, May and June. Michigan has the largest woodcock banding program throughout the United States and Canada, banding >20,000 more birds than the next largest banding program (Maine) since 1981 (Mayhew and Luukkonen 2010).

Previous researchers have identified the value of woodcock banding. Mendell and Aldous (1943) noted that banding woodcock should be part of any management program for this species. They also determined that the most effective capture method in Maine was to locate broods with trained bird dogs. Liscinsky (1962) suggested that data from woodcock banding was the primary source of information used to acquire knowledge about the birds' movement and migration. Sheldon (1967) stated that extensive banding is required to help interpret the population composition of the fall kill as revealed by annual wing collection. In Michigan, Ammann (1973) reported that brood banding appeared to be more efficient than other known methods and that brood banding was about twice as productive as either mist netting or night lighting.

Dwyer and Nichols (1982) noted that poor banding and recovery data have always been a problem in the investigations of woodcock population dynamics. Owen et al. (1977) and McCabe (1982) also identified the high cost and difficulty of banding adequate numbers of woodcock as a problem. Krementz and Bruggink (2000) noted that too few woodcock banding programs following the late 1970s in the Eastern Region and the early 1980s in the Central Region have hindered management decisions. A nationally expanded woodcock banding program would increase our knowledge of how annual harvest and survival influence woodcock demographics (Straw et al. 1994, Krementz et al. 2003, Mayhew and Luukkonen 2010 and Schultz et al. 2010. The data from Michigan are one of the most consistent long-term samples of woodcock banding information (Krementz and Bruggink 2000, Krementz et al. 2003, and Mayhew and Luukkonen 2010). The purpose of this paper is to provide background on the Michigan woodcock banding and training program, describe the volunteer training program, highlight program success, and encourage other states and regions to develop similar programs.

PROGRAM HISTORY

The DNR banding program began in 1960 after the U.S. Bureau of Sport Fisheries and Wildlife (Bureau) enlisted the assistance of natural resource agencies to

---

[1] Email: stewarta1@michigan.gov

band woodcock in key production states. The Bureau needed large numbers of banded woodcock to develop an adequate data-gathering program that could provide information on woodcock population characteristics (Clark 1971). DNR wildlife biologist, G. A. Ammann, participated in this banding effort and successfully used a pointing dog to locate broods. The technique of banding wildlife using pointing dogs was first used in Europe and was later adopted in the United States. In North America, G. Swanson is credited with first using this method in 1937 to band birds in Maine (Mendall and Aldous 1943). Prior to this, game workers in Europe used this technique to band European woodcock (*Scolopax rusticola*; Ammann 1973).

During the infancy of Michigan's banding program, Ammann was joined by DNR wildlife biologists and a limited number of private cooperators (i.e., people not employed by the DNR). Most private cooperators were friends of biologists and were mentored by the biologists. As time progressed, additional private volunteer cooperators participated in the program. From 1960 to 1972, 39 banders participated during part or all of the 13-year period. Twenty-seven of these participants were private cooperators. During this time, there were 2,224 woodcock banded including 2,038 chicks (Ammann 1973).

After Ammann's retirement from the DNR in 1972, he remained active in Michigan's woodcock banding program and also focused on banding woodcock in other regions of the birds' range. Through the years, he refined this banding technique and encouraged others to participate in banding activities (Ammann 1973, 1977, 1981, 1994).

The characteristics of participants involved in the DNR woodcock banding program have changed through the years. In the 1970s and 1980s, the majority of Michigan banders were private cooperators with little background in wildlife management but with an enthusiastic interest in woodcock. Later, dog trainers and field trial competitors became involved in the program and emphasis shifted to dog handling with a major importance placed on number of birds banded by an individual. During the 1990s, mentoring from DNR staff was limited due to other workload activities and banding responsibilities were not well defined.

A program evaluation was conducted in 1999 and 3 areas were identified for program improvement: 1) expand woodcock bander knowledge about woodcock life history, research and management; 2) emphasize importance of good record-keeping; and 3) provide training about proper handling and banding technique, including capture myopathy. A procedure also was developed for becoming a woodcock bander and bander responsibilities were clarified.

Thus, the Michigan woodcock banding program has evolved through the years. Implementation of formal training for banders and an annual evaluation of the program has been valuable for improving efficiency, increasing the rigor in data collection, and reducing stress to woodcock during the banding process.

DNR's WOODCOCK BANDING PROGRAM

In order to band woodcock, volunteers must qualify each year for a DNR banding permit. We annually assess each bander based on established criteria that include attendance at the most recent mandatory training session, a DNR satisfactory rating for previous banding efforts, maintenance of accurate annual banding records, and submission of banding records to the DNR prior to 1 July.

The banding authorization is valid from 1 April–1 July. Prospective banders must apprentice with an established bander (sponsor/mentor) for at least 1 field season. A volunteer coordinator with banding knowledge facilitates these mentor-apprentice contacts. The sponsor must submit a letter of recommendation to the DNR to qualify the potential new bander for a future banding permit. The new bander must attend the mandatory training session and abide by permit stipulations.

The agency hosts a mandatory woodcock bander's training session during April in odd-numbered years. The objective of this one-day training is to keep volunteer banders current in brood banding techniques, banding requirements and woodcock biology. In even-numbered years, a non-mandatory summer bander's picnic is held in July to discuss banding activities. The summer meeting is organized by the banders. Both meetings allow for an exchange of ideas and provide input on methods to improve the program. In years when the mandatory training is not conducted, banders are surveyed to confirm their interest in program participation. Qualified banders who indicate a desire to be involved are identified with an "active status" in our database and are provided current-year banding information.

The mandatory woodcock bander's training session is designed to reinforce bander responsibilities and educate volunteers about current issues pertaining to woodcock. Each topic meets a specific educational objective designed to maintain a high level of bander competency (Table 1). Core agenda items are record-keeping and banding technique. Maintenance of accurate banding records is stressed. Sample banding forms (Appendices A and B) are provided for review and banders are taught or reminded how to complete the documents.

Participants are also taught how to determine banding location coordinates and are tested on their map-reading skills. Because most people are familiar with township, range, and section, we ask them to report their

Table 1. Agenda topics for mandatory woodcock bander's training.

Topic	Objective
Welcome and introductions	Create positive learning environment and define meeting goal.
Woodcock management	
National level	Update banders on current woodcock management and research activities being conducted at national and state level.
State level	
Research	
Woodcock banding sessions	
History	Provide history of banding program and describe why program is important today.
Banding statistics and other survey results	Provide information on banding efforts and band recovery.
Record keeping	Stress importance of maintaining accurate banding records. Train individuals how to collect information necessary to fulfill USGS Bird Banding Laboratory requirements.
Brood searching	Educate banders on how to determine potential areas to locate broods. Describe search dog requirements and necessity of using a trained dog.
Handling and banding technique	Illustrate safe and humane methods to handle and band woodcock through pictures, video, and hands-on activities.
Capture myopathy	Inform banders about capture myopathy and how they can eliminate handling mortality.
Woodcock bander's newsletter	Provide update on newsletter status and content.
Banding program improvement	Solicit feedback from banders about constructive ways to enhance program. Provide opportunity for volunteer coordinator to discuss banding issues with group.
Question and answer session	Provide encouraging atmosphere for individuals to pose questions about banding program and woodcock management.
Distribution of banding packets	Distribute bands, banding forms and banding permit to attendees.

locations using this format. When we enter the data for the U.S. Geological Survey (USGS) Bird Banding Laboratory, we convert these locations to the appropriate ten minute block.

Banding techniques are highlighted through classroom discussion and hands-on activities. Capture myopathy is defined and students learn methods to prevent chick mortality. Proper chick handling and banding skills are illustrated during a quail chick banding exercise. This applied activity replicates banding woodcock chicks in the field. During the training session, attendees are encouraged to share banding tips and methods to streamline banding activities.

Participants are also polled on ways to strengthen the banding program and training curriculum. Agency staff provide updates about woodcock research and management. At the conclusion of the mandatory training, banders receive their written banding authorization, banding forms, and bands.

Agency staff review banding forms submitted by banders and submit banding data to the USGS Bird Banding Laboratory in Laurel, Maryland, USA. State banding information is analyzed by DNR personnel and included in woodcock management documents developed by the DNR. An annual Woodcock Bander's Newsletter is produced in partnership with banders and agency staff. This report documents yearly banding activities and cursory seasonal banding observations. The newsletter serves as a tool to communicate with banders and others about woodcock management.

RESULTS

Volunteers have banded more woodcock in Michigan than in any other state. The number of birds banded has increased from 100 birds banded in 1965 to nearly 1,000 per year recently. The number of banders participating in this program has increased from 6 in 1965 (Amman 1966), 18 in 1975 (Whitcomb 1976), 43 in 1985 (Amman 1986), to 57 in 2006. There were approximately 100 banders in the mid-1990s; however, the number of banders declined in recent years as individuals retired from banding for various reasons. New volunteers are recruited by the DNR and existing banders in an effort to maintain at least 100 banders.

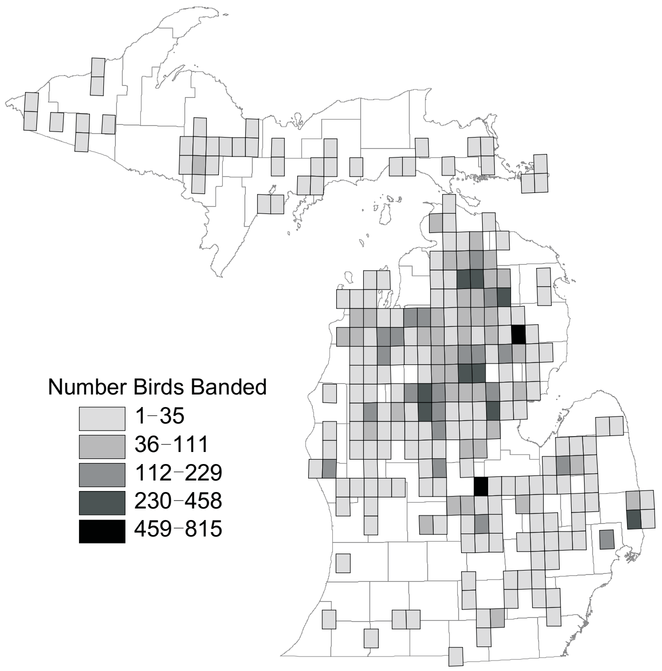


Figure 1. Location of woodcock banded by the Michigan Department of Natural Resources woodcock banding participants by ten-minute latitude and longitude blocks, 1997–2006.

Use of trained volunteers has been paramount to banding efforts within the state. In 2006 banders spent approximately 1,500 hours in search of woodcock, observed over 1,000 chicks, banding 917 chicks and 44 adults. In 2006 there were 86.4 chicks observed and 59.5 chicks banded per 100 hours of search time. In 2005 there were 75.8 chicks observed and 54.2 chicks banded per 100 hours of search time. Woodcock are banded throughout Michigan (Figure 1), with most banding occurring in what is considered good breeding habitat. The majority of chicks are banded in April and May (Figure 2).

At each training session, banders are required to complete an evaluation form. Feedback suggests that the training program amplifies participant enthusiasm. Although most banders are avid woodcock hunters, they confirm that they would trade fall hunting for spring banding, if they had to make a choice. Banders also indicated that they would volunteer to use mist-nets to band woodcock in summer if additional banding efforts were needed by the agency.

Although we lack comparable pre- and post mandatory bander training information relating to chick mortality, we theorize that chick handling mortality has been reduced since the onset of the training. Banders report that they are more aware of the potential for handling myopathy and that they work to abate mortality associated with capture.

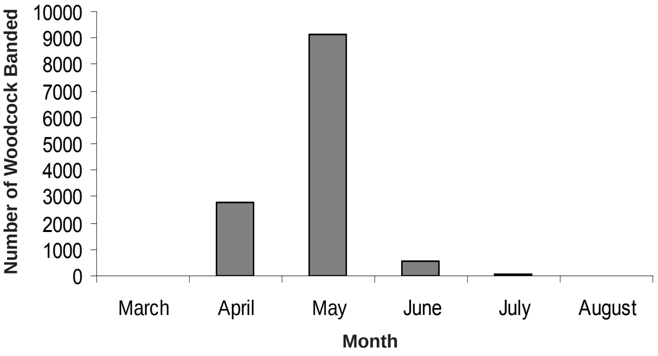


Figure 2. Number of woodcock banded by month by participants in the Michigan Department of Natural Resources woodcock banding program, 1997–2006.

Prior to establishment of the training program, oversight of banding activities and bander records required a significant time commitment by agency personnel to produce accurate records. Since inception of the training program, accuracy and timeliness of submitted data has improved and there has been a major reduction in staff efforts.

DISCUSSION

We believe that banding woodcock using trained volunteers provides information useful for management of woodcock and that assistance from volunteers can be expanded to other areas of the country. Michigan banding efforts have proven invaluable in providing large sample sizes for analysis. Researchers including Krementz and Bruggink (2000), Krementz et al. (2003), and Mayhew and Luukkonen (2010) have analyzed woodcock band recovery data from birds banded by DNR volunteers to better understand woodcock ecology. Woodcock ecology in North America depends on local and international influences that affect population dynamics. To understand these dynamics, woodcock investigators and managers identified the need for increased banding efforts throughout woodcock range. Continued banding of local birds in Michigan and expanded banding in other production areas may prove helpful as researchers study the impacts of harvest and habitat conditions on woodcock populations. In addition, information collected by banders such as woodcock chicks observed per 100 hours of search time may be useful as an index of local woodcock production trends.

As greater emphasis is placed on banding woodcock throughout their breeding range, the Michigan banding program can serve as a template for others agencies to emulate. This is due to the large number of birds banded through the Michigan program and the efficiency of trained Michigan volunteers.

Banders become self-monitoring when they understand that the program could be jeopardized by noncompliance of participants. Since establishment of the training program there has been improvement in timeliness of band record submission and quality. These improvements have reduced staff time required to produce acceptable band records, banding efficiency and a sustainable banding program.

Successful program implementation depends on continued communication, education, and outreach. The primary benefit of the banding program is a large number of woodcock banded by volunteers. Another positive outcome is that trained banders are better informed about woodcock management activities and effectively share this knowledge with other upland game bird enthusiasts. These banders become vested in supporting woodcock management activities and the need to maintain young forest habitat. They develop into educated opinion leaders who network with others to communicate and support the need for woodcock management.

ACKNOWLEDGMENTS

Funding and support of this study were provided by the Michigan Department of Natural Resources and the Federal Aid in Wildlife Restoration, Pittman-Robertson Project 147. We would especially like to thank the many people who volunteer their time to band woodcock in Michigan. Without their keen interest and commitment none of this would be possible. We are grateful to S. Hogle and D Rumrill for maintaining Michigan banding records and submitting the information to the Bird Banding Laboratory. G. Roloff, S. Mayhew and three anonymous reviewers provided invaluable advice on improving the organization and clarity of this manuscript.

LITERATURE CITED

Ammann, G. A. 1966. Woodcock banders' newsletter. Michigan Department of Conservation Game Division Information Circular 143. Lansing, Michigan, USA.

Ammann, G. A. 1973. Methods of capturing American woodcock broods. International Congress of Game Biology. 11: 593–605.

Ammann, G. A. 1977. Woodcock banders' newsletter. Michigan Department of Natural Resources Wildlife Division Information Circular 183. Lansing, Michigan, USA.

Ammann, G. A. 1981. Woodcock banders' newsletter. Michigan Department of Natural Resources Wildlife Division Information Circular 190. Lansing, Michigan, USA.

Ammann, G. A. 1986. Woodcock banders' newsletter. Michigan Department of Natural Resources Wildlife Division Information Circular 198. Lansing, Michigan, USA.

Ammann, G. A. 1994. Woodcock banders' newsletter. Michigan Department of Natural Resources Wildlife Division Information Circular 215. Lansing, Michigan, USA.

Clark, E. R. 1971. Preliminary report on woodcock capture techniques, habitat, and population studies at Moosehorn National Wildlife Refuge, Maine. U.S. Bureau of Sport Fisheries and Wildlife, Laurel, Maryland, USA.

Dwyer, T. J., and J. D. Nichols. 1982. Regional population inferences for the American woodcock. Pages 12–21 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Woodcock ecology and management. U.S. Fish and Wildlife Service Wildlife Research Report 14.

Krementz, D. G., and J. G. Bruggink. 2000. Sources of variation in survival and recovery rates of American woodcock. Pages 55–64 *in* Proveedings of the Ninth American Woodcock Symposium. U. S. Geological Survey, Biological Resources Division Information and Technology Report USGS/BRD/ITR–2000–0009, Patuxent Wildlife Research Center, Laurel, Maryland, USA.

Krementz, D. G., J. E. Hines, and D. R. Luukkonen. 2003. Survival and recovery rates of American woodcock banded in Michigan. Journal of Wildlife Management. 67: 398–407.

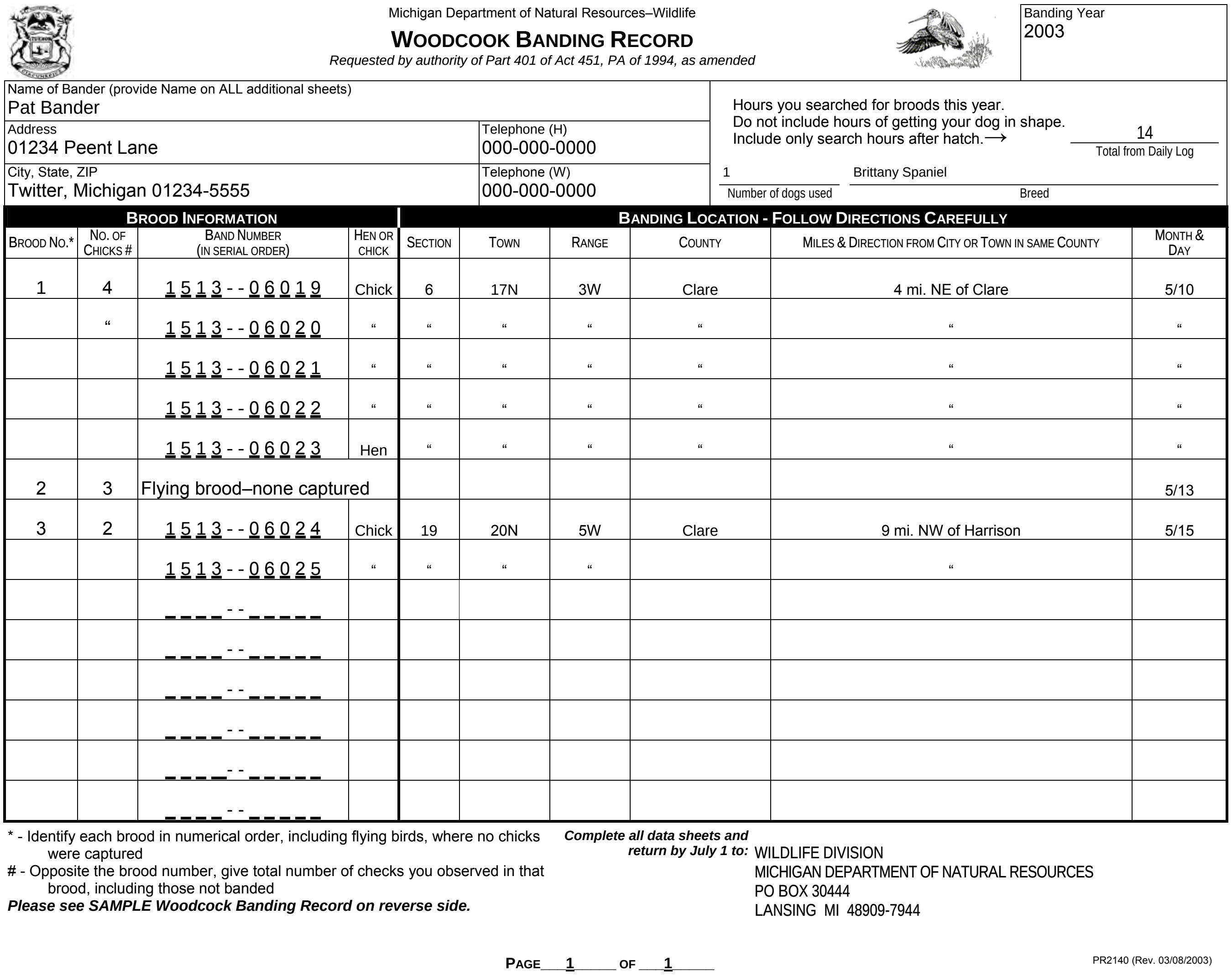
Liscinsky, S. A. 1962. The Pennsylvania woodcock management study. Final Report. Pennsylvania Game Commission. Pittman-Robertson Project W–50–R.

Mayhew, S. L., and D. R. Luukkonen. 2010. Survival and recovery of woodcock banded in Michigan, 1981–2004. Pages 169–174 *in* C.A. Stewart, and V. R. Frawley, editors. Proceedings of the Tenth American Woodcock Symposium. Michigan Department of Natural Resources and Environment, Lansing, Michigan, USA.

McCabe, R. A. 1982. The American woodcock: a keynote address. Pages 1–5 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Woodcock ecology and management. U.S. Fish and Wildlife Service Wildlife Research Report 14.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit. University of Maine, Orono, Maine, USA.

Appendix A. Banding form used by volunteer woodcock banders in Michigan, USA.



Michigan Department of Natural Resources–Wildlife

WOODCOCK BANDING RECORD

Requested by authority of Part 401 of Act 451, PA of 1994, as amended

Banding Year
2003

Name of Bander (provide Name on ALL additional sheets)
Pat Bander

Address
01234 Peent Lane

Telephone (H)
000-000-0000

City, State, ZIP
Twitter, Michigan 01234-5555

Telephone (W)
000-000-0000

Hours you searched for broods this year.
Do not include hours of getting your dog in shape.
Include only search hours after hatch.⟶ 14
Total from Daily Log

1
Number of dogs used

Brittany Spaniel
Breed

BROOD INFORMATION				BANDING LOCATION - FOLLOW DIRECTIONS CAREFULLY					
BROOD NO.*	NO. OF CHICKS #	BAND NUMBER (IN SERIAL ORDER)	HEN OR CHICK	SECTION	TOWN	RANGE	COUNTY	MILES & DIRECTION FROM CITY OR TOWN IN SAME COUNTY	MONTH & DAY
1	4	1513--06019	Chick	6	17N	3W	Clare	4 mi. NE of Clare	5/10
	“	1513--06020	“	“	“	“	“	“	“
		1513--06021	“	“	“	“	“	“	“
		1513--06022	“	“	“	“	“	“	“
		1513--06023	Hen	“	“	“	“	“	“
2	3	Flying brood–none captured							5/13
3	2	1513--06024	Chick	19	20N	5W	Clare	9 mi. NW of Harrison	5/15
		1513--06025	“	“	“	“		“	
		____--_____							
		____--_____							
		____--_____							
		____--_____							
		____--_____							
		____--_____							

* - Identify each brood in numerical order, including flying birds, where no chicks were captured

\# - Opposite the brood number, give total number of checks you observed in that brood, including those not banded

Please see SAMPLE Woodcock Banding Record on reverse side.

Complete all data sheets and return by July 1 to: WILDLIFE DIVISION
MICHIGAN DEPARTMENT OF NATURAL RESOURCES
PO BOX 30444
LANSING MI 48909-7944

PAGE 1 OF 1

PR2140 (Rev. 03/08/2003)

Owen, R. B., J. R., J. M. Anderson, J. W. Artmann, E. R. Clark, T. G. Dilworth, L. E. Gregg, F. W. Martin, J. D. Newsom, and S. R. Pursglove. 1977. American woodcock (*Philohela minor* = *Scolopax minor* of Edwards 1974). Pages 149–186 *in* G. C. Sanderson, editor. Management on migratory shore and upland game birds in North America. International Association of Fish and Wildlife Agencies, Washington, D. C., USA.

Schulz, J. H., D. R. Luukkonen, and R. O. Morgenweck. 2010. Improving woodcock management by implementing lessons from other migratory game birds. Pages 1–11 in C. A. Stewart, and V. R. Frawley, editors. Proceedings of the Tenth American Woodcock Symposium. Michigan Department of Natural Resources and Environment, Lansing, Michigan, USA.

Sheldon, W. G. 1967. The book of the American woodcock. First edition. The University of Massachusetts Press, Amherst, Massachusetts, USA.

Straw, J. A., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Whitcomb, D. A. 1976. Woodcock banders' newsletter. Michigan Department of Natural Resources Wildlife Division Information Circular 180.

Appendix B. Daily field log completed by volunteer woodcock banders in Michigan, USA.

Michigan Department of Natural Resources–Wildlife Division

WOODCOOK BANDERS DAILY FIELD LOG

Requested by authority of Part 401 of Act 451, PA of 1994, as amended

Pat Bander
Name

MONTH & DAY	COUNTY	KEEP DAILY NOTES OF ALL TRIPS AFIELD IN CHRONOLOGICAL ORDER. PRECISE LOCATIONS ARE NOT NEEDED.	NUMBER OF WOODCOCK MOVED	NUMBER OF GROUSE MOVED	DOG HOURS AFIELD
4/26/2003	Clare	Partly cloudy; 50° F; Dog found 3 nests	6	1	1.5
4/27/2003	Clare	Sunny, windy, 65° F; Found one nest.	6	4	2
5/6/2003	Gladwin	Sunny	2	0	3.5
5/10/2003	Clare	Cloudy, windy, 40° F; Banded 4 chicks and 1 hen in Brood #1, found RG nest.	13	5	3.5
5/13/2003	Clare	Partly cloudy, 45° F; First brood we found was flying, 3 chicks.	8	3	1.5
5/15/2003	Gladwin	Mostly cloudy; 55° F. Found one brood with 2 chicks.	1	7	2.0

Please provide your name on every sheet!

PAGE 1 OF 1

PR2140-1 (Rev. 03/08/2003)

Al Stewart is the Upland Game Bird Specialist and Program Leader with the Michigan Department of Natural Resources and is responsible for statewide conservation and management programs for American woodcock, ruffed grouse, sharp-tailed grouse, quail, pheasants, and wild turkeys. He banded his first woodcock in 1971 with Andy Ammann and is the administrator of the Michigan woodcock banding program. He has pursued American woodcock in North America and Eurasian woodcock in Russia. He first participated in the woodcock wingbee in the early 1970s and continues to attend. He has contributed to national management activities for American woodcock and provided input to the American Woodcock Conservation Plan.

Valerie Frawley earned her B.S. in Fisheries and Wildlife Management from Lake Superior State University in 1997 and her M.S. in Range and Wildlife Management from Texas A&M University–Kingsville in 1999. She currently works for the Wildlife Division of the Michigan Department of Natural Resources where she assists the species specialists with a variety of projects. She has participated in the woodcock wingbee. She helps coordinate the American woodcock Singing-ground Survey for Michigan and the woodcock banding program.

SURVIVAL AND RECOVERY OF WOODCOCK BANDED IN MICHIGAN, 1981–2004

10th American Woodcock Symposium
Roscommon, Michigan, USA

SARAH L. MAYHEW[1]**,** Michigan Department of Natural Resources,
PO Box 30444, Lansing, MI 48909-7944, USA

DAVID R. LUUKKONEN, Michigan Department of Natural Resources, Rose Lake Research Center,
8562 E. Stoll Rd., East Lansing, MI 48823, USA

Abstract: Indices from American woodcock (*Scolopax minor*) monitoring programs suggest a long-term population decline in the Central Region. The U.S. Fish and Wildlife Service has restricted hunting regulations for Central Region woodcock because of concern over the apparent population decline. Long-term estimates of woodcock survival can help resolve relationships among population trends, hunting regulations, and survival. Although banding information is unavailable for most Central Region breeding areas, Michigan has coordinated a banding program that has provided enough marked birds to evaluate models explaining temporal variation in survival. These data consist of spring banding of adults and locals as well as limited traditional preseason bandings of adults and hatch-year birds. We fit a suite of models to band-recovery information collected during 1981–2004. The data provided a range of support for models varying from the most general model with year- and age-dependent survival and recovery rates to several reduced models that constrained age and year effects. Our model set included appropriate tests for evidence of effects of the hunting regulation changes enacted in 1997 on adult and juvenile woodcock survival.

Proceedings of the American Woodcock Symposium 10: 169–174

Key words: American woodcock, harvest, management, Michigan, recovery rates, *Scolopax minor*, survival rates.

Indices of spring abundance for American woodcock (*Scolopax minor*) in the Central Region have declined an average of 1.8% per year from 1968 to 2005 as monitored through the annual Singing-ground Survey (Kelley and Rau 2005). The indices for woodcock in Michigan have closely matched that trend with an average 1.7% annual decline (Kelley and Rau 2005). A major component of woodcock preferred habitat, early successional forests, has been declining over the same time period throughout most of the woodcock's northern range leading to speculation that habitat loss is the primary cause of declines in woodcock populations (Dessecker and Pursglove 2000).

Concerns over long-term declines in woodcock abundance led to changes in federal woodcock harvest regulations in the Central Region (Kelley and Rau 2005). Prior to 1991, the framework dates (i.e., the earliest and latest dates on which hunting is allowed) for woodcock hunting seasons extended from 1 September through 28 February with a 5-bird bag limit. The U.S. Fish and Wildlife Service (USFWS) changed the closing framework date to 31 January beginning with the 1991 hunting season. Regulations became even more restrictive in 1997 and included a 45-day season (beginning the Saturday closest to 22 September) and a 3-bird bag limit. Krementz and Bruggink (2000) suggested that changes in harvest regulations such as these could potentially manipulate woodcock survival.

Banding data and subsequent encounter information allow for estimation of survival and recovery rates for different groups within a population and provide a means of testing for effects of regulation changes on these parameters. Michigan has the largest woodcock banding program in the United States and Canada and more than 26,000 woodcock have been banded there since 1981. Krementz et al. (2003) used band-recovery data from woodcock banded in Michigan to estimate long-term (1978–1998) survival and recovery rates and were unable to detect an effect of the 1991 changes in hunting regulations on woodcock survival. The 1997 regulations changes, however, were even more restrictive and may have resulted in a more substantial reduction in harvest rates than the 1991 restrictions. Thus, the effects of 1997 changes on woodcock survival may be more detectable.

---

[1] Email: mayhews@michigan.gov

Our objective was to estimate the long-term survival and recovery rates of local, juvenile, and adult woodcock using the 1981–2004 Michigan woodcock band-recovery data. We also attempted to assess whether the 1997 regulation changes impacted survival rates.

METHODS

Our methods closely followed those of Krementz et al. (2003). We obtained all banding and recovery data from the U.S. Geological Survey Patuxent Wildlife Research Center Bird Banding Laboratory (BBL) in Laurel, Maryland, USA. We analyzed banding data from normal, wild woodcock of known age banded between 1 March and 31 August in Michigan from 1981 through 2004. We used recovery data from birds shot or found dead between 1 September and 28 February. We used data from birds classified as locals (birds incapable of sustained flight and hatched during the banding year), juveniles (capable of sustained flight and hatched during the banding year), and adults (birds banded after the calendar year of hatching) as coded in the BBL files. We eliminated juveniles banded in April or May and locals banded in July, August, September, or October to allow us to estimate survival rates for these age classes over more distinct periods of time and because banders may have misidentified the age class of these birds. Nesting phenology of woodcock in Great Lakes states suggests juveniles are unlikely prior to June and locals unlikely after June (Gregg 1984). Adult bandings occurred between March and October, with the peak falling in May.

We created recovery matrices for each age class from 1981 through 2004. We were unable to assess potential sex differences in survival and recovery rates because banders did not sex local birds at the time of banding and banded most birds as locals. We used Program MARK (White and Burnham 1999) to estimate survival and recovery rates and to test for differences between age classes and over time. To focus on testing for time and age effects on survival, our most general model contained year-dependent survival and recovery rates for each age class.

Birds banded during the spring of their hatching year were subject to several more months of mortality risk prior to the recovery period than birds banded during the summer. We used the method described in Krementz et al. (2003) to account for this difference. We inserted zeros along the diagonal of the local recovery matrix (because hunting recoveries were not possible during the summer months) so that the survival rate estimate for the first time period for the locals corresponded to the summer period. We then adjusted the juvenile and adult recovery matrices by adding a final column of zeros so all matrices had the same number of columns. We fixed the local recovery rate and the final juvenile and adult survival and recovery rates at zero. In the MARK parameter index matrices, we advanced the local parameter indexes to correspond to those of juveniles during the second time period (associated with the locals' first hunting season after hatching).

We tested several candidate models similar to those presented in Brownie et al. (1985) to identify potential effects of time, age, and harvest regulations on survival and recovery rates. The adjustments required to account for the banding of local birds made the most general model unsuitable for testing goodness of fit using program BROWNIE (Brownie et al. 1985). Instead, we tested for overdispersion in the data using the median $\hat{c}$ approach described in the Program MARK help files. Due to the variability in time frames for estimating survival rates, all of the candidate models we tested included the age effect for survival. The importance of age in survival rates in the Krementz et al. (2003) study supported our approach. Among the models Krementz et al. (2003) tested, models with year-dependent survival and recovery rates received very little weight, so we tested only a few models with year-dependent survival and recovery rates; most models we parameterized constrained survival and recovery rates to either be constant or have a linear temporal trend. We looked for potential effects of the 1997 regulations change on survival rates by including models that differentiated between a constant 1981–1997 survival rate and a constant 1997–2004 survival rate (indicated by "regs" in the model name). Krementz et al. (2003) found virtually no support for an effect of the 1991 regulations change on survivorship. Thus, we felt models that included an effect of 1991–1996 framework on survivorship would be overparameterized, and we did not include them.

Model selection followed the approach of Burnham and Anderson (2002) based on Akaike's Information Criterion (AIC) adjusted for small sample size (AIC_c). Models with lower AIC_c values fit the data better than those with higher AIC_c values. Models with ΔAIC_c values ≤ 2 are generally considered to fit the data well, but to account for model uncertainty, we used all models with AIC_c weights ≥ 0.00001 (regardless of ΔAIC_c values) in model averaging procedures. We used model averaging to calculate annual survival rate estimates for locals, juveniles, and adults and recovery rate estimates for juveniles and adults.

RESULTS

To obtain a robust sample, we included bandings and recoveries from 1981 through 2004 in our analysis, the most recent year of available banding data. After

Table 1. Number of normal, wild woodcock banded (between 1 March and 31 August) in Michigan and recovered dead (between 1 September and 28 February) throughout the United States and Canada, 1981–2004.

Year	Number banded	Number recovered
1981	652	18
1982	484	28
1983	438	19
1984	514	15
1985	539	19
1986	518	21
1987	764	35
1988	965	42
1989	1,254	40
1990	953	34
1991	828	41
1992	949	27
1993	842	25
1994	1,502	47
1995	1,488	45
1996	1,444	49
1997	1,706	51
1998	1,613	68
1999	1,682	52
2000	1,472	47
2001	1,439	47
2002	1,162	41
2003	1,049	63
2004	1,049	39

removing birds of unknown age and recoveries that fell outside the 1 September through 28 February time frame, we obtained records for 24,456 banded birds and 913 recoveries (Table 1). Most woodcock (21,862) were banded as locals while only 563 were banded as juveniles. Recoveries of Michigan banded birds occurred throughout the Central Region, primarily in Michigan and Louisiana, and in a few scattered locations in the Eastern Region. About 93% of the woodcock recoveries occurred in Michigan.

The most general model included time varying survival and recovery rates for all age classes. The median $\hat{c}$ test estimated the variance inflation factor at $\hat{c} = 1.1191$ for the global model, suggesting a reasonable fit of the model to the data. Burnham and Anderson (2002) do not recommend using $\hat{c} > 1$ if the model fit is reasonable, so we did not make adjustments to $\hat{c}$ for the analysis. The model with the lowest AIC$_c$ had constant age-specific survival rates over time and a decreasing linear trend (slope = –0.0110 on the logit scale) in recovery rates over time (Table 2). All other models had ΔAIC$_c$ >2. Thirteen models had AIC$_c$ weights >0.0001.

The models with the fewest parameters tended to have the lowest AIC$_c$ values, and a few patterns were apparent. The 4 models with the lowest AIC$_c$ values included constant survival rates. Models that included an effect of the regulations change on survival received little weight, with the highest receiving an AIC$_c$ weight of 0.0064. Models with year-dependent survival and recovery rates had virtually no weight.

We included all models with AIC$_c$ weights $\geq$ 0.00001 to calculate model-averaged estimates of recovery and survival rates. Local birds had high survival during the summer months (0.848; Table 3) and juvenile survival was low (0.273; Table 3). Adult woodcock had a higher annual survival rate than juveniles (0.465; Table 3). Given the absence of age effects on recovery rates in the top model, the lack of a difference between model-averaged estimates of juvenile and adult annual recovery rates (0.028 for juveniles and adults) was expected (Table 3).

DISCUSSION

As expected given the similarity in the datasets, our survival estimates were similar to those Krementz et al. (2003) reported, but with improved precision. Our point estimate of juvenile survival was slightly higher than the estimate Krementz et al. (2003) reported but was still slightly below the range (0.313–0.356) of survival for male and female juvenile woodcock in the Central Region (Dwyer and Nichols 1982). Our adult survival estimates are slightly lower than the estimates reported by Dwyer and Nichols (1982) for adult females in the Central Region, but are slightly higher than estimates reported for adult males. The 1978–1982 adult and juvenile survival rates Krementz and Bruggink (2000) reported were higher than the survival rates we estimated.

The role of harvest in limiting woodcock population growth is uncertain. With an additional 6 years of banding information covering a more restrictive regulatory framework compared to the Krementz et al. (2003) study, we found no discernable change in survival associated with restrictions in woodcock hunting season frameworks. Woodcock harvest in Michigan peaked at about 390,000 birds during 1976 and then declined to less than 150,000 birds annually in recent years (Michigan DNR, unpublished estimates). Despite reduced harvest in Michigan primarily resulting from declining hunter numbers and, to a lesser degree, more restrictive hunting season frameworks (Luukkonen and Frawley 2010), our results suggest that woodcock survival has been stable

Table 2. Model statistics from estimation of survival (*S*) and recovery (*f*) rates for adult, juvenile, and local woodcock leg-banded in Michigan, 1981–2004.

Model Name	AIC_c	$\Delta\ \text{AIC}_c$	AIC_c weight	Parameters	Deviance
$S_{\text{constant local, constant juv, constant ad}}\ f_{\text{linear}}$	9718.288	0.00	0.5409	5	384.882
$S_{\text{constant local, constant juv, constant ad}}\ f_{\text{constant}}$	9720.328	2.04	0.1950	4	388.924
$S_{\text{constant local, constant juv, constant ad}}\ f_{\text{linear juv, linear ad}}$	9721.408	3.12	0.1137	7	384.000
$S_{\text{constant local, constant juv, constant ad}}\ f_{\text{constant juv, constant ad}}$	9722.110	3.82	0.0800	5	388.705
$S_{\text{linear local, linear juv, linear ad}}\ f_{\text{constant juv, constant ad}}$	9724.134	5.85	0.0291	8	384725
$S_{\text{constant local, constant juv, constant ad}}\ f_{\text{year-dependent}}$	9726.104	7.82	0.0109	27	348.641
$S_{\text{linear local, linear juv, linear ad}}\ f_{\text{linear juv, linear ad}}$	9726.486	8.20	0.0090	10	383.075
$S_{\text{constant local, regs juv, regs ad}}\ f_{\text{linear juv, linear ad}}$	9727.172	8.88	0.0064	10	383.761
$S_{\text{linear local, linear juv, linear ad}}\ f_{\text{linear}}$	9727.604	9.32	0.0051	8	388.195
$S_{\text{constant local, regs juv, regs ad}}\ f_{\text{linear}}$	9728.190	9.90	0.0038	8	388.781
$S_{\text{linear local, linear juv, linear ad}}\ f_{\text{constant}}$	9728.865	10.58	0.0027	7	391.457
$S_{\text{linear local, linear juv, linear ad}}\ f_{\text{year-dependent}}$	9729.827	11.54	0.0017	30	346.360
$S_{\text{constant local, regs juv, regs ad}}\ f_{\text{constant}}$	9729.850	11.56	0.0017	7	392.443
$S_{\text{constant local, regs juv, regs ad}}\ f_{\text{year-dependent}}$	9736.143	17.86	0.0001	30	352.666
$S_{\text{constant local, regs juv, regs ad}}\ f_{\text{year-dependent juv, year-dependent ad}}$	9740.273	21.99	0.0000	54	308.635
$S_{\text{year-dependent local, year-dependent juv, year-dependent ad}}\ f_{\text{linear}}$	9761.087	42.80	0.0000	72	293.268
$S_{\text{constant local, regs juv, regs ad}}\ f_{\text{constant juv, constant ad}}$	9767.905	49.62	0.0000	8	428.496
$S_{\text{year-dependent local, year-dependent juv, year-dependent ad}}\ f_{\text{year-dependent}}$	9788.960	70.67	0.0000	94	276.849
$S_{\text{year-dependent local, year-dependent juv, year-dependent ad}}\ f_{\text{year-dependent juv, year-dependent ad}}$	9815.591	97.30	0.0000	118	255.074

over time. Perhaps larger changes in woodcock season frameworks (e.g., season lengths, bag limits) or hunter numbers would have been necessary to affect changes in harvest rates that would result in temporal changes in survival rates. Another possibility is that annual woodcock survival is relatively invariant to hunting mortality rate across the range of harvests realized during our study (i.e., a pattern expected under a hypothesis of compensatory mortality [Anderson and Burnham 1976]) or that reproduction is declining in response to density-dependent limitation on the breeding grounds. We note that harvest age ratios (juveniles to adult females) have been declining in the Central Region since the mid-1980s (Kelley and Rau 2005), suggesting reduced productivity could be contributing to woodcock declines.

Additional information will likely be required to resolve uncertainties surrounding the effects of hunting on woodcock populations. Unlike some migratory waterfowl species, there are no estimates of band-reporting rates for woodcock that would allow estimation of harvest rates from band-recovery data. We concur with others that expanding the spatial extent of woodcock banding in the Central Region and estimating woodcock band-reporting rates via reward banding would provide additional insights into the role of harvest and survival in woodcock demographics (Straw et al. 1994, Krementz et al. 2003). Effects of changing survival and reproduction on population growth could be assessed

Table 3. Model-averaged annual survival and recovery rate estimates, standard errors (SE), and 95% confidence intervals (CI) for adult and juvenile American woodcock and summer survival rates of local American woodcock banded in Michigan, USA, 1981–2004 (this study) and 1978–1998 (Krementz et al. 2003).

	Survival			**Recovery**	
Source	**Local**	**Juvenile**	**Adult**	**Juvenile**	**Adult**
This study	0.848	0.273	0.465	0.028	0.028
SE	0.1180	0.0365	0.0204	0.0036	0.0026
95% CI	0.4813–0.9711	0.2078–0.3501	0.4251–0.5050	0.0215–0.0358	0.0236–0.0338
Krementz et al. (2003)	0.878	0.265	0.490	0.033	0.031
SE	0.1048	0.0423	0.0319	0.0053	0.0047
95% CI	0.4025–0.9873	0.1859–0.3619	0.4251–0.5549	0.0216–0.0491	0.0216–0.0452

within the context of population models that incorporate all relevant vital rates. Resolving uncertainty about the effects of both habitat limitation and harvest on woodcock populations should be a priority for woodcock researchers and managers, and there may be useful templates available from experiences with other migratory game bird groups or species that would assist in developing a strategic research plan for woodcock (Schultz et al. 2010).

ACKNOWLEDGMENTS

Funding and support for this study were provided by the Michigan Department of Natural Resources and the Federal Aid in Wildlife Restoration, Pittman-Robertson Project 147. We would especially like to thank the many people who volunteered their time to band woodcock in Michigan. V. Frawley and A. Stewart of the Michigan Department of Natural Resources coordinated the banding program and S. Hogle maintained banding equipment and records for submission to the BBL.

LITERATURE CITED

Anderson, D. R., and K. P. Burnham. 1976. Population ecology of the mallard VI. The effect of exploitation on survival. U.S. Fish and Wildlife Service Resource Publication 128, Washington, D.C., USA.

Brownie, C., D. R. Anderson, K. P. Burnham, and D. S. Robson. 1985. Statistical inference from band recovery data—a handbook. Second Edition. U.S. Fish and Wildlife Service Resource Publication 156, Washington D.C., USA.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second Edition. Springer-Verlag, New York, New York, USA.

Derleth, E. L., and G. F. Sepik. 1990. Summer-fall survival of American woodcock in Maine. Journal of Wildlife Management 54: 97–106.

Dessecker, D. R., and S. R. Pursglove, Jr. 2000. Current population status and likely future trends for American woodcock. Pages 4–8 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey Information and Technology Report 2000-0009. Patuxent Wildlife Research center, Laurel, Maryland, USA.

Dwyer, T. J., and J. D. Nichols. 1982. Regional population inferences for the American woodcock. Pages 12–21 *in* T. J. Dwyer and G. L. Storm, technical coordinators. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14, Washington, D.C., USA.

Gregg, L. 1984. Population ecology of woodcock in Wisconsin. Wisconsin Department of Natural Resources, Technical Bulletin 144. Madison, Wisconsin, USA.

Kelley, J. R., Jr. and R. D. Rau. 2005. American woodcock population status, 2005. U.S. Fish and Wildlife Service. Laurel, Maryland, USA.

Krementz, D. G., and J. G. Bruggink. 2000. Sources of variation in survival and recovery rates of American woodcock. Pages 55–64 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. U.S. Geological Survey Information and Technology Report 2000-0009.

Krementz, D. G., J. E. Hines, and D. R. Luukkonen. 2003. Survival and recovery rates of American woodcock banded in Michigan. Journal of Wildlife Management 67: 398–407.

Lebreton, J-D., K. P. Burnham, J. Clobert, and D. R. Anderson. 1992. Modeling survival and testing biological hypotheses using marked animals: a unified approach with case studies. Ecological Monographs 62: 67–118.

Luukkonen, D. R., and B. J. Frawley. 2010. Michigan woodcock hunter and harvest dynamics in relation to hunting season frameworks, 1954–2004. Pages 185–194 *in* C. A. Stewart, and V. R. Frawley, editors. Proceedings of the Tenth American Woodcock Symposium. Michigan Department of Natural Resources and Environment, Lansing, Michigan, USA.

Schulz, J. H., D. R. Luukkonen, and R. O. Morgenweck. 2010. Improving woodcock management by implementing lessons from other migratory game birds. Pages 1–11 *in* C. A. Stewart, and V. R. Frawley, editors. Proceedings of the Tenth American Woodcock Symposium. Michigan Department of Natural Resources and Environment, Lansing, Michigan, USA.

Straw, J. A., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

White, G. C., and K. P. Burnham. 1999. Program MARK: survival estimation from populations of marked animals. Bird Study 46 Supplement: 120–138.

Not Pictured

Sarah L. Mayhew is a Wildlife Research Biologist with the Michigan Department of Natural Resources where her focus is data collection and analysis techniques, population monitoring, and data management. She earned her M.S. in Fisheries and Wildlife from Michigan State University in 2001 and her B.A. in Biology from Hamilton College in 1999. Her professional interests are in wildlife population estimation and monitoring techniques applicable at large scales.

David R. Luukkonen is a Wildlife Research Specialist with the Michigan Department of Natural Resources; he is also an adjunct faculty member of the Department of Fisheries and Wildlife at Michigan State University. His primary interest is research to improve management decisions for migratory and resident game birds.

SURVIVAL OF AMERICAN WOODCOCK BROODS AND CHICKS IN MAINE

10th American Woodcock Symposium
Roscommon, Michigan, USA

DANIEL G. MCAULEY[1], United States Geological Survey, Patuxent Wildlife Research Center-Orono,
5768 South Annex A, Orono, ME 04469-5768 USA

JERRY R. LONGCORE, United States Geological Survey, Patuxent Wildlife Research Center-Orono,
5768 South Annex A, Orono, ME 04469-5768 USA

DAVID A. CLUGSTON[2], United States Geological Survey, Patuxent Wildlife Research Center-Orono,
5768 S. Annex A, Orono, ME 04469-5768, USA

WILLIAM HALTEMAN, Department of Mathematics and Statistics, Neville Hall, University of Maine,
Orono, ME 04469 USA

GREG F. SEPIK[3], United States Fish and Wildlife Service, Moosehorn National Wildlife Refuge,
Rural Route 1 Box 202, Suite 2, Baring, ME 04694-9703 USA

Abstract: During 1986–1989, we radio-marked 89 female American woodcock (*Scolopax minor*) during the period 1 April–30 June at Moosehorn National Wildlife Refuge in Maine. We followed 61 broods comprised of 212 chicks for a 21-day brood period to determine survival. Brood survival, the probability of fledging >1 chick from a brood, varied among years and during the 21-day brood period ranged from 0.438 (95% CI: 0.189–1.000) to 0.833 (95% CI: 0.583–1.000). Survival of chicks varied from 0.222 (95% CI: 0.103–0.480) to 0.787 (95% CI: 0.6325–0.980) and averaged 0.469 (95% CI: 0.403–0.547) among years. Over all years, brood survival averaged 0.617 (95% CI: 0.500–0.762) and chick survival averaged 0.469 (95% CI: 0.403–0.547) for the brood period. We tested for relationships between survival and independent variables with Cox proportional hazards models. We examined covariates year, clutch size (3 or 4), age of the hen, and weather variables potentially related to survival: average daily maximum temperature, average daily minimum temperature, and average daily rain. Chick and brood survival differed among years, and was related to minimum daily temperature, with higher survival associated with higher minimum daily temperature. Survival of chicks and broods of after-second-year females did not differ from survival of chicks and broods of second-year females.

Proceedings of the American Woodcock Symposium 10: 175–184

Key words: American woodcock, brood survival, chick survival, Maine, radio telemetry, *Scolopax minor*.

American woodcock (*Scolopax minor*) populations have exhibited declines in the United States since at least the late 1960s (Straw et al. 1994, Cooper et al. 2008). The Singing-ground Survey (SGS) provides an index to changes in woodcock abundance and there have been long-term (1964–2007) annual declines in counts of male woodcock on the SGS in both the Eastern (–1.2%) and Central Management Regions (–1.1%) (Cooper et al. 2008). Dwyer et al. (1983) documented an association between increases in urban and industrial development along survey routes and declines in numbers of woodcock counted in the late 1960s to the late 1970s in 9 northeastern states. The ratio of immature birds per adult females in the harvest provides an index to recruitment of young into the population and is measured by the Wing-collection Survey (WCS). There have been long-term declines in woodcock recruitment in both management regions of North America (Cooper et al. 2008) suggesting that the population declines could be the result of declining reproductive success. It

---

[1] E-mail: dan_mcauley@usgs.gov

[2] Present address: United States Army Corps of Engineers, Environmental Resources Branch, P.O. Box 2946, Portland, OR 97208 USA.

[3] Deceased

is widely believed that loss of early successional forest habitat is responsible for the observed declines in woodcock populations and recruitment (Dessecker and McAuley 2001, Kelley et al. 2008).

Most estimates of annual survival for woodcock are derived from analyses of annual band recoveries from birds banded in the 1970s and 1980s (Dwyer and Nichols 1982, Krementz and Bruggink 2000) and are for fledged birds. Mendall and Aldous (1943) reported that chick mortality was about 10% for the pre-fledging period but provided no data. Krementz et al. (2003) estimated survival of pre-fledged young from mid-May to August as 0.843 (SE = 0.101) by comparing the ratio of direct recoveries for birds banded as flightless chick versus those banded as fledglings. Dwyer et al. (1982) regressed brood size on brood age and estimated attrition rate as 0.09 chicks per day in Maine. Gregg (1984) used a similar method to estimate chick mortality at 0.04 chicks per day in Wisconsin, but this method fails to include mortality from loss of entire broods (Cowardin and Johnson 1979). Wiley and Causey (1987) used radio telemetry and reported survival of woodcock chicks to 21 days in Alabama of 0.84. Our objectives were to determine survival of woodcock chicks from hatch to fledging (21 days) and to relate survival to weather variables and female age.

Study Area

We conducted this study on the 65 km^2 Baring Unit, Moosehorn National Wildlife Refuge (MNWR), Washington County, Maine, near Calais (67° 15’ W, 45° 5’ N). Since 1973, 40-50 ha of woodlands on MNWR have been harvested annually to maintain habitat for woodcock (Sepik et al. 1977), resulting in a mostly uneven-aged, second-growth, northern hardwood-conifer forest with mixed stands of quaking aspen (*Populus tremuloides*), bigtooth aspen (*P. grandidentata*), paper birch (*Betula papyrifera*), gray birch (*B. populifolia*), and red maple (*Acer rubrum*) (Derleth and Sepik 1990). Dominant conifer types included white spruce (*Picea glauca*), red spruce (*P. rubens*), and balsam fir (*Abies balsamea*) with scattered white pine (*Pinus strobus*), red pine (*P. resinosa*), and tamarack (*Larix laricina*). Margins of streams and some fields contain extensive stands of alder (*Alnus incana*). Habitat management for woodcock at MNWR was detailed by Sepik et al. (1977, 1981) and Sepik and Dwyer (1982).

METHODS

Field Techniques

During 30 March–31 May, from 1986 to 1989 we used mist nets (Sheldon 1960) set near and around display sites of males and along edges of known nesting areas and feeding sites to capture female woodcock during the crepuscular period (McAuley et al. 1993*a*, *b*). During daylight, we used long-handled nets to capture females with broods and occasionally on nests, which were located using a pointing dog (Ammann 1974). We distributed our effort among forest types to obtain a sample of females from all potential habitat types on the study area. We banded captured birds with United States Fish and Wildlife Service (USFWS) leg bands, sexed and aged captured birds (SY = second year [1-year old], ASY = after second year [> 2-year old]) by plumage characteristics (Martin 1964), and measured mass (± 1 g) with a spring scale. We attached radio transmitters (3–4 g, <3% body mass) to birds’ backs with cattle tag cement and a single loop of Teflon®-coated steel wire, which encircled the birds’ breasts (McAuley et al. 1993*a*).

Following capture and when we expected female woodcock to have broods, we homed in on radio signals to visually locate the female and count chicks in her brood. We assumed all broods contained 4 chicks and carefully searched the area for each chick. If 4 chicks were not found we re-located the brood the following day and searched again to verify there were <4 chicks. If the hen and brood were located via a pointing dog, we allowed the dog to search for other chicks. We banded all chicks in each brood using USFWS bands. We aged (in days) chicks that were not from nests with known hatch dates by measuring their bill length (Ammann 1982). If a captured female was not already radio-marked, we attached a transmitter and released her with the brood at the site of capture.

We located signals of radio-marked females daily with programmable scanning receivers and vehicle-mounted 7-element Yagi antennas. Two to 3 times per week we used hand-held antennas to home in on radio signals and visually locate females and their broods. We located and counted the number of chicks, while making every effort to not flush females or chicks. We considered reductions in the number of chicks from the previous encounter to be the result of chick mortality. We assumed mortality had occurred at the midpoint between visits (Mayfield 1975).

Statistical Analyses

We used the Kaplan-Meier (Kaplan and Meier 1958) product-limit procedure as modified by Pollock et al. (1989) to estimate survival rates of chicks and broods, standard errors, and 95% confidence intervals. The Kaplan-Meier product-limit procedure allows for staggered entry of individuals into the model and right-censoring of data (Pollock et al. 1989). We began monitoring for mortality the day after birds were marked and followed broods to 21 days of age. Woodcock chicks grow rapidly and at 25 days are nearly full grown (Pettingill 1936, Mendall and Aldous 1943). We calculated chick survival, which is the probability of individual chicks surviving the entire 21-day period and brood survival, which is the probability of >1 chick in a brood surviving to 21 days. We tested for differences in yearly survival rates between and among years using Wald tests, score tests, and likelihood-ratio tests (Agresti 2007). The Wald test compares individual parameters (e.g., 1986 vs. 1987, 1987 vs. 1988, etc.). The score test compares individual parameter estimates to zero and requires rearranging parameterization of the model, although survival curves are unaffected. For this test we constructed a model where 1986 was treated as the baseline and we compared other years to 1986. We then re-parameterized the model using 1987 as the baseline. With likelihood-ratio tests we constructed models with different parameter sets to evaluate the needed complexity of the model.

We compared 4 separate year parameters versus 3 year parameters (1986, 1987, and a combination of 1988 and 1989), then those 3 year parameters versus 2 year parameters (1986 and combination of 1987, 1988, and 1989), and finally 3 year parameters versus 2 year parameters (1986 and 1987 combined and 1988 and 1989 combined). We tested for relationships between survival and independent variables with Cox proportional hazards models (Cox and Oakes 1984, Kalbfleisch and Prentice 1980) using S-plus version 6.2 (Insightful Corporation, Somerville, Massachusetts, USA). In analyses of individual chick survival, we used “death” as the event of interest. We used Akaike’s Information Criterion (AIC) to compare among models in an information-theoretic framework (Burnham and Anderson 1998). We examined covariates year, age of female (SY, ASY), clutch size, and weather variables: average daily maximum temperature (maxT), average daily minimum temperature (minT), and average daily rain. We added all variables into the initial model and then deleted non-significant ($\alpha = 0.05$) variables using a backward stepwise approach. We obtained weather data from a weather station set up in the center of the study area at MNWR headquarters. For each chick and brood, we averaged daily temperature (º C) over the period they were monitored, producing an average temperature for that chick or brood’s period of observation. The yearly and overall average temperatures were the averages of each chick or brood’s average temperature for all chicks or broods in a year or over all years combined. We calculated an average minT for the brood period for all years to scale all years to a common temperature and plotted survival in relation to this average minimum temperature.

Table 1. Number of American woodcock chicks and broods captured at Moosehorn National Wildlife Refuge (NWR) during 1986–1989.

	Year			
	1986	**1987**	**1988**	**1989**
Broods	13	17	23	8
Chicks	42	61	82	27

RESULTS

During 1986–1989 we captured and radio-marked 89 female woodcock. Marked females produced 61 broods and 212 chicks (Table 1) that we monitored and used in survival analyses. During the study 100 chicks died, 36 broods had >1 chick die, and 20 of the broods lost all chicks. Average temperatures during the brood period varied among years. Average maximum temperature was 18.3º C in 1986, 22.8º C in 1987, 21.1º C in 1988, and 22.2º C in 1989. Average minimum temperature was 2.8º C in 1986, 6.1º C in 1987, 3.9º C in 1988, and 8.9º C in 1989. Peak hatching dates for broods varied each year, resulting in a wide range of temperature variation among years. In 1986, 11 of 13 broods hatched before 15 May; in 1987, 9 of 17; in 1988, 17 of 23; and in 1989, only 1 of 8 hatched before 15 May.

Survival of chicks was different among years (Figure 1). The Kaplan-Meier (K-M) survival curve for chicks in 1986 was different from that in 1987 ($z = 1.93$, $P = 0.054$), 1988 ($z = 4.08$, $P = 0.00$), and 1989 ($z = 3.86$, $P = 0.00$). Pairwise comparisons of chick K-M survival curves from 1987, 1988, and 1989 were mixed. Wald tests indicated that chick survival curves in 1987 and 1988 were not different ($z = 1.40$, $P = 0.162$), 1987 and 1989 curves were not different ($z = 1.45$, $P = 0.147$), and the 1989 curve was similar to the 1988 curve ($z = 0.071$, $P = 0.993$). Score tests indicated 1987 chick survival was different from that in 1988 ($z = 3.82$, $P < 0.001$) and 1989 ($z = 3.16$, $P = 0.002$). Likelihood-ratio tests indicated 1988 and 1989 chick survival were not different ($\chi^2 = 0.03$, $P = 0.86$, df = 1), 1987 survival was different from survival in 1988 and 1989 ($\chi^2 = 18.46$, $P = 0.000$, df = 1), and 1986 survival was different from that in 1987 ($\chi^2 = 4.48$, $P = 0.034$, df = 1). Based on results of all tests we concluded that 1987 chick survival

Table 2. Model selection for survival of woodcock chicks captured at Moosehorn NWR 1986–1989 using Akaike's Information Criterion (AIC). Variables included minimum temperature (minT), years (1986, 1987, 1988, and 1989, which were treated as categorical data), maximum temperature (maxT), and rainfall (rain).

Model	Log Likelihood	No. of parameters	AIC	∆AIC
minT, year	–455.98	4	919.95	0.00
maxT, minT, year	–455.94	5	921.88	1.93
Full model [maxT, minT, rain, year]	–455.92	6	923.84	3.89
minT, year (1987 and 1988 combined)	–459.22	3	924.45	4.50
maxT, year	–469.31	4	946.62	26.67
year	–485.33	3	976.67	56.71
minT	–497.70	1	997.39	77.44

was different from that in 1988 and 1989. The 21-day period survival of chicks varied from 0.787 (95% CI: 0.6325–0.980) in 1986 to 0.222 (95% CI: 0.103–0.480) in 1989 (Figure 1), with a composite rate of 0.469 (95% CI: 0.403–0.547) over all 4 years.

Based on AIC, the model of chick survival including minT and year (Table 2) was the best-supported model among our suite of candidate models. Similarly, Cox proportional hazards analyses indicated a strong minT and year effect on chick survival (Table 3), with high values of minT decreasing the hazard and thereby increasing survival probability. Results of other tests confirmed the proportional hazards analyses ($R^2 = 0.367$ (max possible= 0.991), Likelihood ratio test = 97, $P < 0.001$, df = 4; Wald test = 76.8, $P < 0.001$, df = 4;Score test = 89, $P < 0.001$, df = 4). We calculated the average minT for the brood period for all years (4.9º C) and using the best-supported model, plotted survival in relation to this average minT (Figure 2). Age of hen and clutch size had no effect on survival.

Survival of broods during the 21-day brood period varied by year and ranged from 0.833 (95% CI: 0.583–1.000) in 1986 to 0.438 (95% CI: 0.189–1.000) in 1989 (Figure 3). Composite period survival rate across all 4 years was 0.617 (95% CI: 0.500–0.762). Results of tests comparing yearly estimates were mixed. Wald tests in-

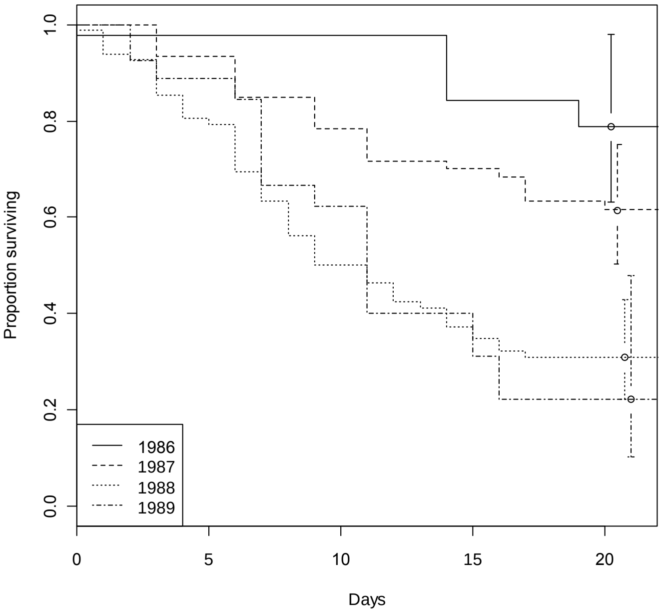


Figure 1. Kaplan-Meier estimates of survival of American woodcock chicks during the 21-day brood period by year. Broods were captured at Moosehorn NWR during April–June 1986–1989. Confidence intervals (95%) are indicated for the end of the 21-day period.

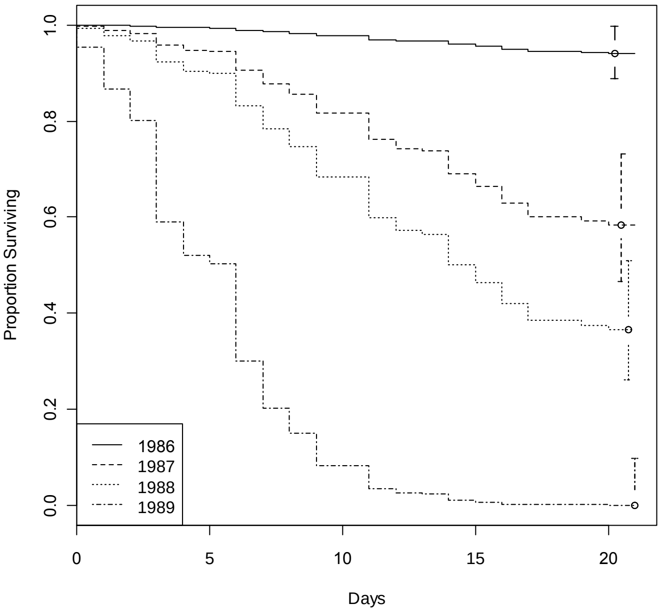


Figure 2. Proportional hazards estimates of survival of American woodcock chicks during the 21-day brood period by year calculated for a common average minimum temperature of 4.9º C. Broods were captured at Moosehorn NWR during April–June 1986–1989. Confidence intervals (95%) are indicated for the end of the 21-day period.

Table 3. Parameter estimates for best-supported (based on Akaike's Information Criterion) Cox proportional hazards model of survival of woodcock broods captured at Moosehorn NWR 1986–1989. Model included minimum temperature (minT; ° C) and years (1987, 1988, and 1989, which were treated as categorical variables).

Variable	Coeff	SE (coeff)	$e^{(coeff)}$	z^a	P^a
minT	–0.204	0.0286	0.816	–7.12	<0.001
year 1987	2.177	0.5150	8.819	4.23	<0.001
year 1988	2.805	0.4823	16.527	5.82	<0.001
year 1989	4.677	0.6477	107.449	7.22	<0.001

[a] Test of the null hypothesis that the parameter is equal to zero

dicated yearly survival rates were not different (z ranged from 0.03–0.647, all *P*s >0.514) and the score test gave similar results (z ranged from 0.75–1.75, all *P*s >0.079). We re-parameterized the model using combinations of years. Likelihood-ratio tests indicated that survival was similar during 1989 and 1988 ($\chi^2 = 0.01$, $P = 0.939$, df = 1) and during 1986 and 1987 ($\chi^2 = 0.65$, $P = 0.420$, df = 1). We then used proportional hazards to construct a model with 1986–1987 combined and with 1988–1989 combined. The resulting model indicated survival of broods was similar in 1988 and 1989 but differed from 1986 and 1987 survival ($R^2 = 0.106$; $\chi^2 = 6.84$, $P = 0.09$, df = 1; Wald $z = 5.78$, $P = 0.016$, df = 1; score $z = 6.55$, $P = 0.010$, df = 1). Similar to the analyses for chicks, the best-supported model included minimum temperature and year (Table 4). The best-supported Cox proportional hazards model included both minimum temperature and year effects on brood survival (Table 5), with high values of minimum temperature decreasing hazard, thereby increasing survival probabilities. Results of other tests confirmed the proportional hazards analyses ($R^2 = 0.265$ (max possible = 0.927); Likelihood ratio test = 18.8, $P = 0.0009$, df = 4; Wald test = 15.6, $P = 0.0035$, df = 4; Score test = 17.6, $P = 0.0015$, df = 4). As with the analysis of chick survival, we used the average minimum temperature for the brood period to scale all years to a common temperature and then plotted survival in relation to this average minimum temperature (Figure 4).

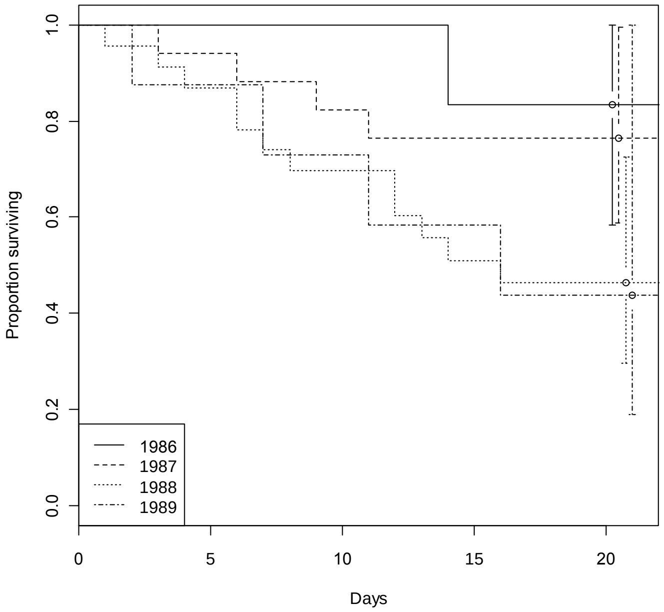


Figure 3. Kaplan-Meier estimates of survival of American woodcock broods (probability >1 chick from a brood survives) during the 21-day brood period by year. Broods were captured at Moosehorn NWR during April–June 1986–1989. Confidence intervals (95%) are indicated for the end of the 21-day period.

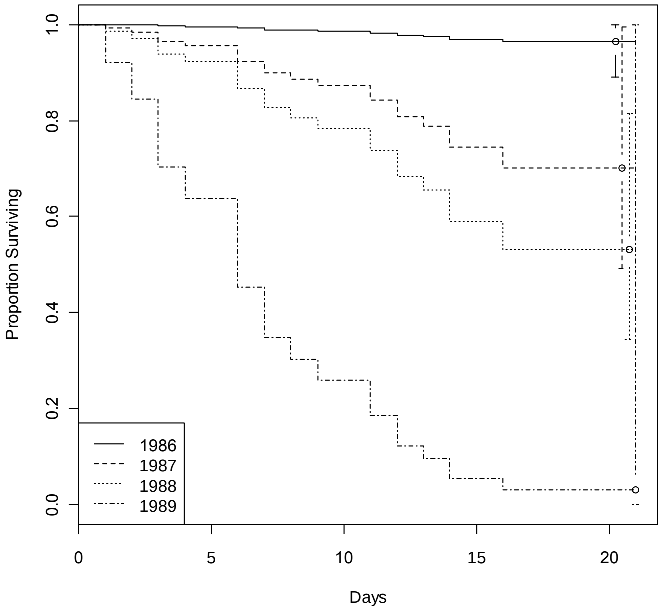


Figure 4. Proportional hazards estimates of survival of American woodcock broods (probability >1 chick from a brood survives) during the 21-day brood period by year calculated for a common average minimum temperature of 4.9º C. Broods were captured at Moosehorn NWR during April–June 1986–1989. Confidence intervals (95%) are indicated for the end of the 21-day period.

Table 4. Model selection for survival of woodcock broods captured at Moosehorn NWR 1986-1989 using Akaike's Information Criterion (AIC). Variables included minimum temperature (minT; ºC), years (1986, 1987, 1988, and 1989, which were treated as categorical data), maximum temperature (maxT; ºC), and rainfall (rain).

Model	Log Likelihood	Parameters	AIC	∆AIC
minT, year	–70.52	4	149.03	0.00
maxT, minT, year	–69.57	5	149.13	0.10
minT, year(1988 and 1989 combined)	–72.50	3	151.00	1.97
Full: maxT, minT, rain, year	–69.54	6	151.09	2.06
minT, year(1986 and 1987 combined)	–72.78	3	151.55	2.52
year	–76.17	3	158.35	9.32
minT	–78.74	1	159.47	10.44

DISCUSSION

Dwyer et al. (1982) and Gregg (1984) used pointing dogs to locate, band, and measure woodcock chicks (Ammann 1974) and make inferences about survival of broods and chicks. Dwyer et al. (1982) reported that in Maine there were age-related differences in production by female woodcock that resulted in smaller broods, later hatching dates, and slower mass gain of chicks for broods from SY birds. Despite these differences in production they reported no difference in survival through the brood period and felt year effects were more important than hen age in affecting chick survival. Similarly, we found no differences in survival between broods from SY and ASY females. Gregg (1984) in Wisconsin reported brood attrition was 0.04 chicks per day (0.89 chicks over a 21-day survival period) and Dwyer et al. (1982) reported attrition was 0.09 per day (1.89 chicks over a 21-day survival period). If the average brood size was about 3.5 chicks, 21-day chick survival would be about 0.76 in the Wisconsin study and about 0.46 in Maine. A shortcoming of the regression analyses used by these authors is that broods that lose all chicks are not represented because these broods cannot be observed. In our study, 60% of broods had >1 chick die and 33% of broods lost all chicks.

Table 5. Parameter estimates for best-supported (based on Akaike's Information Criterion) Cox proportional hazards model of survival of woodcock broods captured at Moosehorn NWR 1986–1989. Model included minimum temperature (minT; º C) and years (1987, 1988, and 1989, which were treated as categorical variables). Brood survival is the probability of ≥1 chick in a brood surviving the 21-day brood period.

Variable	Coeff	SE (coeff)	$e^{(coeff)}$	z^a	P^a
minT	–0.201	0.063	0.818	–3.16	0.002
year 1987	2.256	1.193	9.546	1.89	0.059
year 1988	2.833	1.080	17.005	2.62	0.009
year 1989	4.4545	1.434	94.170	3.17	0.002

[a] Test of the null hypothesis that the parameter is equal to zero

Wiley and Causey (1987) used radio-telemetry and reported survival of chicks to 15 days as 0.95, but reported that survival from 15–32 days was 0.67. They estimated that survival to 21 days was 0.84 (95% CI: 0.64–0.96). They asserted that mortality increased after woodcock chicks fledged at around 21 days. We followed 26 broods past 21 days and observed no mortality after 20 days.

Contrary to our findings, survival of woodcock chicks in Alabama was not related to weather (Wiley and Causey 1987). In Maine, we found a strong positive relationship between average minimum temperature and survival—low temperatures correlated with lower survival. When we plotted survival as a function of a common average temperature (Figure 1), survival increased for years with lower average temperatures (1986) and decreased for years with higher average temperatures (1989). At 4.9º C survival of chicks in 1986 would be about 0.93, while in 1989 no chicks would have survived. Similarly, we found that the probability that ≥1 chick in a brood survived (brood survival) was related to average minimum temperature during the brood period. Brood survival ranged from about 0.833 in 1986 to 0.438 in 1989 (Figure 3). When we plotted survival scaled to an average temperature of 4.9º C, survival in 1986–1988 would be similar and around 0.475, and no broods would have survived in 1989. Vander Haegen et al. (1993) reported that persistent frost in April affected earthworm availability on Moosehorn NWR. In 1989, lack of snow cover in winter and cold temperatures in April caused frost to persist into May. Earthworm availability and female mass were lower in April 1989 than in 1987 and 1988 (Vander Haegen et al. 1993). Initiation of nesting was 3–4 weeks later than usual in 1989. We found only 1 brood that hatched before 15 May in 1989 and no radio-marked woodcock re-nested after losing a nest or brood (unpublished data). Dwyer et al. (1988) found a significant negative relationship between chick production and total precipitation and a non-significant negative relationship between chick production and average maximum temperature. In our study we found no association between total precipitation and survival but lower average minimum temperature was negatively related to survival. In most years, rain during spring is associated with cooler temperatures (McAuley personal observation). During cooler weather chicks would need to be brooded more and would feed less, which could increase mortality. Rabe et al. (1983) looked at bioenergetics of breeding woodcock and reported that the greatest potential for weather-related stress on woodcock occurs during brood rearing. They reported that energy requirements of chicks were equal to those of the hen after 4–5 days. Vander Haegen (1992) found there was a positive relationship between ambient air temperature and activity rates of females with broods and that activity patterns of brood females seemed to be governed by the thermoregulatory requirements of chicks. He surmised that reduced activity was caused by frequent brooding of chicks.

Dwyer et al. (1988) revised their earlier estimate of chick survival (Dwyer et al. 1982) and estimated daily survival of 0.9707 (SE = 0.0067). This would translate into a survival estimate of 0.53 for the 21-day brood period and is similar to our estimates. Annual survival rates for juvenile woodcock have been estimated using banding data (Dwyer and Nichols 1982, Krementz and Bruggink 2000, and Krementz et al. 2003) and are low (0.26–0.36). Dwyer et al. (1988) used mark-recapture data and estimated that spring–summer survival of fledged juvenile woodcock was high (0.836 for females; 0.926 for males). Derleth and Sepik (1990) used radio-telemetry and determined that survival of woodcock in Maine from summer to fall (15 June–20 October) was 0.63 and 0.71 for juvenile males and females, respectively. Krementz et al. (2003) used banding data from chicks banded during the brood period and estimated that survival from the brood period to the end of summer was 0.88, although their 95% CI was large (0.4025–0.9873). They felt that once woodcock eggs hatched, young had a high probability of surviving and departing on fall migration. Our data do not support that assertion. Using our estimate of chick survival (0.46) and the summer survival estimate of Dwyer at al. (1988), survival from hatching to the beginning of fall would be 0.384–0.425, which is considerably lower than the point estimate of Krementz et al. (2003) but similar to the lower bound of the 95% CI of their estimate. This low production rate could be mitigated somewhat by re-nesting effort of female woodcock. Female woodcock are persistent re-nesters and will lay a replacement clutch even after losing broods <11 days old (McAuley et al. 1990). We found that the probability of a brood surviving to fledging was about 0.475. If most of the females that lost broods re-nested, and assuming nest success of 50% (McAuley et al. 1990), production might increase another 25%.

MANAGEMENT IMPLICATIONS

Our study in eastern Maine indicated that survival of woodcock chicks is variable and is likely affected by weather, especially low temperatures that may be associated with precipitation. Under warm spring conditions, survival of chicks during the 21-day brood period can be as high as 0.90 whereas cold temperatures are associated with low survival. Under average spring temperatures, chick survival during the 21-day brood period of about 0.50 is probable. Because survival of fledged young is fairly high (Derleth and Sepik 1990), poor survival of chicks during the brood period is probably the primary determinant of lower yearly production and recruitment. Longcore et al. (1996, 2000) found an association between survival and habitat use of adult males and females; therefore, providing habitat conditions that provide overhead cover, high stem densities and moist soils for abundant earthworms could enhance survival by reducing thermoregulatory costs and foraging time, especially during periods of cool, wet weather.

ACKNOWLEDGMENTS

We thank B. E. Benedict, S. E. Benjamin, S. B. Bonnefield, S. D. Coutu, D. R. Granfors, R. A. Houston, R. S. Hughes, R. Jerofke, D. S. Licht, C. G. Kitchens, R. C. Kantz III, J. D. Sayre, L. A. Skonier, R. T. Speer, A. P. Weik, E. K. Wilbrecht, K. N. Wood, and K. G. Wright for assistance in marking and monitoring woodcock. D. M. Mullen, Refuge Manager, and the staff of Moosehorn NWR provided logistical and administrative support throughout the study.

LITERATURE CITED

Agresti, A. 2007. An introduction to categorical data analysis. Second edition. John Wiley & Sons. Hoboken, New Jersey, USA.

Ammann, G. A. 1974. Methods of capturing American woodcock broods. Pages 593–605 *in* S. Lundstrom, editor. Eleventh International Congress of Game Biologists. Stockholm, Sweden.

Ammann, G. A. 1982. Age determination of American woodcock chicks by bill length. Pages 22–25 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14, Washington, D.C., USA.

Burnham, K. P., and D. R. Anderson. 1998. Model selection and inference: a practical information-theoretic approach. Springer-Verlag, New York, New York, USA.

Cooper, T. R., K. Parker, and R. D. Rau. 2008. American woodcock population status, 2008. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Cowardin, L. M., and D. H. Johnson. 1979. Mathematics and mallard management. Journal of Wildlife Management 43: 18–35.

Cox, D. R., and D. Oakes. 1984. Analysis of survival data. Chapman and Hall, London, U.K.

Derleth, E. L., and G. F. Sepik. 1990. Summer-fall survival of American woodcock in Maine. Journal of Wildlife Management 54: 97–106.

Dessecker, D. R., and D. G. McAuley. 2001. Importance of early successional habitat to ruffed grouse and American woodcock. Wildlife Society Bulletin 29: 456–465.

Dwyer, T. J., G. F. Sepik, E. L. Derleth, and D. G. McAuley. 1988. Demographic characteristics of a Maine woodcock population and effects of habitat management. U.S. Fish and Wildlife Service, Fish and Wildlife Research 4, Washington, D.C, USA.

Dwyer, T.J., G. F. Sepik, D. G. McAuley, and E. L. Derleth. 1983. Woodcock singing-ground counts and habitat changes in the northeastern United States. Journal of Wildlife Management 47: 772–779.

Dwyer, T.J., and J. D. Nichols. 1982. Regional population inferences for the American woodcock. Pages 12–21 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14, Washington, D.C., USA.

Dwyer, T. J., E. L. Derleth, and D. G. McAuley. 1982. Woodcock brood ecology in Maine. Pages 63–70 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14, Washington, D.C., USA.

Gregg, L. 1984. Population ecology of woodcock in Wisconsin. Department of Natural Resources, Technical Bulletin No. 14. Madison Wisconsin, USA.

Kalbfleisch, J. D., and R. L. Prentice. 1980. The statistical analysis of failure time data. John Wiley and Sons, New York, New York, USA.

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of the American Statistical Association 53: 457–481.

Kelley, J., S. Williamson, and T. R. Cooper, editors. 2008. American woodcock conservation plan. A summary of and recommendations for woodcock conservation in North America. Wildlife Management Institute, Washington, D.C., USA.

Krementz, D. G., and J. G. Bruggink. 2000. Sources of variation in survival and recovery rates of American woodcock. Pages 55–64 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, U.S. Geological Survey, Laurel, Maryland, USA.

Krementz, D. G., J. E. Hines, and D. R. Luukkonen. 2003. Survival and recovery rates of American woodcock banded in Michigan. Journal of Wildlife Management 67: 398–405.

Longcore, J. R., D. G. McAuley, G. F. Sepik, and G. W. Pendleton. 1996. Survival of breeding male American woodcock breeding in Maine. Canadian Journal of Zoology 74: 2046–2054.

Longcore, J. R., D. G. McAuley, G. F. Sepik, and G. W. Pendleton. 2000. Survival of female American woodcock breeding in Maine. Pages 65–76 *in* D. G. McAuley, J. G. Bruggink, and G. F. Sepik, editors. Proceedings of the Ninth American Woodcock Symposium. Biological Resources Division Information and Technology Report USGS/BRD/ITR-2000-0009, Patuxent Wildlife Research Center, U.S. Geological Survey, Laurel, Maryland, USA.

Mayfield, H. 1975. Suggestions for calculating nest success. Wilson Bulletin 87: 456–466.

Martin, F. W. 1964. Woodcock age and sex determination from wings. Journal of Wildlife Management 28: 287–293.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1990. Renesting by American woodcock (*Scolopax minor*) in Maine. Auk 107: 407–410.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993*a*. Techniques for research into woodcocks: experiences and recommendations. Pages 5–11 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium, U.S. Fish and Wildlife Service Biological Report 16, Washington, D.C., USA.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993*b*. Behavior of radio-marked breeding American woodcocks. Pages 116–125 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium, U.S. Fish and Wildlife Service Biological Report 16, Washington, D.C., USA.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit, University of Maine, Orono, USA.

Pettingill, O. S. 1936. The American woodcock *Philohela minor* (Gmelin). Memoirs of the Boston Society of Natural History 9: 169–391.

Pollock, K. H., S. R. Winterstein, C. M. Bunck, and P. D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53: 7–15.

Rabe, D. L., H. H. Prince, and D. L. Beaver. 1983. The effect of weather on bioenergetics of breeding American woodcock. Journal of Wildlife Management 47: 762–771.

Sepik, G. F., and T. J. Dwyer. 1982. Woodcock response to habitat management in Maine. Pages 106–113 *in* T. J. Dwyer and G. L. Storm, editors. Woodcock ecology and management. U.S. Fish and Wildlife Service, Wildlife Research Report 14, Washington, D.C., USA.

Sepik, G. F., R. B. Owen, Jr., and M. W. Coulter. 1977. Experimental woodcock management of the Moosehorn National Wildlife refuge. Proceedings of the Sixth Woodcock Symposium. Fredericton, New Brunswick, Canada.

Sepik, G. F., R. B. Owen, Jr., and M. W. Coulter. 1981. A landowner's guide to woodcock management in the northeast. University of Maine, Orono, Life Science and Agricultural Experiment station, miscellaneous report 253. Orono, Maine, USA.

Sheldon, W. G. 1960. A method of mist netting woodcocks in summer. Bird-Banding 31: 130–135.

Straw, J. A., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America. International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

Vander Haegen, W.M. 1992. Bioenergetics of American woodcock during the breeding season on Moosehorn National Wildlife Refuge, in Maine. Dissertation, University of Maine, Orono, USA.

Vander Haegen, W. M., W. B. Krohn, and R. B. Owen, Jr. 1993. Effects of weather on earthworm abundance and foods of American woodcock in spring. Pages 26–31 *in* J. R. Longcore and G. F. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium, U.S. Fish and Wildlife Service Biological Report 16, Washington, D.C., USA.

Wiley, E. N., and M. K. Causey. 1987. Survival of woodcock chicks in Alabama. Journal of Wildlife Management 51: 583–586.

Dan McAuley is the Station Leader and Research Wildlife Biologist with the U.S. Geological Survey's Patuxent Wildlife Research Center, Orono, Maine field station. He has worked for Patuxent since 1978. Primary responsibility is to conduct field research on migratory bird issues identified by the U.S. Fish and Wildlife Service and other Department of Interior agencies. He has worked on American woodcock population ecology and conservation for the past 30 years, addressing issues related to population dynamics; ecology; spring, summer, and fall survival and habitat use; habitat change along woodcock Singing-ground Surveys routes; and the effects of hunting pressure on American survival of woodcock in Maine, New Hampshire, Vermont, and Pennsylvania. He is the Assessment and Research Coordinator for the American Woodcock Initiative and has helped to develop Best Management Practices for woodcock for the 4 regional woodcock initiatives. Current research includes studies on adaptive habitat management and habitat use of American woodcock in the Northeast, survival of American woodcock during fall migration using radio telemetry, as well as studies on survival and recruitment of common eiders using mark-recapture methods and band recovery analyses, and evaluating use of fixed-wing aircraft to survey red-necked phalaropes in the Bay of Fundy.

Jerry Longcore is a retired Wildlife Biologist (Research), U.S. Fish & Wildlife Service and former field station Leader, Patuxent Wildlife Research Center, Orono, Maine. He is a Certified Wildlife Biologist and fellow of The Wildlife Society with a continued interest in migratory bird research and management. He resides in Orono, Maine.

David Clugston spent most of his career involved with large-scale population and habitat management evaluations varying from wild horse censusing and behavioral studies in the high desert of Wyoming to New England harvest and habitat use of American woodcock. He has had the good fortune of having captured, handled, radio-tagged, and tracked a wide variety of species in some of the wildest parts of the United States. For the last 9 years he has been a Fishery Biologist with the Corps of Engineers, Northwest Division and Portland District Offices overseeing the RM&E programs dealing with fish passage and migration in the Columbia River Basin.

Greg Sepik died May 28, 1998 at the age of 48. At the time of his death he was a Zone Biologist for Region 5 of the U.S. Fish and Wildlife Service. He was stationed at Moosehorn NWR, where he was deeply involved in research and habitat management for woodcock during his entire career. His studies at Moosehorn began with graduate work 1976 and continued professionally in 1979 when he was hired as the refuge biologist at Moosehorn NWR. He was a persistent advocate for managing some portion of every refuge for early successional habitat. Through his work Moosehorn NWR became the premiere showcase of how to manage habitat for American woodcock and other early successional species.

In 1971 ***Bill Halteman*** graduated from Oberlin College with a B.A. in Mathematics. After a 4-year interlude for military service, he began studies for the Ph.D. in Biostatistics at the University of Washington. He graduated in 1980 and joined the Mathematics faculty at the University of Maine where he continues to serve. His time is divided between teaching applied statistics courses to graduate students in the experimental sciences and providing statistical consulting for whomever needs help analyzing their data.

MICHIGAN WOODCOCK HUNTER AND HARVEST DYNAMICS IN RELATION TO HUNTING SEASON FRAMEWORKS, 1954–2004

10th American Woodcock Symposium
Roscommon, Michigan, USA

DAVID R. LUUKKONEN[1]**,** Michigan Department of Natural Resources, Rose Lake Wildlife Research Center,
8562 E. Stoll Rd., East Lansing, MI 48823, USA

BRIAN J. FRAWLEY, Michigan Department of Natural Resources, Stevens T. Mason Building,
Box 30444, Lansing, MI48909-7944, USA

Abstract: The Michigan Department of Natural Resources has monitored American woodcock (*Scolopax minor*) hunting effort and harvest via post-season mail surveys of randomly selected small-game hunters since 1954. We analyzed hunter numbers and harvest over the period 1954–2004 to model the impact of changes in woodcock abundance, hunter numbers, and U.S. Central Management Region (CMR) hunting season frameworks on woodcock harvest in Michigan. We found that the best models predicting woodcock harvests included the following variables in decreasing order of importance: number of woodcock hunters, license type, hunting season frameworks, and woodcock abundance indices. The best models predicting woodcock hunter numbers included the following variables in decreasing order of importance: number of ruffed grouse (*Bonasa umbellus*) hunters, hunting season frameworks, license type, and woodcock population indices. We used these models to partition harvest reductions after the implementation of recent regulation restrictions into 3 components: 1) direct effects of regulation restriction on annual harvests by active hunters, 2) indirect effects of regulation restrictions operating via reduced hunter participation, and 3) reduced hunter participation not associated with regulation change. The direct effect of regulation restrictions was an estimated reduction in annual harvest among active hunters by approximately 26,090 woodcock, and we estimated an additional harvest reduction of about 55,490 woodcock associated with reduced hunter numbers. Based on models of hunter numbers, regulation restrictions may have directly resulted in about 6,170 fewer woodcock hunters, which translated to an annual harvest reduction of 15,230 woodcock or about 27% of the harvest reduction associated with fewer hunters. Thus, we estimate the cumulative effects of "background" declines in hunter numbers, declines in hunter activity associated with regulation restrictions, and the effects of regulation restriction on active hunters reduced annual harvest by 81,580 birds; this estimate was about 2% higher than the observed difference in mean annual woodcock harvests before and after implementation of regulation restrictions. Although the overall decline in small game hunters in Michigan has likely reduced risks of overexploitation for a number of small game species, research and management directed toward reducing uncertainties about the roles of harvest and habitat loss in woodcock declines would help agencies better address conservation goals for this species.

Proceedings of the American Woodcock Symposium 10: 185–194

Key words: American woodcock, harvest, hunting, frameworks, hunting regulations, Michigan.

The United States Fish and Wildlife Service (USFWS) regulates American woodcock (*Scolopax minor*) harvest through hunting season frameworks (season length, daily limits, and earliest and latest dates; Kelley and Rau 2005); states then choose specific seasons that must conform to these frameworks. The USFWS manages woodcock populations within 2 management regions in cooperation with the Atlantic, Mississippi, and Central Flyways with Michigan being part of the Central Management Region (CMR). Between 1954 and 2004, the USFWS changed earliest and latest dates for woodcock hunting seasons 8 times while woodcock season length or daily limits changed 3 times in the CMR (Kelley and Rau 2005). Annual estimates of harvest and hunting effort provide wildlife managers one means to evaluate impacts of changing migratory bird hunt-

---

[1] Email: luukkonend@michigan.gov

ing season frameworks. State agency harvest surveys provide the best historic estimates or indices to long-term woodcock harvest as federal surveys only included hunters who purchased a U.S. Migratory Bird Hunting and Conservation (Duck) Stamp prior to initiation of the Harvest Information Program (Straw et al. 1994, Kelley and Rau 2005).The Michigan Department of Natural Resources (MIDNR) has estimated woodcock hunting effort and harvest via post-season surveys of small game hunters since 1954 (Frawley 2004*a*) and Michigan has led the nation in number of woodcock hunters and annual harvest (Straw et al. 1994, Kelley and Rau 2005).

Breeding population indices in the CMR indicate a long-term decline in woodcock abundance since 1968 (Kelley and Rau 2005). Although U.S. woodcock harvests have also declined, some biologists attributed reduced harvests more to declining hunter numbers than to declining woodcock abundance (Straw et al. 1994). Incomplete sampling frameworks for historic federal harvest surveys as well as changing woodcock abundance and hunter numbers complicate interpretation of harvest estimates in response to changing woodcock hunting season frameworks. Hunting regulations may impact hunter behavior and the number of woodcock harvested in several ways. For example, changing season length or daily bag limits may modify the number of active hunters, the number of days hunted per active hunter, or the daily harvest per hunter. Our objective was to evaluate the influence of hunter numbers, woodcock abundance, and hunting season frameworks on woodcock harvest and hunting effort in Michigan from 1954–2004.

METHODS

Although sample sizes varied each year, the basic survey methodologies and the sampling plan for estimating Michigan woodcock hunter effort and harvest was changed only once since 1954. The MIDNR made an important change in the small game licensing structure by the creation of a sportsman license in 1970 (Hawn 1979). This changed the sampling frame for surveys, and we included a variable in our analyses that grouped years before and after initiation of this license type to account for this change. Each year following the completion of small game hunting seasons, the MIDNR sent a questionnaire to randomly selected small game hunting license purchasers. The number of small game licensees that received questionnaires increased from about 4,000 during 1954–1962 to 5,000–6,000 during 1963–1978 (Hawn 1979). Since 1978, the number of small game hunters surveyed by MIDNR has ranged from about 5,000 to 16,000 hunters, except in 1984 when the MIDNR did not conduct a survey. Response rates were variable, so MIDNR sent ≤2 follow-up questionnaires to non-respondents in an attempt to achieve >70% response each year; response rates ranged from 60 to 95% over the course of our study. The survey produced estimates of woodcock hunter numbers, hunting effort, and harvest. Hunting effort was quantified as the number of individual days an individual hunted, regardless of how long they spent hunting each day. Recently, MIDNR estimated harvest with a stratified random sampling design, using county of residence as the stratum, to improve precision (Frawley 2004*a*). More detailed year-specific sampling methodologies are documented in MIDNR Wildlife Division Reports (e.g., Frawley 2004*a*) maintained on file in the MIDNR Lansing office.

We modeled harvest using linear models with 2 categorical explanatory variables: hunting season frameworks and license types (years <1970 or years >1970), and 2 continuous covariates: woodcock abundance indices for Michigan (Kelley and Rau 2005) and hunter numbers. Our decision to use hunter numbers instead of hunting effort (hunter-days) for analysis was somewhat arbitrary as hunter numbers and effort were highly correlated ($r = 0.96$). We defined 4 season frameworks based on combinations of season lengths and daily limits: 40 days, 4 birds (1954–1962); 50 days, 5 birds (1963–1966); 65 days, 5 birds (1967–1996); and 45 days, 3 birds (1997–2004). We also considered including an indicator variable to account for years when federal frameworks allowed seasons to open on or before September 15 or after that date (September 15 was the traditional opening date for ruffed grouse (*Bonasa umbellus*) and woodcock hunting in Michigan); however changes in framework opening dates were coincident with recent changes in season lengths and daily limits, making it impossible to unambiguously estimate effects of framework dates.

We modeled woodcock harvest by fitting 2 sets of models corresponding to different partitions of the data because woodcock abundance indices were not collected prior to 1968. The first model set included the entire time series considering all variables except woodcock abundance indices. The second model set included all explanatory variables (i.e., including woodcock abundance indices) for the period 1968–2004. Our most complex models included an interaction between hunter numbers and hunting season frameworks and an interaction between woodcock abundance indices and hunting season frameworks, which allowed slopes of linear relationships between harvest and covariates to differ among hunting season framework categories. We ranked 9 candidate models fit to the full data set and 17 models fit to the reduced data set using information-theoretic methods and estimated model weights based on Akaike's Information Criterion adjusted for small sample size (AIC_c; Burnham and Anderson 2002). For each model, we calculated the number of parameters (K), small sample Akaike's information criterion (AIC$_c$), difference in AIC$_c$ relative to smallest AIC$_c$ in the model set (Δ_i), AIC$_c$ weight (w_i), and coefficient of determination adjusted for number of parameters (R^2). We calculated model-weighted parameter estimates using subsets of models relevant to the parameters of interest (Burnham and Anderson 2002). We did not attempt to calculate model-weighted parameter estimates for the regulation framework change from 50 days and 5 birds (1963–1966) to 65 days and 5 birds (1967–1996) because of the short duration of the 50-day framework and the changes made in the mail survey sampling frame shortly after this framework change.

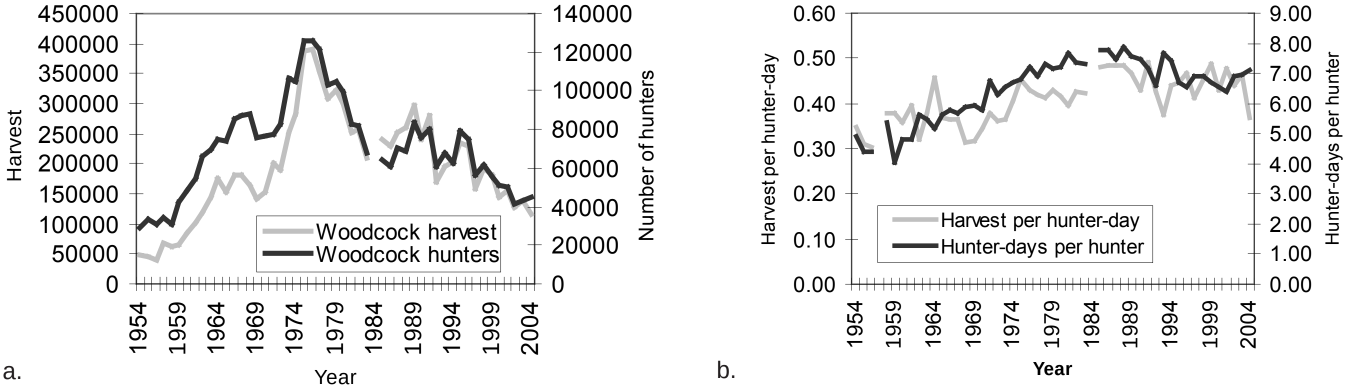
We modeled woodcock hunter numbers as a function of woodcock abundance indices, hunting season frameworks, license type, and numbers of ruffed grouse hunters. Since ruffed grouse and woodcock are commonly hunted at the same time, we included ruffed grouse hunter numbers in the model to account for changes in hunting participation among the population of potential hunters (i.e., woodcock hunters could be considered a subgroup of ruffed grouse hunters). Our methods for fitting and ranking these models were similar to methods used to fit harvest models; we considered 2 partitions of the data and our most complex models included an interaction between ruffed grouse hunter numbers and hunting season frameworks and an interaction between woodcock abundance indices and hunting season frameworks.

For the most recent regulation restriction, we used model-averaged parameter estimates from harvest and hunter models to partition effects of season frameworks into those resulting from direct effects of regulation restriction on annual harvests of active hunters, indirect effects of regulation restrictions operating via reduced hunter participation, and effects of reduced hunter participation not associated with regulation change (i.e., background decline in hunter numbers). We used differences in mean annual hunter numbers 8 years before and after regulation change as our overall estimate of change in hunter numbers after implementation of regulation restrictions. We estimated effects of overall change in hunter numbers on harvest as the product of the parameter estimate relating number of hunters to harvest and observed differences in mean number of hunters. We estimated the indirect effect of regulations reducing hunter participation as the product of parameters for effects of regulations on hunter numbers and the parameter estimate relating number of hunters to harvest. We utilized the program SPSS Version 16 (SPSS Inc., Chicago, Illinois) for all statistical analyses.

RESULTS

Estimates of woodcock hunter numbers ranged from 29,150 during 1954 to 126,270 during 1976; estimates of woodcock harvest ranged from 40,630 during 1956 to 390,370 during 1976; annual estimates of hunter numbers and harvest were highly correlated ($r = 0.883$, $n = 50$; Figure 1a). Hunter numbers and harvest increased during the period 1954–1976 and then declined (Figure 1a). Estimates of hunter-days per hunter and harvest per hunter-day increased from 1954 through the late 1980s, and then declined slightly through 2004 (Figure 1b). Unlike changing trends in hunter numbers and harvest, woodcock abundance indices for Michigan indicated an overall long-term decline in woodcock abundance with shorter periods of relative stability during 1968–1980 and 1982–1991 (Figure 2).

Based on Akaike weights, the top-ranked harvest model among 9 models fit to the entire time series included number of hunters and license type (Akaike



a. b.

Figure 1. Estimates of (a) American woodcock harvest and hunter numbers and (b) woodcock harvest per hunter-day and hunter-days per hunter in Michigan, 1954–2004.

Table 1. Candidate linear models considered for predicting American woodcock harvest in Michigan, 1954–2004.For each model, we report number of parameters (K), small sample Akaike's information criterion (AIC_c), difference in AIC_c relative to smallest AIC_c in the model set (Δ_i), AIC_c weight (w_i), and coefficient of determination adjusted for number of parameters (R^2).

Model	Variables[a]	K	AIC_c	Δ_i	w_i	R^2
1	Hunters, license	4	1,014.2	0.00	0.576	0.92
2	Hunters, regulations, license	7	1,014.9	0.66	0.415	0.93
3	Hunters×regulations, license	10	1,022.6	8.34	0.009	0.93
4	Hunters, regulations	6	1,053.5	39.27	<0.001	0.84
5	Hunters×regulations	9	1,061.4	47.15	<0.001	0.83
6	Hunters	3	1,066.8	52.60	<0.001	0.78
7	Regulations, license	6	1,081.8	67.61	<0.001	0.72
8	Regulations	5	1,095.4	81.16	<0.001	0.62
9	License	3	1,112.7	98.46	<0.001	0.44

[a] All models include an intercept parameter, and models with interactions include associated single-variable effects.Hunters = number of woodcock hunters; license = variable indicating years before and after change in licensing options; regulations = federal regulation framework.

weight, $w = 0.576$; Table 1). A model including hunting season frameworks in addition to number of hunters and license type received almost as much support as the top-ranked model ($w = 0.415$; Table 1). The best single-explanatory variable model included number of hunters; however, this model received relatively little support ($w < 0.01$; Table 1). The sum of Akaike weights for models containing number of hunters was >0.99 as was the sum of weights for models containing the variable license type. The sum of Akaike weights for models containing hunting season frameworks was 0.42. Although coefficients of determination (R^2) were high for models with high Akaike weights (Table 1), the R^2 statistic was nearly identical for the top 3 models and provided no basis for discriminating among the top models.

The top 2 harvest models among 17 models fit to the 1968–2004 time series (including woodcock abundance) accounted for about 72% of the Akaike weight. These models were identical to the top 2 models fit to the entire time series, but the ranking order was reversed, with the model including number of hunters, hunting season frameworks, and license type receiving most support ($w = 0.383$; Table 2). A harvest model including number of hunters, license type, and woodcock abundance indices ranked third among models fit to the reduced time series ($w = 0.130$; Table 2) and the fourth-ranked model, including all explanatory variables without interaction, fit the data nearly as well ($w = 0.102$; Table 2). The sum of Akaike weights for models containing number of hunters was >0.99 as was the sum of weights for models containing the variable license type. Summed Akaike weights for models containing hunting season frameworks and woodcock population indices were 0.53 and 0.28, respectively.

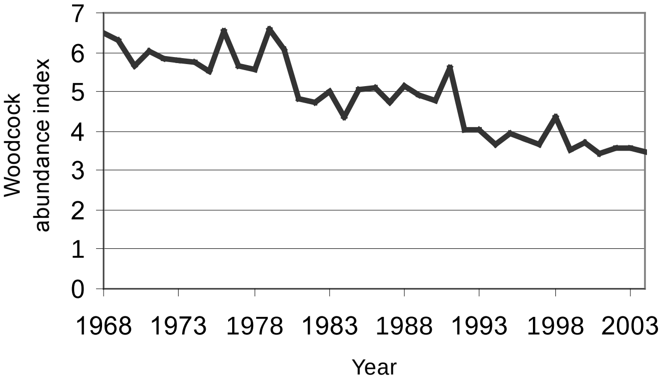


Figure 2. Annual indices of American woodcock heard during Singing-ground Surveys in Michigan (Kelley and Rau 2005), 1968–2004.

The top 2 ranked models predicting woodcock hunter numbers among 9 models fit to the entire time series (excluding woodcock abundance) received almost equal support and together these models accounted for about 88% of the Akaike weight (Table 3); the top ranked model included grouse hunter numbers, hunting season frameworks, and license type ($w = 0.458$; Table 3), whereas the second-ranked model included the same explanatory variables, excluding license type ($w = 0.425$; Table 3). The sum of Akaike weights for models containing number of grouse hunters was >0.99 as was the sum of weights for models containing the hunting season framework variable. The sum of Akaike weights for models containing license type was 0.46.

The top-ranked model predicting woodcock hunter numbers among 17 models fit to the reduced time series (including woodcock abundance indices) included num-

Table 2. Candidate linear models considered for predicting American woodcock harvest in Michigan, 1968–2004.For each model, we report number of parameters (K), small sample Akaike's information criterion (AIC$_c$), difference in AIC$_c$ relative to smallest AIC$_c$ in the model set (Δ_i), AICc weight (w_i), and coefficient of determination adjusted for number of parameters (R^2).

Model	Variables[a]	K	AIC$_c$	Δ_i	w_i	R^2
1	Hunters, regulations, license	5	740.5	0.00	0.383	0.86
2	Hunters, license	4	740.7	0.27	0.335	0.86
3	Hunters, license, population	5	742.6	2.16	0.130	0.86
4	Hunters, regulations, license, population	6	743.1	2.65	0.102	0.86
5	Hunters×regulations, license, population	7	745.8	5.36	0.026	0.86
6	Hunters, regulations×population, license	7	746.1	5.61	0.023	0.86
7	Hunters, population	4	759.9	19.47	<0.001	0.76
8	Hunters	3	762.3	21.80	<0.001	0.73
9	Hunters, regulations, population	6	761.0	23.46	<0.001	0.76
10	Hunters, regulations	4	764.6	24.14	<0.001	0.72
11	Regulations, license, population	5	768.4	27.95	<0.001	0.71
12	License, population	4	769.8	29.34	<0.001	0.68
13	Regulations, license	4	787.2	46.72	<0.001	0.48
14	Regulations, population	4	794.9	54.39	<0.001	0.36
15	Regulations	3	795.9	55.38	<0.001	0.32
16	Population	3	796.6	56.16	<0.001	0.30
17	License	3	806.6	66.18	<0.001	0.08

[a] All models include an intercept parameter, and models with interactions include associated single-variable effects.Hunters = number of woodcock hunters; license = variable indicating years before and after change in licensing options;

ber of grouse hunters and hunting season frameworks (w = 0.205; Table 4). A model including woodcock population indices in addition to number of grouse hunters and a model including license type in addition to number of grouse hunters both received almost as much support as the top-ranked model (w > 0.142; Table 4). The best single-explanatory variable model included the number of grouse hunters; model weights were relatively dispersed among the top 6 models (w > 0.104; Table 4). The sum of Akaike weights for models containing num-

Table 3. Candidate linear models considered for predicting American woodcock hunter numbers in Michigan, 1954–2004.For each model, we report number of parameters (K), small sample Akaike's information criterion (AIC$_c$), difference in AIC$_c$ relative to smallest AIC$_c$ in the model set (Δ_i), AIC$_c$ weight (w_i), and coefficient of determination adjusted for number of parameters (R^2).

Model	Variables[a]	K	AIC$_c$	Δ_i	w_i	R^2
1	Grouse hunters, regulations, license	7	904.0	0.00	0.458	0.90
2	Grouse hunters, regulations	6	904.1	0.15	0.425	0.90
3	Grouse hunters×regulations	9	908.0	3.98	0.063	0.90
4	License, grouse hunters×regulations	10	908.3	4.28	0.054	0.90
5	Grouse hunters, license	4	924.3	20.28	<0.001	0.84
6	Grouse hunters	3	927.1	23.08	<0.001	0.83
7	Regulations	5	976.0	72.01	<0.001	0.56
8	Regulations, license	6	978.4	74.42	<0.001	0.55
9	License	3	1008.3	104.79	<0.001	0.11

[a] All models include an intercept parameter, and models with interactions include associated single-variable effects.Grouse hunters = number of ruffed grouse hunters; license = variable indicating years before and after change in licensing options; regulations = federal regulation framework.

Table 4. Candidate linear models considered for predicting American woodcock hunter numbers in Michigan, 1968–2004. For each model, we report number of parameters (K), small sample Akaike's information criterion (AIC_c), difference in AIC_c relative to smallest AIC_c in the model set (Δ_i), AIC_c weight (w_i), and coefficient of determination adjusted for number of parameters (R^2).

Model	Variables[a]	K	AIC_c	Δ_i	w_i	R^2
1	Grouse hunters, regulations	4	656.8	0.00	0.205	0.86
2	Grouse hunters, population	4	657.4	0.59	0.153	0.86
3	Grouse hunters, license	4	657.5	0.74	0.142	0.86
4	Grouse hunters, regulations, license	5	657.6	0.79	0.138	0.86
5	Grouse hunters, regulations, population	5	658.0	1.28	0.108	0.86
6	Grouse hunters	3	658.1	1.36	0.104	0.85
7	Grouse hunters×regulations	5	659.5	2.69	0.053	0.86
8	Grouse hunters, license, population	5	659.7	2.90	0.048	0.86
9	Grouse hunters, regulations, license, population	6	660.4	3.62	0.033	0.86
10	Grouse hunters, license, regulations×population	7	663.2	6.46	0.008	0.86
11	License, population, grouse hunters×regulations	7	663.5	6.70	0.007	0.86
12	License, population	4	683.5	26.74	<0.001	0.71
13	Regulations, license, population	5	684.4	27.69	<0.001	0.71
14	Population	3	692.3	35.51	<0.001	0.61
15	Regulations	3	708.4	51.66	<0.001	0.39
16	Regulations, license	4	710.7	53.96	<0.001	0.38
17	License	3	727.4	70.60	<0.001	0.03

[a] All models include an intercept parameter, and models with interactions include associated single-variable effects.Grouse hunters = number of ruffed grouse hunters; license = variable indicating years before and after change in licensing options; regulations = federal regulation framework; population = woodcock population index.

Table 5. Parameter estimates resulting from averaging linear models predicting American woodcock harvest response to changing hunting regulations, woodcock hunter numbers, woodcock abundance, and hunting license types. We modeled response of woodcock hunter numbers using the same explanatory variables as we used to predict harvest, except ruffed grouse hunter numbers replaced woodcock hunter numbers.

Parameter	Data set (Years)	Response variable			
		Woodcock harvest		Woodcock hunters	
		$\bar{\hat{B}}$	SE	$\bar{\hat{B}}$	SE
Intercept	1954–2004	41,461	18,133	6,279	6,694
	1968–2004	32,166	27,256	2,739	9,355
Regulation change 40(4) to 50(5)[a]	1954–2004	7,800	13,104	20,319	14,738
Regulation change 65(5) to 45(3)[a]	1954–2004	–26,093	6,744	–6,167	6,084
	1968–2004	–26,717	23,385	–7,118	4,016
License type	1954–2004	–82,395	13,547	6,686	2,136
	1968–2004	–96,093	17,993	6,801	2,258
Woodcock hunter numbers	1954–2004	2.47	0.31	—	—
	1968–2004	2.57	0.32	—	—
Ruffed grouse hunter numbers	1954–2004	—	—	0.44	0.04
	1968–2004	—	—	0.42	0.05
Woodcock abundance index	1954–2004	—	—	—	—
	1968–2004	6,128	9,791	2,980	1,018

[a] Regulation changes are expressed as days (daily limit).

Table 6. Estimates of mean annual American woodcock harvest and hunting effort for 8-year periods before (1989–1996) and after (1997–2004) implementation of a restricted hunting season framework allowing 45 days of hunting and a 3-bird daily limit.

	Woodcock hunting season framework			
	65 days, 5-bird limit		45 days, 3-bird limit	
Variable	$\bar{x}$	SE	$\bar{x}$	SE
Woodcock harvest	231,328	14,986	151,595	8,995
Woodcock hunters	73,008	2,988	50,543	2,477
Harvest per hunter-day	0.443	0.012	0.441	0.013
Days hunted per hunter	7.13	0.16	6.80	0.08

ber of grouse hunters was >0.99 whereas sums for models containing hunting season framework, license type, and woodcock population indices were 0.55, 0.38, and 0.36, respectively.

Model-averaged parameter estimates for predicting the effects of woodcock hunter numbers on harvests suggested that each Michigan hunter contributed an expected 2.47 (95% CI = ± 0.61) or 2.57 (95% CI = ± 0.63) woodcock to the annual harvest, depending on which time series we used for estimation (Table 5). Our model-averaged parameter estimates relating woodcock abundance indices to harvest suggested an increasing harvest with increasing woodcock abundance, but the estimate was imprecise and confidence intervals broadly overlapped zero ($\bar{B}$ = 6,128; 95% CI = ± 19,190). Our estimate of the effects of hunting season liberalizations enacted in 1963 (increase from 40 to 50 days and increased daily limit from 4 to 5) was imprecise, but suggested an increase in annual harvest by about 7,800 woodcock (95% CI = ± 25,684); the regulation restriction enacted in 1997 (reduced from 65 to 45 days and decreased daily limit from 5 to 3) resulted in an estimated decrease in annual woodcock harvest of 26,093 (95% CI = ± 13,218) and 26,717 (95% CI = ± 45,834), depending on the time series we used for the estimate. The most precise estimates for the 1997 regulation restriction was from the full time series. Values predicted from model-averaged estimates derived from these data showed a reasonable model fit when plotted with observed values (Figure 3).

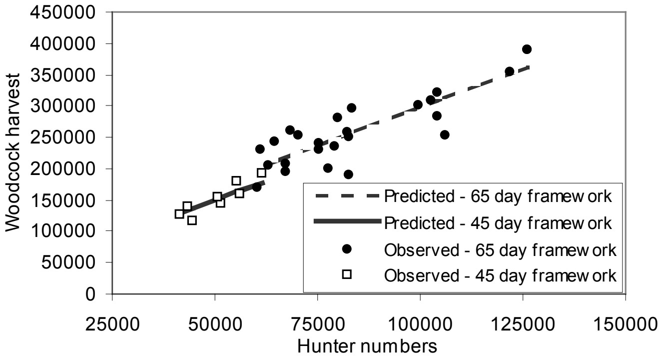


Figure 3. Observed relation between American woodcock harvest and hunter numbers in Michigan under 2 hunting season frameworks and predicted values based on model-averaged parameter estimates, 1971–2004.

Model-averaged parameter estimates for predicting the effects of ruffed grouse hunter numbers on woodcock hunter numbers suggested that for each grouse hunter there were about 0.44 (95% CI = ± 0.08) or 0.42 (95% CI = ± 0.10) woodcock hunters in Michigan, depending on the time series we used for estimation (Table 5). Model-averaged parameter estimates for the effects of woodcock abundance indices on hunter numbers suggested increasing hunter numbers with increasing woodcock abundance (Table 5). Our estimate of the effects of hunting season liberalizations enacted in 1963 was imprecise, but suggested an increase in hunter activity by 20,319 woodcock hunters (95% CI = ± 28,886). The regulation restriction enacted in 1997 resulted in an estimated decrease of 6,167 (95% CI = ± 11,924) and 7,118 (95% CI = ± 7,871) active woodcock hunters, depending on the time series we used for the estimate.

During the most recent 8-year period after woodcock hunting season frameworks were restricted (i.e., after 1996), mean annual harvest declined 34% and mean annual numbers of hunters declined 31% compared to the previous 8-year period; mean number of days hunted per hunter declined 4.7% and mean harvest per hunter-day declined 0.3% over the same period (Table 6). Based on parameter estimates from our linear models predicting harvest from hunter numbers, the direct effect of regulation restriction was a reduction in annual harvest among active hunters by 26,093 woodcock (Table 5). Based on a mean reduction of 22,465 hunters associated with the period of regulation restrictions (Table 6) and an annual harvest of 2.47 woodcock per hunter (Table 5), we estimate an annual harvest reduction of about 55,490 associated with reduced hunter numbers. This estimate includes any effect of regulation restrictions on hunter activity. Our model predicting hunter numbers suggests that regulations may have contributed to lack of participation by about 6,167 hunters, which translates to a harvest reduction of about 15,230 or about 27% of the harvest reduction associated with fewer hunters. Thus, we estimate the cumulative effects of "background" declines in hunter numbers, declines in hunter activity associated with regulation restrictions, and the effects of regulation restriction on active hunters reduced annual harvest by 81,583 birds (55,490 + 26,093); this estimate is about 2% higher than the observed difference in mean annual woodcock harvests before and after implementation of regulation restrictions (79,730: Table 6).

DISCUSSION

Game bird harvests likely vary in response to a suite of factors. We found that the best models predicting woodcock harvests included, in decreasing order of importance: number of woodcock hunters, license type, hunting season frameworks, and woodcock abundance indices. Although woodcock harvests were closely associated with numbers of active hunters, our analyses suggested that the 1997 restriction in federal regulation frameworks contributed to woodcock harvest declines among active woodcock hunters in Michigan; however, the 1997 regulation restriction did not reduce harvest per hunter-day after this regulation change (Table 6). Changes in woodcock hunting regulations may also impact harvest indirectly via reduced hunter recruitment or loss of hunters. The effect of woodcock abundance on harvest was relatively small compared to the effects of hunter numbers and regulations—our parameter estimates indicated that a change in woodcock population indices by one singing male per route results in a change in harvest of about 6,100 woodcock annually. Although license type was not a variable of direct interest in our study, it was important to consider models that accounted for changes in the sampling frame for post-season mail surveys.

We found that the best models predicting woodcock hunter numbers included, in decreasing order of importance: number of ruffed grouse hunters, hunting season frameworks, license type, and woodcock population indices. We found a strong association between numbers of grouse hunters and woodcock hunters, which is not surprising since these species are often hunted together in early-succession forested habitats. Although imprecise, parameter estimates suggest that recent regulation restrictions may have contributed to declines in woodcock hunter numbers in Michigan. Hunter numbers and resulting harvests also likely changed for reasons unrelated to regulation restrictions. Woodcock and ruffed grouse hunters have been declining in Michigan since the 1980s and these declines paralleled overall declining numbers of small game hunters (Frawley 2004*b*). Also, about half of the woodcock harvest reduction coincident with 1997 regulation restrictions appears linked to declines in hunter numbers not directly related to regulation restrictions. Changes in hunter numbers or effort have been related to wildlife abundance for some species either linearly (e.g., bobwhite quail [*Colinus virginianus*]; Guthery et al. 2004) or curvilinearly (e.g., white-tailed deer [*Odocoileus virginianus*]; Van Deelen and Etter 2003) and we observed a positive relation between woodcock population indices and hunter numbers; however, woodcock hunters and harvest declined at average rates of about 4–5% per year from 1989 through 2004, which outpaced the woodcock population decline of about 2% per year in Michigan. Since ruffed grouse and woodcock are often hunted together and we did not consider models including ruffed grouse abundance, our analysis did not consider the possibility that woodcock hunter numbers respond more closely to changes in ruffed grouse rather than woodcock abundance. Data collected by MIDNR on ruffed grouse abundance since 1990 lends little support to this model (Figure 4), although this time series is relatively short compared to data available for woodcock.

Although stakeholders may perceive a tight linkage between regulations and harvest, experience with other migratory birds suggests that for some species regulation changes have had relatively small effects on harvest or harvest rates. For example, probability distributions for harvest rates expected with 60- and 45-day seasons for mid-continent mallards (*Anas platyrhynchos*) showed large overlap in distributions and substantial re-

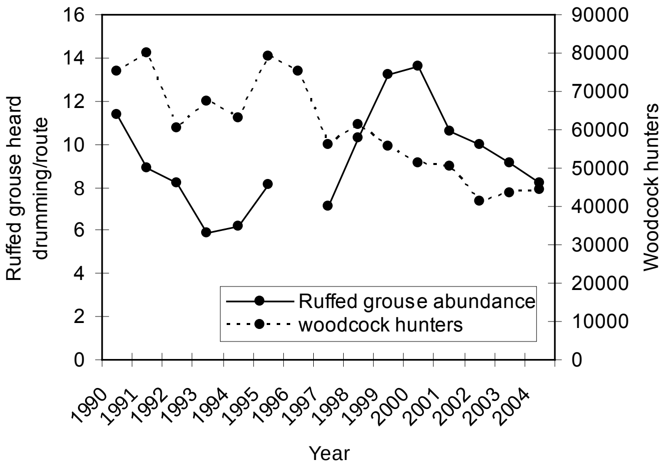


Figure 4. Ruffed grouse drumming count index and woodcock hunter numbers in Michigan, 1990–2004.

duction in harvest rates were expected only with 30-day or closed seasons (USFWS 2006). Responses of harvest and harvest rates to regulation changes might be better predicted with additional studies directed at understanding how hunter numbers and harvest respond to changes in hunting regulations and animal abundance. Specifically, the relationship of woodcock harvest to these variables could be assessed at the woodcock management region scale if historic estimates of regional woodcock harvest can be converted to the same scale as more recent Harvest Information Program estimates. These studies should also include characterizing hunter ability as more skillful hunters may persist as hunter numbers decline (Guthery et al. 2004).

(*Editors' note: After the symposium was held, a working group composed of USFWS and Flyway biologists, converted woodcock harvest estimates from the old Mail Survey Questionnaire Survey to the same scale as the Harvest Information Program Survey using the methods developed by Padding et al. 2010.)*

MANAGEMENT IMPLICATIONS

There remains considerable uncertainty about the system involving hunters, harvest, and woodcock population response to exploitation. Agencies managing wildlife populations and hunters via harvest regulations often attempt to simultaneously meet multiple objectives that balance biological and social risks of exploitation with goals associated with providing recreational hunting opportunities. Uncertainty about impacts of harvest on a declining population tends to shift decisions in favor of regulation restrictions; however, strategies that are too risk-aversive unnecessarily constrain recreational opportunities and could inhibit goals for hunter recruitment and retention. For example, if woodcock are declining for reasons unrelated to harvest, then additional regulation restrictions may not benefit woodcock populations, but might incur the cost of expediting the decline in participation of woodcock hunting. Hunting regulations that are too liberal may accelerate the decline of woodcock, leading to loss of interest in hunting because of low woodcock abundance. For some species, hunting effort may be self-regulatory in the sense that number of hunters decline along with declining game abundance (Guthery et al. 2004); however when decisions about hunting participation are based on multiple species (e.g., woodcock and ruffed grouse), there is a risk that hunting effort will be maintained by the species in greater abundance and not track abundance of a species in decline. Although the overall decline in small game hunters in Michigan has likely reduced risks of overexploitation for a number of small game species, research and management directed toward reducing uncertainties about the roles of harvest and habitat loss in woodcock declines would help agencies better address conservation goals for this species.

ACKNOWLEDGMENTS

Funding and support for this study were provided by the Michigan Department of Natural Resources and the Federal Aid in Wildlife Restoration, Pittman-Robertson Project 147. We would especially like to thank Michigan DNR employees who assisted with harvest and field surveys over the many years of data used in this study. We appreciate comments provided by T. Cooper, D. R. Etter, P. Lederle, S. Mayhew, P. Padding, and one anonymous reviewer.

LITERATURE CITED

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information–theoretic approach. Second edition. Springer-Verlag, New York, New York, USA.

Frawley, B. J. 2004*a*. Small game harvest and characteristics of small game hunters in Michigan, 2004. Michigan Department of Natural Resources, Wildlife Division Report No. 3449, Lansing, Michigan, USA.

Frawley, B. J. 2004*b*. Demographics, recruitment, and retention of Michigan hunters. Michigan Department of Natural Resources, Wildlife Division Report No. 3426, Lansing, Michigan, USA.

Guthery, F. S., A. K. Crews, J. J. Lusk, R. N. Chapman, and M. Sams. 2004. Effects of bag limits on bobwhite hunters and harvest. Journal of Wildlife Management 68: 1095–1103.

Hawn, L. J. 1979. Hunting results, Michigan small game seasons, 1978. Surveys and Statistical Services Report 189. Michigan Department of Natural Resources, Lansing, Michigan, USA.

Kelley, J. R., Jr., and R. D. Rau. 2005.American woodcock population status, 2005. U.S. Fish and Wildlife Service. Laurel, Maryland, USA.

Padding, P. I., M. T. Moore, K. D. Richkus, and E. M. Martin. 2010. Estimating woodcock hunter activity and harvest in the United States. Pages 29–35 *in* C. A. Stewart, and V. R. Frawley, editors. Proceedings of the Tenth American Woodcock Symposium. Michigan Department of Natural Resources and Environment, Lansing, Michigan, USA.

Straw, J. A., D. G. Krementz, M. W. Olinde, and G. F. Sepik. 1994. American woodcock. Pages 97–114 *in* T. C. Tacha and C. E. Braun, editors. Migratory shore and upland game bird management in North America.International Association of Fish and Wildlife Agencies, Washington, D.C., USA.

U.S. Fish and Wildlife Service. 2006. Adaptive harvest management: 2006 hunting season. U.S. Department of the Interior, Washington, D.C., USA.

Van Deelen, T. R., and D. R. Etter. 2003. Effort and the functional response of deer hunters. Human Dimensions of Wildlife 8: 97–108.

David R. Luukkonen is a Wildlife Research Specialist with the Michigan Department of Natural Resources; he is also an adjunct faculty member of the Department of Fisheries and Wildlife at Michigan State University. His primary interest is research to improve management decisions for migratory and resident game birds.

Not Pictured

Brian Frawley is a Wildlife Research Specialist with the Michigan Department of Natural Resources. He earned his B.S. from the University of Wisconsin-Stevens Point and his M.S. from Iowa State University.

AMERICAN WOODCOCK WINGBEE RELIABILITY

10th American Woodcock Symposium
Roscommon, Michigan, USA

DAVID G. KREMENTZ[1], U.S. Geological Survey Arkansas Cooperative Fish & Wildlife Research Unit, Department of Biological Sciences, University of Arkansas, *Fayetteville, AR 72701*

EDWARD E. GBUR, JR., Agriculture Statistics Lab, University of Arkansas, *Fayetteville, AR 72701*

Abstract: Recruitment indices are estimated annually for the American woodcock (*Scolopax minor*) using data collected through the Wing-collection Survey. At the annual woodcock wingbee, participants identify the age and sex of woodcock wings harvested by hunters. Participants go through training and testing to ensure that they are competent at aging and sexing woodcock wings, but the efficiency of these efforts has not been evaluated. We collected data on participants over 6 years to address their reliability in aging and sexing wings. Only about 65% of participants successfully passed a mandatory test in identification skills before scoring wings, and only about 60% of participants passed the same test on finishing scoring at the end of the wingbee. The most common mistakes included designating a wing from an immature bird as an adult or misidentifying a female as a male. We make a number of suggestions for improving the wingbee operation.

Proceedings of the American Woodcock Symposium 10: 195–201

Key words: aging, American woodcock, sexing, *Scolopax minor*, wingbee.

The American woodcock (*Scolopax minor*) is a popular game bird throughout eastern North America. The authority for management of this game bird resides with the U.S. Fish and Wildlife Service (USFWS) and Canadian Wildlife Service. In order to make sound management decisions for this bird, annual information on population abundance, harvest, and recruitment are necessary (Kelley and Rau 2006).

To address recruitment information needs, a Wing-collection Survey was developed (Kelley and Rau 2006). The survey is administered as a cooperative effort between woodcock hunters, the USFWS, and state wildlife agencies. Wing-collection Survey participants are provided with prepaid mailing envelopes and asked to submit one wing from each woodcock they bag. The age and sex of the birds are determined by examining plumage characteristics (Martin 1964, Sepik 1994) during the annual woodcock wingbee conducted by state, federal, and private biologists. The ratio of immature birds per adult female in the harvest provides an index of recruitment of young into the population.

Determining the age and sex of woodcock wings is not straightforward (McAuley et al. 1993) and for this reason, the USFWS trains all participants who assist with the wingbee. The reliability of these participants at aging and sexing wings has never been evaluated. Our objectives were to assess the following questions: 1) whether some participants learn more quickly than others; 2) whether participants who attend multiple wingbees improve at aging and sexing with experience; 3) whether there have been any annual patterns in reliability of participants; 4) whether participants consistently misidentify either by age or sex and if so, in what direction; and 5) whether participants make aging or sexing mistakes at the end of the wingbee because of fatigue. With information on the reliability of past wingbee participants, and assuming that such mistakes will be made in the future, we made a number of recommendations aimed at improving the wingbee operation.

METHODS

During the first morning of the week-long wingbee, all participants are given a short course by the USFWS woodcock specialist, lasting about 2 hours, in woodcock aging and sexing methods. The primary method used to age wings is based on feather appearance (Martin 1964, Sepik 1994). Briefly, the age of juveniles is based on a distinct subterminal band on secondary feathers 5–8, symmetrical mottling on both sides of the midline of the feather, and a relatively pointed feather tip. Martin (1964) found that an aging error rate of <2 percent could be achieved with sufficient training, and reported no errors in determining sex. Additional aging and sexing methods also described and include 1) measuring

---

[1] Email: Krementz@uark.edu

the wing length (from the bend of the wing to the tip of the longest straightened primary) for sex (Mendall and Aldous 1943); 2) measuring the combined width of the outer 3 primaries for sex (Greeley 1953, Blankenship 1957); 3) examining the barbules of the primaries for the presence of frayed tips for age (Sheldon et al. 1958); and 4) observing the presence of retained secondaries by adult woodcock for age (G. F. Sepik, USFWS, personal communication). Wingbee participants were encouraged to use any or all methods with which they felt confident to determine age and sex from wings. The instructor emphasized that methods described are not infallible, and encouraged newcomers in particular to seek the assistance of experienced participants when uncertainties arose regarding age or sex of wings examined. Wingbees involved both newcomers and experienced participants.

Sets of woodcock wings and feathers that had been identified to age and sex by a group of expert biologists were available for training and reference. Participants received all publications on woodcock aging and sexing and were encouraged to review materials and practice with the reference parts to become proficient at aging and sexing. Once participants were confident at aging and sexing, they took a required test to assess their reliability. Tests included either 25 or 30 known-age and known-sex wings. The known-age and -sex designations for wings in each test were based on the consensus of >5 expert biologists trained in aging and sexing woodcock wings. Note that a few test answers were changed in subsequent years by consensus of expert biologists. About 5 tests were available to take each year. As test wings became worn, those tests were replaced. One of the 5 tests was an "expert" test and included wings that were especially difficult to age and/or sex. This test was little used. Each participant was asked to take the test and grade themselves with the provided answer sheet. The age and sex of each wing had to be identified. Valid ages were immature, adult, or unknown, while valid sexes were male, female, or unknown. Unknown wings were those wings that were damaged to the extent that correctly identifying either age or sex was not possible. Although it was possible that a wing was both unknown-sex and unknown-age, no such wings were included in any of the tests. Misidentification of ≤1 woodcock wing per test constituted a passing score. An incorrect answer was one where either age or sex for a wing was incorrect. Because hunters included wings of birds other than woodcock in their wing envelopes, the tests also included some wings of the more common non-woodcock species, e.g., northern bobwhite (*Colinus virginianus*), and Wilson's snipe (*Gallinago delicata*). In the case of the non-woodcock wing, the participant was allowed to answer that the wing was not a woodcock, but an answer of unknown–unknown was considered incorrect. If >1 answer per test was incorrect, the participant was encouraged to review the methods for aging and sexing and then take another test. The organizer encouraged participants taking additional tests to use a different set of wings each time. Tests were taken until the participant passed. Once the test was passed, the participant could begin aging and sexing woodcock wings from hunter envelopes.

The reality of the wingbee was that not all participants followed instructions. Some participants did not take any tests, some participants made mistakes while self-grading, and some participants only reported some test results. We believe also that these inconsistencies varied by year. For these reasons, our results are biased. We expect that these biases will continue into the future without changes in the current operation of the wingbee.

We asked that all participants turn in their answer sheets for all tests taken at the end of the training session. We instructed the participants taking each test to record on their answer sheet an individual identification number, year, test identification number, and whether the test taken was a pretest or an exit test. A pretest was any test taken before the participant began aging and sexing wings from hunter envelopes. An exit test was a test taken on the last day that the participant was present at the wingbee and after they were finished aging and sexing wings from hunter envelopes. We only asked participants to take a single exit test although some participants took >1 exit test. For those participants taking multiple tests before passing, a few participants recorded the sequence number on the test sheet, i.e., if a participant took 3 tests before passing, each answer sheet had the additional information of the sequence number of that particular test in the scheme of the 4 tests taken.

Quality control issues for the answer sheets involved interpreting the letter or symbol used to identify age/sex of a wing, interpreting which answer was the answer used to check against, which test the participant took, and whether the test was the exit test. Interpreting which answer was the final answer when multiple answers were given caused us the most concern. Often an answer was crossed out and another answer was recorded adjacent to the crossed out answer. Two interpretations could explain this case: 1) the original answer was incorrect and the correct answer was recorded adjacent to the incorrect answer upon grading the test, or 2) the participant changed their mind, crossed out their original answer and recorded what they thought was the correct answer before grading the test.

Two measures of improvement were considered and calculated for the entire group as well as for those testing in consecutive years and those who had skipped at least one year between their first and second testing. The first measure of improvement was based on the number of pretests taken during their second year compared to their first year. The other measure compared whether or not the participant obtained a passing grade in their second year compared to their first year.

Another way of thinking about improvement is to examine the within-year improvement of pretest scores. We were able to compile the test scores in the order in which they were taken for a subset of the participants who took multiple pretests in a year. At most, we were able to compile 7 tests for a participant. If participants were learning from their mistakes, subsequent test scores should have increased with each attempt.

ANALYSES

Because of the problems with data collection and interpretation described above, the assumptions underlying formal statistical inference procedures are not satisfied and the results of statistical analysis would not be valid. Hence, only descriptive statistics that summarize various aspects of the data will be presented.

RESULTS

Pretest

The number of participants taking the pretest varied across years from 11 to 24 for a total of 110 participants across all 6 years (Table 1). Not all participants took pretests. For example in 1994, one participant did not take a pretest but did take an exit test. Further, during each year, several experienced biologists excused themselves from the testing process. The modal number of tests taken by each participant in order to pass successfully was 1 but the mean was 2.8 (0.2 SE). One participant took 11 tests before passing, but this person voluntarily did not age and sex hunter envelope wings. The percent of participants successfully passing the pretest each year ranged from 32% in 1994 to 86% in 1995. Over all years, only 66% passed the pretest (Table 1).

The overall percentage of participants passing the pretest in a year was not greatly influenced by the number of tests each participant attempted (Table 2). Examining only those participants that passed the pretest on their first attempt (the bottom row of Table 2), we found no evidence that the passing rate differed across years. The percentage of participants that took more than one test before passing (the top row of Table 2) ranged from a low of 27% in 1994 to 89% in 1995. However, for these last 2 analyses, the numbers of participants each year ranged only from 4–17.

Next, we examined the annual pattern for participants who passed the pretest (Table 2 "passed" column). We found no practically significant difference in the percent who passed taking only one test or passed taking multiple tests in different years. Most participants took more than one test each year before passing the pretest.

Table 1. Numbers of woodcock wingbee participants who took and passed a pretest during 1994–2002. Values in parentheses are percentages.

	Pretest result		
Year	**Failed**	**Passed**	**Total**
1994	13 (68)	6 (32)	19
1995	2 (14)	12 (86)	14
1996	7 (37)	12 (63)	19
1997	4 (17)	20 (83)	24
2000	7 (30)	16 (70)	23
2002	5 (45)	6 (55)	11
Total	38 (34)	72 (66)	110

Table 2. Comparison of passing rate for woodcock wingbee participants that either took one pretest or more than one pretest during 1994–2002. Values in parentheses are percentages.

	Pretest result		
Number of pretests taken	**Failed**	**Passed**	**Total**
>1	21 (31)	47 (69)	68
1	17 (40)	25 (60)	42
Total	38 (34)	72 (66)	110

Table 3. Numbers of woodcock wingbee participants who passed an exit test during 1994–2002. Values in parentheses are percentages.

	Exit test result		
Year	**Failed**	**Passed**	**Total**
1994	2 (50)	2 (50)	4
1995	7 (50)	7 (50)	14
1996	4 (25)	12 (75)	16
1997	12 (57)	9 (43)	21
2000	6 (46)	7 (54)	13
2002	3 (27)	8 (73)	11
Total	34 (43)	45 (57)	79

Exit Test

Fewer participants took the exit test (Table 3). The number of participants taking pretests was the same as the number taking the exit test only during 1995 and

2002. The largest difference occurred in 1994 when only 4 of 20 participants took the exit exam. Again, experienced biologists usually excused themselves from taking the exit exam. Across years, we found the percentage of participants who passed ranged from 43% in 1997 to 73% in 2002 and 75% in 1996. On average over years, 57% passed the exit exam.

Score Improvement

There were 18 participants who scored wings for >2 years, ranging from 2–6 years. Of these, 9 participated in only 2 years, two-thirds of whom skipped at least 1 year between returning. Those participants scoring wings for more than 2 years tended to participate in consecutive years.

We examined only the first- and second-year pretest scores from all 18 of these participants in detail. The change in the mean of the highest pretest score from the first to second year was 1.3 (0.9 SE). The results were the same when we considered those who participated in consecutive years and those who did not. In fact, 10 individuals (55.6%) improved or had perfect scores in both years, 5 (27.8%) showed no change and 3 (16.7%) had lower scores in their second year compared to their first year. The largest improvement was 2 additional questions answered correctly and the largest reduction was 2 fewer questions answered correctly. Recall that the room for improvement was small because returning participants were expected to pass with >95% before scoring.

Two-thirds of the multiple-year participants took fewer tests in their second year compared to their first year. However, 44.4% of these participants still took more than one test in their second year. When we considered only whether or not the participant obtained a passing score, 10 participants passed in both years while 6 individuals passed in their second year but not in their first year. There were 2 participants who did not obtain a passing grade in either year.

In looking at the change in participant scores within a year (Figure 1), there was no consistent pattern. If anything, the pattern was for a general improvement, but this was not always the case. In 4 of 28 cases (14.3%), the final score was lower than the first score. The large fluctuation of scores between consecutive tests for many participants provides additional evidence that the data should not be subjected to formal statistical analyses and that the testing procedure needs to be improved.

Aging and Sexing Mistakes

Some 680 mistakes were made in aging a wing during pretests—375 immature woodcock were identified as adults (55.1%; 1.9% SE), and 305 adults were identified as immature birds. A rough approximation of a 95% confidence interval for the percentage of immatures misclassified as adults would span 51.4% to 58.5%. Because this interval does not contain 50%, this suggests that, of the mistakes made, more immatures were misidentified as adults than adults misidentified as immatures. In examining these mistakes by year, we found that in 1994, participants tended to misclassify adults as immatures more often (64%) than in any other year except 2002 (49%).

Many fewer mistakes were made in sexing wings—90 males were identified as females (30.6% of the mistakes) while 204 females were identified as males. More than twice as many females were misidentified as males than males misidentified as females. In the case of sexing, there appeared to be no effect of year on misidentification of the sex of a wing.

DISCUSSION

McAuley et al. (1993) noted that aging woodcock reliably by examining plumage characteristics is difficult. They reported that to achieve about 95% accuracy in differentiating between immature and adult woodcock, most technicians without experience needed about 20 hours of practice with wings of birds of known age and sex. In discussing the problem of aging immature and adult woodcock, McAuley et al. (1993) indicated that most misclassifications were of immature birds being identified as adult because observers tended to examine secondaries proximal to the body that have been replaced by adult feathers. We too found that misidentifying immature birds as adult birds was the pattern for wingbee participants. This error is important because one of the primary goals of the wingbee is to produce the recruitment index for the previous breeding season. The impact of this error would be to calculate recruitment indices that are lower than they should be. An independent review (J. R. Kelley, Jr., USFWS, unpublished data) asked 5 experienced wingbee participants to score again 1,653 woodcock wings from Maine, Pennsylvania, and Virginia that were scored by general participants. Using data assessed by experienced participants resulted in changes in age ratios from 1.494 to 1.597 for Maine, from 0.847 to 1.20 for Pennsylvania, from 1.605 to 1.631 for Virginia and from 1.31 to 1.49 for a combined score. The difference between the general participants' scoring and the expert scoring was in the direction that we found, i.e., general participants were misidentifying immatures as adults and so producing an age ratio that was lower than it should have been.

To address the problem of new participants aging and sexing duck wings at the waterfowl wingbee, a group of experts check every wing assessed (P. I. Pad-

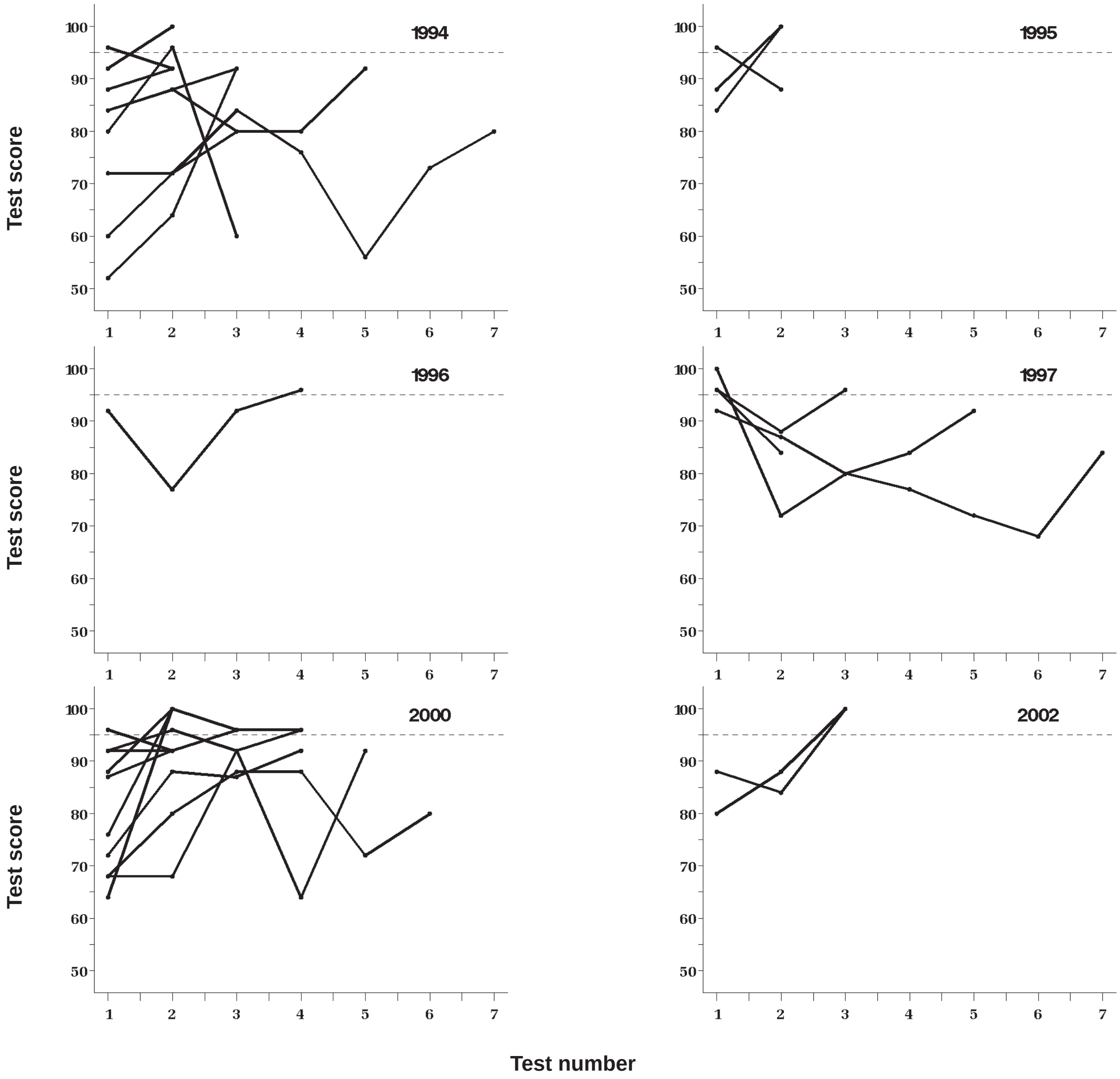


Figure 1. Consecutive pretest scores of wingbee participants within a year.

ding, USFWS, personal communication). Each expert attends a week of rigorous training with reference wings and must pass a test. The test includes 100 mallard (*Anas platyrhynchos*) wings and 3 tests are available. The passing scores required to become recognized as an expert are 95% on the first try, 96% on the second try, and 98% on the third try. Each year, experts spend 1 day before the wingbee reviewing 200 known-age and -sex wings. During this day, very experienced experts review mistakes made by the experts and advise them on how to avoid such mistakes in the future.

The question of whether scores improved with experience at consecutive wingbees is an important one that was not well addressed by our tests. Our tests were centered on improvement in subsequent pretest scores, but only so much improvement in a passing score was possible, i.e., the only improvement possible was to shift from a 96% to a perfect score. We suspect that returning participants perform better at aging and sexing because of their previous wingbee experience, but we cannot state so based on our test results. We agree with the waterfowl wingbee approach that returning participants with sufficient training are a valuable part of the wingbee checking process. Having said this, we were intrigued at the resistance by expert participants to take tests. Not all experts excused themselves, but some consistently did so. That experts can make mistakes was demonstrated through the test answer sheets. The answer sheets were compiled usually by consensus of >5 experts, yet in subsequent years, answers were changed by experts. Aging and sexing wings is difficult and through test scores, even experts can learn from their mistakes.

The low passage rate for both the pretest and exit test are a concern. On average, about 35% of participants failed the pretest, yet apparently, these people went on to score hunter envelope wings. We can think of 2 explanations to this problem. First, mistakes in grading the test can occur. Only a single grading error can make the difference between passing or not. Second, we think that some participants recognized that they made an identification error on the test, convinced themselves that they would not make such an error in the future, and proceeded on to score hunter envelope wings. Concerning the exit test, after scoring hundreds of wings and discussing the ages and sexes of many individual wings, we would have expected that all participants should have been proficient by the end of the wingbee. Such was not the case as only about 60% passed the exit test. We can think of 2 explanations to this problem. Participants were not proficient at aging and sexing and were consistently making mistakes throughout the wingbee. Alternatively, after aging and sexing many wings through the week, fatigue contributed to poor performance on the exit test. In either case, a better understanding of why these mistakes were made is warranted.

MANAGEMENT IMPLICATIONS

Our results indicate that the current age ratios are biased. If so, then two options exist. First, a correction factor could be developed annually and applied to adjust the age ratio. While this approach has merit, we believe that a second option, changing the wingbee protocol, is more appropriate. We agree with McAuley et al. (1993) that aging and sexing woodcock wings requires sufficient training. At present training consists of a few hours during the first morning of the wingbee. We suggest that training be increased, especially for newcomers. McAuley et al. (1993) recommended 20 hours of training, but we recognize that 20 hours of training does not fit into the time frame of the week-long wingbee. We suggest that newcomers be sent a package of information for review before the wingbee commences. At the wingbee, we recommend a minimum of 8 hours of training for newcomers. Along with this additional training, it is important that the known-age and -sex wings be correctly identified. Truly known-age and -sex wings can be obtained during the hunting season from trained biologists who have the bird in hand to make the final determination. Grading of pretests needs to be completed by an impartial person. Permitting participants to grade themselves allows mistakes to slip into the process. Expert biologists need to take pretests too. Aging and sexing wings requires practice, even for experts.

Although we did not investigate these next two suggestions, we think that they are worth considering. First, at each table, an expert should oversee all identifications made at that table. The expert should sample wings from each participant at the table to ensure that mistakes are not being made. Second, it is possible to clandestinely mark a set of known age-sex woodcock wings to check that misidentifications are not slipping through the system. Fluorescent dyes can be applied to known age-sex wings and these wings can be monitored remotely to assess quality control of the experts. This step too has been used at duck wingbees. We think that these two steps can improve the reliability of the scoring.

While these and other steps may slow down the wingbee process, we believe that correctly aging and sexing fewer wings will result in more precise age ratio estimates. One result of more precise age ratio estimates will be that managers will not consider more restrictive regulations when unnecessary.

ACKNOWLEDGMENTS

We thank all of the wingbee participants who agreed to take part in this work, and especially J. G. Bruggink and J. R. Kelley for allowing us the opportunity to get in the way during the wingbees. Thanks to B. Fancher, A. Schaffer, and D. Moler for data entry and quality control, and we thank S. Rashidi for assisting with early data analyses. We thank E. N. Johnson, F. Kimmel, S. Mayhew, and 3 anonymous reviewers for comments made on an early version of our manuscript.

LITERATURE CITED

Blankenship, L. H. 1957. Investigations of the American woodcock in Michigan. Michigan Department of Conservation., Report Number 2123. Lansing, Michigan, USA.

Greeley, F. 1953. Sex and age studies in fall-shot woodcock (*Philohela minor*) from southern Wisconsin. Journal of Wildlife Management 17: 29–32.

Kelley, J. R., Jr., and R. D. Rau. 2006. American woodcock population status, 2006. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Martin, F. W. 1964. Woodcock age and sex determination from wings. Journal of Wildlife Management 28: 287–293.

McAuley, D. G., J. R. Longcore, and G. F. Sepik. 1993. Techniques for research into woodcocks: experiences and recommendations. Pages 5–11 *in* J. R. Longcore and G. R. Sepik, editors. Proceedings of the Eighth American Woodcock Symposium. U.S. Fish and Wildlife Service Biological Report 16. Washington, D.C., USA.

Mendall, H. L., and C. M. Aldous. 1943. The ecology and management of the American woodcock. Maine Cooperative Wildlife Research Unit, University of Maine. Orono, ME, USA.

SAS Institute, Inc. 2003. Version 9.1. SAS Institute, Cary, North Carolina, USA.

Sepik, G. F. 1994. A woodcock in the hand. Ruffed Grouse Society, Coraopolis, PA, USA.

Sheldon, W. G., F. Greeley, and J. Kupa. 1958. Aging fall-shot American woodcocks by primary wear. Journal of Wildlife Management 22: 310–312.

David Krementz David received a B.S. in Wildlife Management and Conservation, a M.S. in Zoology and Physiology from University of Wyoming in 1977 and 1980, respectively, and a Ph.D. in Zoology from University of Western Ontario in 1984. After completing his doctorate, he served as a wildlife biologist for the U.S. Fish and Wildlife Service and then the U.S. Geological Survey at the Patuxent Wildlife Research Center from 1986–1999 where he studied waterfowl, woodcock, and songbird population biology and habitat use. Currently, David is the Unit Leader of the U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit which he has held since 1999. David is a Past-President of the Arkansas State Chapter of the Wildlife Society.

Edward E. Gbur is Professor and Director of the Agricultural Statistics Laboratory at the University of Arkansas. He received his M.S. in Mathematics and Ph.D. in Statistics from the Ohio State University. His research interests include experimental design, generalized linear mixed models, and applications of statistics to the agricultural and natural resources sciences.

MAGNITUDE AND SPATIAL DISTRIBUTION OF AMERICAN WOODCOCK HUNTING PRESSURE IN A CENTRAL MINNESOTA WILDLIFE MANAGEMENT AREA

10th American Woodcock Symposium
Roscommon, Michigan, USA

DAVID E. ANDERSEN[1], U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit[2], Department of Fisheries, Wildlife, and Conservation Biology, *University of Minnesota, St. Paul, MN 55108, USA*

MATTHEW E. REITER[3], Minnesota Cooperative Fish and Wildlife Research Unit, Department of Fisheries, Wildlife, and Conservation Biology, *University of Minnesota, St. Paul, MN 55108, USA*

KEVIN E. DOHERTY[4], Minnesota Cooperative Fish and Wildlife Research Unit, Department of Fisheries, Wildlife, and Conservation Biology, *University of Minnesota, St. Paul, MN 55108, USA*

DAVID C. FULTON, U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit, Department of Fisheries, Wildlife, and Conservation Biology, *University of Minnesota, St. Paul, MN 55108, USA*

Abstract: Hunting is considered a potential factor influencing American woodcock (*Scolopax minor*) population dynamics, yet little is known about the magnitude or spatial distribution of hunting pressure. In 2004 and 2005 as part of a larger telemetry study of fall movements, habitat use, and mortality of woodcock in central Minnesota, we investigated distribution of hunting pressure and hunters in a wildlife management area recently opened to woodcock hunting. We measured hunter use of the area by recording how many vehicles passed access points (2004 only), interviewed hunters as they prepared to hunt, asked hunters to carry Global Positioning System (GPS) units while hunting, and recorded information in post-hunt interviews about hunting success and methods. Over the 2-year study period, we obtained information from 48 hunts where hunters carried GPS units. On average, individuals hunted approximately 2.3 hours (n = 41) and shot and retrieved 0.54 (n = 48) woodcock and 0.18 (n = 38) ruffed grouse (*Bonasa umbellus*) per hunt. Most hunters (77%, n = 53) employed dogs while hunting, but there was no association between hunting success and use of dogs. Trips averaged just over 4.7 km (n = 33) and hunters on average traveled <1 km from their vehicle (n = 32), with the majority of hunting pressure close to existing trails. Woodcock hunters exhibited the strongest preference for aspen (*Populus* spp.) forest, even though this cover type was the most abundant on the study area. Our results suggest that even in an area managed and well known for upland bird hunting opportunities, hunting pressure was not widely distributed and woodcock harvest rate was low.

Proceedings of the American Woodcock Symposium 10: 203–212

Key words: American woodcock, *Bonasa umbellus*, habitat use, hunting pressure, Minnesota, radio telemetry, ruffed grouse, *Scolopax minor*, survival.

In light of declines in counts of displaying male American woodcock on annual Singing-ground Surveys in both the Eastern and Central Management Units (Kelley and Rau 2006), several recent studies (Andersen et al. 2005, McAuley et al. 2005, Oppelt 2006) have investigated hunter harvest as a factor in woodcock mortality.

---

[1] dea@umn.edu

[2] Cooperators include the U.S. Geological Survey, University of Minnesota, Minnesota Department of Natural Resources, The Wildlife Management Institute, and the U.S. Fish and Wildlife Service.

[3] Present address: Point Reyes Bird Observatory Conservation Science, P.O. Box 763, Pescadaro, CA 94060, USA.

[4] Present address: U.S. Fish and Wildlife Service, Prairie Pothole Joint Venture, Bismark, ND 58501, USA.

Although changes in distribution and quality of woodcock breeding habitat are thought to be the primary factors responsible for indicated population declines (Dwyer et al. 1983, Sauer and Bortner 1991, Woehr 1999), the role of hunting in woodcock population dynamics is not well understood. Managing harvest has been the primary regulatory response to apparent woodcock population declines, with reduced bag limits and season lengths implemented in 1985 in the Eastern Management Unit and in 1997 in the Eastern and Central Management Units (Kelley and Rau 2006).

Relatively little is known regarding the impact of hunting pressure and harvest rate on woodcock population dynamics. In the Eastern Management Unit, recent telemetry studies suggested that hunter harvest did not play an important role in the fall survival of woodcock (McAuley et al. 2005). However, in the Central Management Unit, telemetry indicated that woodcock survival in areas open to hunting was consistently lower than in areas closed to hunting or that experienced low hunting pressure (Andersen et al. 2005, Oppelt 2006), but that mortality rates attributable to hunting exhibited high annual variation. Together, these studies suggest that woodcock harvest on breeding areas with heavy hunting pressure may decrease woodcock survival rates in some circumstances, but impacts of hunter harvest is highly variable.

We hypothesized that much of the spatial and temporal variation in the magnitude of hunter harvest in woodcock populations was due to differences in hunting pressure at a local scale. Unfortunately, most information regarding woodcock hunting pressure comes from hunter success and harvest estimates at a much broader spatial scale. Based on Harvest Information Program (HIP) data, the median of the average number of woodcock shot by hunters per day in the Eastern Management Unit in 2005–2006 was 0.49, with high variability among states (range = 0.17–1.5, data from Kelley and Rau [2006]). During the 2005–2006 hunting season, hunter success in the Central Management Unit was similar with a median of the average number of woodcock bagged per day afield of 0.50 (range = 0–1.08, data from Kelley and Rau [2006]). Kelley and Rau (2006) also reported a U.S. harvest of approximately 297,200 woodcock in 2005–2006, with approximately 76% of harvest occurring in the Central Management Unit, suggesting that at the management-unit scale, hunting pressure was higher in the Central Management Unit than in the Eastern Management Unit. However, distribution of woodcock hunting pressure at local spatial scales is not well understood.

As part of a larger study of woodcock survival and mortality factors in east-central Minnesota (Andersen et al. 2005), we investigated hunter behavior and the spatial distribution and magnitude of woodcock hunting pressure in a public area as it first opened to woodcock hunting. Specifically, we (1) estimated the magnitude of hunting pressure, (2) measured spatial distribution of this hunting pressure, (3) characterized hunter behavior (e.g., hunt duration, use of dogs, etc.), (4) compared and contrasted behavior and success of different categories of hunters (e.g., those with and without dogs), and (5) assessed the relative risk of our radio-marked woodcock population that could have been exposed to hunting pressure by comparing the spatial distribution of hunting pressure with the spatial distribution of our marked woodcock population.

STUDY AREA

We conducted this study in 2004 and 2005 on a portion of the 1,166-ha Four Brooks Wildlife Management Area in east-central Minnesota (Figure 1). Four Brooks was expected to experience high upland bird hunting pressure, as the adjacent Mille Lacs Wildlife Management Area was highly regarded as an upland bird hunting area, and both areas were in relatively close proximity to the Minneapolis-St. Paul Metropolitan Area. Four Brooks was acquired by the Minnesota Department of Natural Resources (MN DNR) in 2000 and opened to the public in 2001, except that as part of a larger telemetry study (Andersen et al. 2005), woodcock hunting (not other bird hunting) was prohibited on Four Brooks until 2004. Habitat management on Four Brooks consisted primarily of timber harvest prior to acquisition by MN DNR. Since acquisition, habitat manipulation has emphasized the regeneration of existing aspen (*Populus* spp.) forest stands. In addition, on the far eastern portion of Four Brooks, open habitats were maintained by mowing and brush removal as part of a dog trialing area. Predominant vegetative communities on Four Brooks included aspen forest (42% of total area), northern hardwood forest (21%), permanently flooded mixed-emergent marsh (18%), and alder (*Alnus* spp.)–willow (*Salix* spp.) swamp (9%). Public entry to Four Brooks was primarily through a single access point on the east side of the wildlife management area (WMA).

METHODS

Visitor use

During the fall hunting seasons in 2004 and 2005, we observed the primary public access point at Four Brooks on weekend days and a random sample of weekdays and approached all visitors who entered the WMA and appeared to be hunters. If the purpose of their trip was to hunt upland birds, we asked if 1 person in the party would carry a hand-held Global Positioning System (GPS) unit to track their hunting path and complete a voluntary survey about their trip. The survey asked hunters to record the number of people in their party, whether they used a dog to hunt, the primary purpose of their trip, and to record all birds they harvested.

We used a combination of visitor intercept and traffic count procedures (Gregoire and Buhyoff 1999, Watson et al. 2000) to estimate the number of woodcock hunters using Four Brooks during the woodcock hunting season in 2004, using standard sampling theory (Cochran 1977) to make these estimates. We defined the woodcock hunting period as the 42-day period from 25 September (opening day) through 5 November 2004 (the day before deer hunting season started and after most radio-marked woodcock had migrated from the study area). Because we suspected hunting pressure to be higher on weekends, we stratified the hunting period by weekend days (*n* = 12) and weekdays (*n* =30). We then intercepted visitors at the primary hunting entrance site on all weekend days and 10 randomly selected weekdays.

We used visitor intercepts and observations to estimate the proportion of visitors who were upland bird hunters. In 2004 only, we used traffic counters at the primary and 2 minor access sites for the entire duration of the woodcock hunting period to record the number of vehicles visiting the study site. We based total visitor estimates on traffic counts for the primary parking site providing hunting access, because vehicle counts at minor access sites were sporadic and few. Based on these traffic counts, we used the estimate of the proportion of

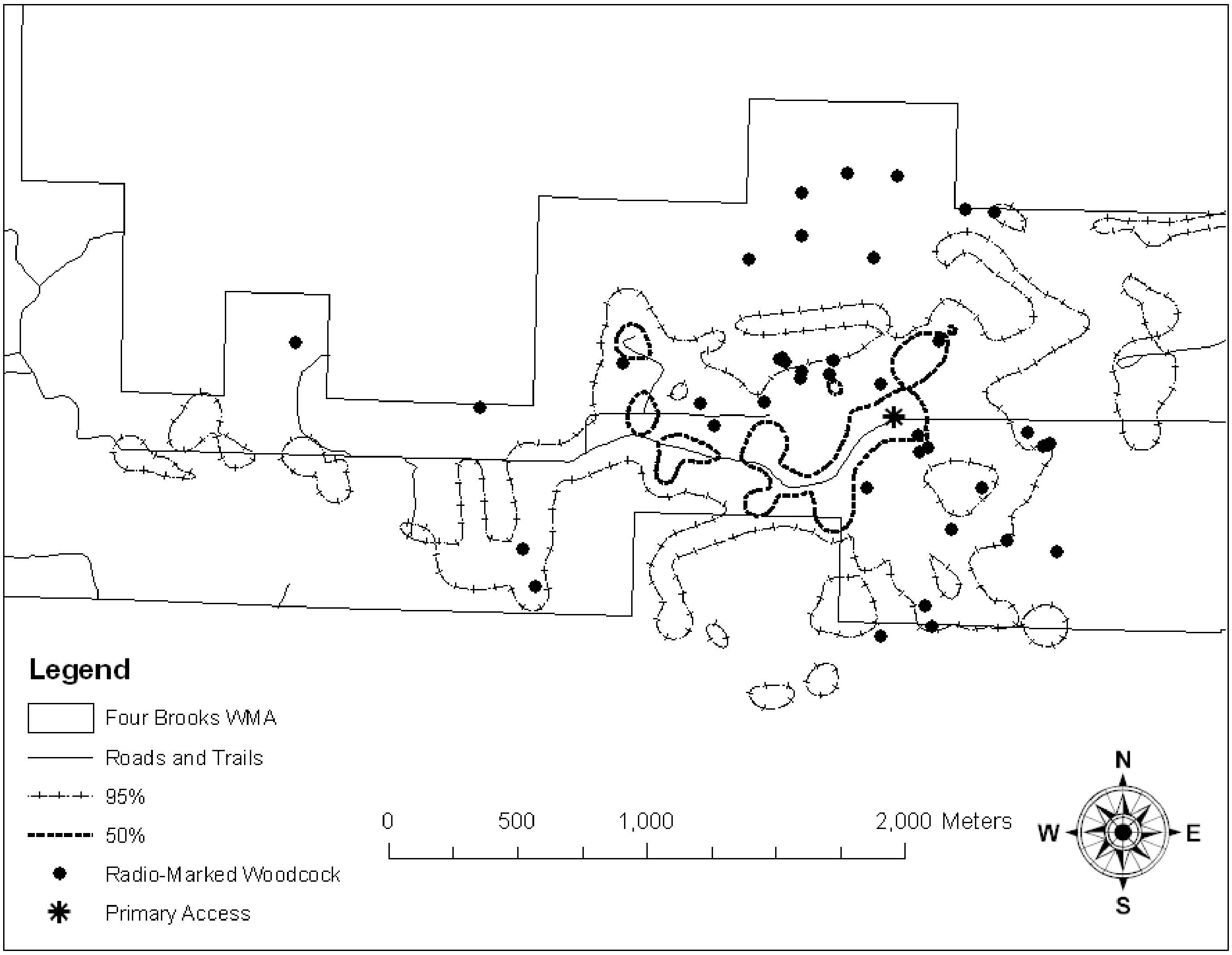


Figure 1. Hunting pressure and locations of radio-marked American woodcock (*n* = 39, 2004 only) on the Four Brooks Wildlife Management Area (WMA) in central Minnesota, estimated from upland bird hunter GPS tracks (*n* = 33, 2004 and 2005) using a weighted fixed-kernel density estimator. Points were weighted based on cumulative time (minutes) across all hunters spent at that location. Contours represent 50 and 95% utilization distributions.

visitors who were upland bird hunters to calculate the number of visits to the area for the purpose of upland bird hunting. We stratified use estimates by weekend and weekday users.

In 2005, we similarly used visitor intercepts on 7 randomly selected weekend days and asked upland bird hunters to carry a GPS receiver and complete a voluntary survey. We did not employ traffic counters (because our radio-telemetry study had concluded in 2004) nor intercept hunters on weekdays (based on results from 2004, which suggested that most hunting pressure occurred on weekends) in 2005, and were thus unable to make data-based estimates of hunter use in 2005.

Hunter behavior and habitat use

In addition to information provided by hunters on the voluntary survey, we used GPS tracks recorded by upland bird hunters in 2004 and 2005 to spatially quantify hunter behavior, characterize hunter habitat use, and estimate the spatial distribution of hunting pressure (see section on Data Analysis, below).

Telemetry

As part of a larger telemetry study (Andersen et al. 2005), we captured and attached radio transmitters to woodcock on Four Brooks in 2004 prior to the hunting season. We captured woodcock at dusk in mist nets, attached radio transmitters, and released radio-marked woodcock at capture locations as described in McAuley et al. (2005) and Andersen et al. (2005). On Four Brooks in 2004, we monitored radio-marked woodcock via both ground-based and aerial telemetry through the hunting season or until mortality occurred or radio-marked birds left on southward migration. Radio transmitters were equipped with mortality thermisters, which slowed the signal pulse interval if the transmitters cooled (i.e., was no longer attached to a woodcock or if the woodcock died). We monitored radio signals daily and assessed whether birds were alive based on signal pulse interval. In addition, through the course of the study period (mid-September through early November), we flushed each radio-marked woodcock at least once to assess status (alive or dead) and to obtain a precise location estimate, which we used to approximate woodcock use of the study site (see Doherty 2004). We used these locations to compare the relative exposure to hunting pressure among radio-marked woodcock. We also estimated hunting-season survival of radio-marked woodcock in 2004 using program MARK (http://www.warnercnr.colostate.edu/~gwhite/mark/mark.htm).

Table 1. Description of 9 cover type classifications available to upland bird hunters in 2004 and 2005 in the Four Brooks Wildlife Management Area in central Minnesota.

Cover type	Description
Alder-willow	Alder/Willow Swamp, saturated
Artificial	Artificial surfaces with < 25% cover
Aspen	Aspen forest
Grass	Planted grasses with sparse tree cover
Hardwood	Northern hardwood forest
Marsh	Mixed emergent marsh, permanently flooded
Upland shrub	Native dominated upland shrubland
Conifer	Saturated coniferous forest
Wetland	Wetland – Open water

Data Analysis

We first summarized hunter survey data and assessed whether there were differences in hunter behavior (e.g., whether hunters employed dogs) and hunting success based on if the primary quarry was woodcock (W), both ruffed grouse and woodcock (B), or only grouse (G). We compared characteristics of hunters across categories using analysis of variance (ANOVA) and chi-square analyses.

Second, we evaluated spatial use patterns by hunters based on GPS tracks. Because GPS coverage may be lost more frequently in certain cover types or when farther from a trail (Graves and Waller 2006) resulting in the most complete tracks being from hunters who do not stray from trails, we assessed potential bias in GPS tracks in 2 ways. For both assessments we assigned all GPS locations within a track to a cover type based on habitat data provided by the MN DNR (Table 1). For the first assessment, we used logistic regression to identify factors influencing GPS coverage loss. We investigated whether the average distance from a trail over the interval between the 2 previous GPS fixes and cover type at the previous and subsequent GPS fixes influenced the probability of reacquiring GPS coverage (evidence that coverage had been lost during the previous interval). Hunter GPS tracks indicated when satellite contact (contact with ≥ 3 satellites is required to estimate position) was reacquired by indicating the start of a new track segment, which we used as the response variable in logistic regression. To account for correlation of track segments within hunting parties, we included a fixed effect of hunting party.

In our second assessment, we used time between successive GPS fixes as the response variable (log-transformed to achieve a normal distribution) in a generalized mixed-effects linear model (both fixed and random effects; Littell et al. 1996) using cover type (Table 1) at the current and previous location and average distance from a trail over the previous interval as fixed-effect predictor variables. Because GPS units acquire point data on a constant time interval if satellite reception is not blocked, a longer interval between successive locations within a cover type or away from a trail would indicate bias in the GPS point data. We modeled the dependence among within-hunting party GPS points (i.e., repeated observations of the same hunter) using a compound symmetric correlation error structure, which was chosen from alternative error structures using Akaike's Information Criterion (AIC; Burnham and Anderson 2002). An underlying assumption in this analysis was that the probability of losing GPS coverage may be greater farther from the trail or in some habitat types, but was not so great that zero fixes came from those areas. Based on the outcome of these analyses, we characterized hunter behavior using more complete (≥49% coverage) GPS tracks. We also accounted for the differences in likelihood of GPS fixes by cover type by weighting GPS points by time between successive fixes across all hunter tracks across the study area. To do this, for each hunter track we drew a line between successive GPS fixes and placed points at 1-m intervals along this line. We then divided the time between successive GPS fixes by the distance (m) between fixes, and assigned the resulting amount of time to each of the points we generated on the line between GPS fixes. We assigned time remaining from the division of total time by distance between successive GPS fixes to the second GPS fix.

From the GPS track data, we calculated distance traveled (m), rate of travel (m per minute), and average distance from a trail (natural logarithm transformed) and categorized these variables as a function of dogs or no dogs and hunter type. To describe spatial extent of hunting pressure, we also estimated maximum distance from entry location. We then modeled the probability of success (i.e., bagging ≥1 bird = 1, bagging no birds = 0) using stepwise logistic regression, considering use of dogs, hunter type, total distance traveled, and average distance from a trail as independent variables.

To examine cover type use by hunters and to assess choices made within a hunt by hunters on where to go next, we examined third-order cover type selection (e.g., cover type use within the area traversed by a hunter; Johnson 1980). To estimate habitat availability, we used Hawth's Analysis Tools (Version 3.24, Beyer 2004; use of trade names does not imply endorsement by the U.S. Geological Survey or the University of Minnesota) in ArcMap (Version 9.0, Environmental Systems Research Institute, Redlands, CA) to generate a minimum convex polygon (MCP; Mohr 1947) based on all woodcock hunter tracks originating at the primary access point and to assign the proportion of cover types within this MCP. We estimated hunter use of cover types based on the proportion of cumulative time that hunters spent in each cover type across all woodcock hunters who initiated their hunt from the primary access point. We then used compositional analysis (Aebischer et al. 1993; BYCOMP_2002, P. Ott © 2002) to assess selection at the scale of individual hunters.

We were interested in factors that influenced hunting pressure such as cover type and ease of access (i.e., trails, distance from parking lot). To account for the differences in GPS fixes by cover type, we estimated the magnitude and spatial distribution of hunting pressure by weighting GPS points by time spent at that location across all hunter tracks across the study area. We used a fixed-kernel density estimator weighted by the amount of time spent at each point (at 1-m intervals along each hunter track, see above) location within 100 m to assign weighted average time spent by hunters per unit area (10 x 10 m pixel), and used these measures of hunter use to define a utilization distribution (Worton 1989). We graphically compared cumulative hunting pressure to flush locations of radio-marked woodcock, and assigned relative hunting pressure to individual woodcock based on average fall home range sizes of after-hatch-year adult female woodcock reported in Doherty (2004). We summed hunting pressure across estimated home ranges for radio-marked woodcock, and scaled this pressure to the woodcock with the highest hunting pressure. We used SAS (Version 9.1, SAS Institute, Inc., Cary, NC) for all statistical analyses, except as indicated above.

RESULTS

Visitor Use

We observed 98 visitors (72 weekend, 26 weekday) during the on-site visitor sampling days in 2004 and 2005. During weekends, 41.3% (SE = 5.1) of visitors (n = 72) were upland bird hunters, while 64.3% (SE = 13.1) of visitors during the week were upland bird hunters. Thirty-six upland bird hunters agreed to participate in the GPS portion of the study in 2004 and 18 upland bird hunters agreed to participate in 2005.

Because the proportion of visitors who hunted upland birds differed between week and weekend days in 2004, we stratified traffic count estimates. Traffic count data were incomplete for the study period with 4 of 12 days missing on the weekends and 10 of 30 days missing for weekdays. We used the average of the available data for each stratum to estimate 87 weekend and 113 weekday visits during the 42-day study period in 2004. Based on the estimated activity proportions provided by visitor intercepts, we estimated 36 ± 4 (95% CI) weekend and 73 ± 19 weekday visits for upland bird hunting during the study period (total estimated bird hunting visits = 110). Average party size for upland bird hunters was 1.48, providing an estimate of 163 visitor days for upland bird hunting at the site during the 42-day woodcock hunting period in 2004. In 2005, we did not use traffic counters to monitor access to Four Brooks, but we did monitor and intercept 18 upland bird hunters at the primary access site on randomly selected weekend days. Of these 18 hunters in 2005, 16 completed the voluntary survey.

Hunter Behavior

Of the 52 hunters who responded to our voluntary surveys in 2004 and 2005, 14 (27%) indicated they were hunting woodcock (W), 34 (65%) were hunting both grouse and woodcock (B), and 4 (8%) were hunting only grouse (G). Combined across hunting seasons, 12 (22% of sampled hunters) hunting parties bagged on average 0.54 woodcock (n = 48) and 0.18 ruffed grouse (n = 38) per trip. There was no association ($\chi^2 = 1.83$, df = 2, $P = 0.40$) between hunter type and the probability of successfully bagging ≥1 bird. The duration of hunts averaged just over 2 hours (138 minutes, SE = 11.6, n = 41), maximum distance hunters traveled from vehicles averaged just under 1 km (SE = 0.1, n = 32, maximum distance ≈ 3 km), and on average, hunters traveled 4.7 km (SE = 0.37, n = 33) per hunt. We found no difference ($F_{2,37} = 2.31$, $P = 0.11$) in the duration of hunts among hunter types or between hunts where hunters bagged no versus ≥1 bird ($F_{1,39} = 2.06$, $P = 0.16$). Forty-one (77%) of 53 parties hunted with dogs and there was a significant association between hunter type and the probability of employing dogs to hunt ($\chi^2 = 7.99$, df = 2, $P = 0.02$); 93% (13 of 14) of woodcock hunters and 76% (25 of 33) of both species hunters used dogs but only 25% (1 of 4) of grouse-only hunters employed dogs. Surprisingly, there was no association ($\chi^2 = 1.81$, df = 1, $P = 0.18$) between the probability of a successful hunt and the use of dogs.

Forty-eight hunting parties carried a GPS unit to record their hunting track and 44 of these parties successfully recorded their track. However, 1 track fell completely outside of Four Brooks and we excluded this track from further analysis. Hunting tracks were primarily (n = 39) initiated at 1 entry point, however 3 other entry points were used infrequently (n = 4). Hunting tracks averaged 205 fixes (SE = 24.3), and of the 43 tracks considered for analysis, on average, 34% (SE = 5.0) of the time was missing due to either loss of GPS coverage, equipment malfunction, or user error. Nine tracks contained 0 missing data, 13 tracks were missing 0–25% of time, 9 tracks were missing >25–50% of time, 4 tracks were missing >50–75% of time, and 8 tracks were missing >75% of time.

Logistic regression analyses suggested that the probability of reacquiring GPS coverage (i.e., loss of and subsequent connection with ≥3 satellites) was influenced by all variables we evaluated, including current cover type, previous cover type, average distance from a trail, and hunting party. These results suggested that GPS coverage was not equivalent for all hunters in all portions of Four Brooks. Furthermore, generalized linear models of factors affecting time interval between successive GPS locations suggested that there was an association between average distance from the trail between 2 successive GPS fixes ($\beta_{\mathrm{AVGTRAIL}} = 0.0004$; 95% CI: 0.0002–0.0006) and the time between those successive GPS fixes. However, all of the 95% CI for coefficient estimates of the cover type at the first and second locations of an interval overlapped zero, indicating that cover type was not a significant predictor of missing time due to lost GPS satellite reception. These analyses suggested that more complete tracks, based on time, were those closer to trails, but that there did not seem to be an influence of cover type on GPS coverage. Therefore, because our analyses suggested that location (i.e., GPS fixes) data may be biased toward being near trails or due to cover type, but that the amount of time between successive locations was only affected by distance from trails, we used time rather than location in subsequent habitat analyses and used only a subset of tracks where <52% (we included 2 tracks with slightly >50% of track time missing to maximize sample size) of the track time was missing (2004, n = 22; 2005, n = 11) to describe hunter behavior.

Stepwise logistic regression analyses indicated that only the distance traveled ($\chi^2 = 4.55$, df = 1, $P = 0.03$) by a hunter was a significant predictor of the probability of bagging at ≥1 bird ($\beta_{\mathrm{DISTANCETRAVELED}} = 0.0007$; 95% CI: = $0.2 \text{ x } 10^{-16}$ – 0.0009). We observed no difference between hunters with or without dogs in distanced traveled ($F_{1,31} = 0.43$, $P = 0.52$) or average distance from trails ($F_{1,31} = 0.01$, $P = 0.91$). However, hunters with dogs traversed their routes more quickly than hunters without dogs ($F_{1,20} = 4.09$, $P = 0.05$). We found no difference among hunter types in distance traveled ($F_{2,28} = 0.19$, $P = 0.82$), average distance to trail ($F_{2,28} = 0.35$, $P = 0.71$), or rate of travel ($F_{2,27} = 0.76$, $P = 0.48$).

Hunter Habitat Use

We assigned cover types to all fixes in hunter GPS tracks that occurred within Four Brooks—hunters used 7 of 9 available cover types: (1) alder-willow, (2) artificial, (3) aspen, (4) grass, (5) hardwood, (6) marsh, and (7) upland shrub (Table 1). We used GPS tracks from 25 hunters who initiated their hunt from the primary access point to define an MCP of 3.26 km^2 that included 7 cover types (aspen [proportion = 0.787], alder-willow

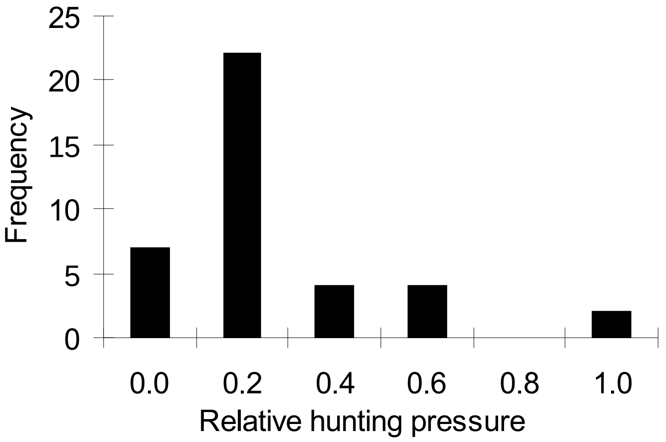


Figure 2. Relative estimated hunting pressure (1.0 = maximum, 0.0 = minimum) experienced by radio-marked woodcock (*n* = 39) on the Four Brooks Wildlife Management Area in central Minnesota in 2004. Hunting pressure is scaled to woodcock with the highest estimated hunting pressure.

[0.020], marsh [0.107], upland shrub [0.072], hardwood [0.003], conifer [0.010], and wetland [0.001]). However, hardwood, conifer, and wetland cover types combined accounted for only 1.5% of total area in the MCP and none of these cover types was used by any hunter. Therefore, we considered these cover types to be unavailable to hunters in compositional analysis, because including cover types with near zero availability precludes computation of relative preference. Using this estimate of availability, we then used the proportion of total time hunters used each cover type to estimate use, and conducted a compositional analysis of third-order cover type selection by hunters. Results of this compositional analysis indicated that hunters used cover types non-randomly (χ^2 = 78.87, df = 3, $P < 0.001$) and selected cover types in the following order: aspen > marsh > upland shrub = alder

Hunting Pressure and Telemetry

We captured and radio-marked 96 woodcock on Four Brooks in 2004, and used data from 81 of these woodcock to estimate survival during the woodcock hunting season (beginning the day before the woodcock hunting season opened and ending the day after the season closed).We excluded 15 radio-marked woodcock from survival analyses because of problems associated with handling or adjustment to radio attachment, and censored data from 4 woodcock because they were killed by hunters solicited near the end of the hunting season to hunt woodcock at Four Brooks as part of our survival study. Hunting-season survival of woodcock at Four Brooks in 2004 was 0.903 (95% CI = 0.797–0.955), with 2 woodcock killed by hunters (approximately 25% of observed mortality).

The spatial distribution of hunting pressure estimated based on the time spent across the study area by all hunters who provided GPS tracks was concentrated along trails close to the primary access point (Figure 1). The average maximum distance hunters traveled from entry points was <1 km and the maximum distance any hunter traveled from their entry point was slightly <3 km. Most woodcock on Four Brooks experienced relatively little hunting pressure (Figure 2), with 14 (35.9%) of 39 radio-marked woodcock occurring outside of the 95% contour of the estimated (Figure 1) hunter utilization distribution and 7 (17.9%) radio-marked woodcock experiencing no hunting pressure (Figure 2). Two radio-marked woodcock occurred within the estimated 50% hunter utilization contour (Figure 1). These 2 birds experienced 40% more hunting pressure than woodcock that experienced the next-highest estimated hunting pressure (Figure 2). None of the 39 woodcock with home ranges that included part of Four Brooks was harvested by hunters interviewed in 2004.

DISCUSSION

Using GPS, voluntary surveys of hunters, and radio telemetry of American woodcock, we were able to characterize how hunting pressure in a public hunting area was distributed in relation to access points and existing trails systems and relate hunting pressure to distribution of woodcock in central Minnesota. In 2004, the first year that Four Brooks Wildlife Management Area was open to the public for woodcock hunting, we estimated that there were 110 visits to Four Brooks for the purpose of upland bird hunting. Based on hunter GPS tracks from 2004 and 2005, most hunters hunted close to existing trails and did not venture far from access points. In 2004, woodcock mortality during the hunting season was approximately 10%, and approximately 25% of this mortality was attributable to hunting (i.e., hunting mortality of approximately 2.5%). Together, these results suggest that woodcock hunting in central Minnesota in 2004 at a newly opened public hunting area adjacent to one of the premier public upland bird hunting sites in the state had little influence on local woodcock survival.

In large part, low hunter-caused mortality rates were likely due to the spatial distribution of hunting pressure in relation to the distribution of woodcock. Hunters primarily hunted close to existing trails and near the primary entry point to the wildlife management area. In contrast, radio-marked woodcock occurred throughout Four Brooks, and many radio-marked woodcock appeared not to have experienced any hunting pressure. If this spatial distribution of hunting pressure is typical of that in forested habitats elsewhere in woodcock habitat, manipulating the number and location of access points may be a management tool that both affords hunter access and limits hunting pressure to birds in close proximity to entry points. McCaffery et al. (1996) reported that ruffed grouse hunting pressure in northern Wisconsin was similarly related to distribution and maintenance of trails, and Gullion (1983) reported that ruffed grouse farther from trails survived longer than ruffed grouse near trails. In our study, overall woodcock hunting mortality rates remained low, even though use of the WMA by upland bird hunters was high.

Most (92%) upland bird hunters who visited Four Brooks were in pursuit of woodcock, either as the primary quarry, or in conjunction with hunting ruffed grouse. Woodcock hunters exhibited preference for aspen and marsh cover types, suggesting that they preferentially hunted along aspen forest edges, perhaps at the edge of marshes, where better shooting opportunities may have existed. Woodcock used aspen cover types during fall in our study area and in study areas in northern Wisconsin and Michigan's Upper Peninsula (Meunier et al. 2010), and hunters appeared to focus on this cover type. However, woodcock also use a variety of other cover types (Meunier et al. 2010), including alder and upland shrub cover types. Hunters in our sample did not target these cover types compared with aspen cover types, thus reducing hunting pressure for a portion of woodcock in this population.

Approximately a third of upland bird hunters in our sample hunted without dogs (*n* = 12). Surprisingly, hunting with or without a dog did not appear to influence hunting success, although our sample sizes were too low to detect differences in hunting success. GPS tracks of both hunters and their dogs (T. Gartner, Garmin International, Olathe, Kansas, USA, unpublished data) suggest that hunting dogs traverse approximately 1.5–2.5 times the distance that their human hunting companions do. Hunting dogs presumably also increase the encounter rate with birds. Thus, the explanation for our finding that hunters without dogs had the same success rate as hunters with dogs is not readily apparent. Perhaps hunters with dogs chose not to shoot all woodcock that they had the opportunity to shoot, as some hunters reported to us that they primarily were interested in training their dogs on woodcock and not necessarily shooting woodcock.

Our results are similar to those reported by Stedman et al. (2004), who monitored white-tailed deer (*Odocoileus virginianus*) hunter behavior in Pennsylvania using GPS technology to track hunter movements, and Millspaugh et al. (2000), who used radio telemetry and location information reported by elk (*Cervus elaphus*) hunters in South Dakota to estimate space-use sharing between hunters and elk. They found that hunter density was negatively associated with distance to roads, and suggested that managers could use information about spatial distribution of hunters to redistribute hunting pressure to more effectively meet management goals (e.g., increase deer harvest). Our results similarly suggest that hunter access could be used to distribute upland bird hunting pressure. Depending upon the objectives of management, hunting pressure could be more widely distributed across suitable habitat by providing regularly spaced entry points. Alternatively, harvest mortality on local woodcock could likely be minimized by providing few entry points, while at the same time providing hunting opportunity. These results also highlight that regulatory actions such as bag limits or season lengths represent only one of several alternative management strategies for influencing recreational hunting behavior (Manning 1999). Alternative management actions such as site management might also be perceived as less of a constraint on hunting opportunity than regulatory actions. This consideration is important as hunting participation is declining and regulations perceived to be restrictive have led to reduced hunting participation in other contexts (Fulton and Manfredo 2002).

Finally, using GPS tracks of woodcock hunters provided a means of understanding how hunting pressure was distributed spatially—a factor influencing harvest that has not been studied in upland game birds. Only a few existing studies have focused on hunter spatial distribution and intensity of use, and these have involved large ungulates. Our results suggest that harvest rate of woodcock at local scales could be influenced by manipulating hunter access, and consequently limit the extent of hunting pressure. Even in areas that experience high hunting pressure, managing entry points could limit the extent of hunting pressure, directing hunting pressure to a portion of the local woodcock population.

Future Research

Future research on woodcock hunting pressure could focus on state and regional scales. A combination of diary surveys of upland bird hunters and intercept GPS studies at multiple sites across Minnesota could determine: (1) the status (private vs. public) and cover types of the land most frequently hunted; and (2) whether the same movement patterns and onsite hunting pressure apparent at Four Brooks are occurring throughout the state and/or region. This information is relevant to assessing the effectiveness of bag limits versus other management tactics for managing hunting impacts on woodcock. In addition, it would be useful to understand whether hunting pressure was similarly distributed among migrating woodcock stopping on our study site.

ACKNOWLEDGMENTS

We thank J.G. Bruggink and E. Oppelt for providing estimates of woodcock survival based on radio-telemetry data. B. Reichert, R. Hylton, M. Truwe, J. Hill, and C. Henneman assisted with intercepting and interviewing hunters at Four Brooks, and R. Engh and M. Thomatz of the Minnesota Department of Transportation allowed us to borrow traffic counters and summarized traffic count data for us. R. Tuszynski, C. Kostrzewski, J. Abel, R. "Zeke" Black, T. Pharis, M. Trenholm and T. Pfingston of the Minnesota Department of Natural Resources assisted with logistics of field work and radio telemetry. Funding for the larger telemetry project was provided by the U.S. Fish and Wildlife Service (Region 3, Migratory Birds), U.S. Geological Survey (Science Support Initiative), and the Minnesota Department of Natural Resources. Additional funding support and logistical support was provided by the Minnesota Cooperative Fish and Wildlife Research Unit. S. Wilds, J. Kelley, and D. McAuley supported the larger telemetry study in important ways and D. Diefenbach and K. Martin reviewed earlier drafts of this manuscript.

LITERATURE CITED

Aebischer, N. J., P. A. Robertson, and R. E. Kenward. 1993. Compositional analysis of habitat use from animal radio-tracking data. Ecology 74: 1313–1325.

Andersen, D. E., J. G. Bruggink, K. Doherty, R. S. Lutz, J. Muenier, and E. Oppelt. 2005. Fall survival, movements, and habitat use of American woodcock in the western Great Lakes Region: 2004 field season report. U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit, St. Paul, Minnesota, USA.

Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at <http://www.spatialecology.com/htools>.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodal inference. Springer-Verlag, New York, New York, USA.

Cochran, W. G. 1977. Sampling techniques. Wiley and Sons, New York, New York, USA.

Doherty, K. E. 2004. Fall movement patterns of adult female American woodcock (*Scolopax minor*) in the western Great Lakes region. Thesis, University of Minnesota, St. Paul, Minnesota, USA.

Dwyer, T. J., D. G. McAuley, and E. L. Derleth. 1983. Woodcock singing-ground counts and habitat changes in the northeastern United States. Journal of Wildlife Management 47: 772–779.

Fulton, D. C., and M. J. Manfredo. 2002. A panel design to assess the effects of regulatory induced reductions in opportunity on deer hunters' satisfaction. Human Dimensions of Wildlife 9: 35–56.

Graves, T. A., and J. S. Waller. 2006. Understanding the causes of missed Global Positioning System telemetry fixes. Journal of Wildlife Management 70: 844–851.

Gregoire, T. G., and G. J. Buhyoff. 1999. Sampling and estimating recreational use. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. General Technical Report PNW-GTR-456. Portland, Oregon, USA.

Gullion, G. W. 1983. Ruffed grouse habitat manipulation—Mille Lacs Wildlife Management Area, Minnesota. Minnesota Wildlife Resource Quarterly 43: 25–98.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61: 65–71.

Kelley, J. R., Jr., and R. D. Rau. 2006. American woodcock population status, 2006. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Littell, R. C, G. A. Milliken, W. W. Stroup, and R. D. Wolfinger. 1996. SAS system of mixed models. SAS Institute, Cary, North Carolina, USA.

Manning, R. E. 1999. Studies in outdoor recreation: search and research for satisfaction. Oregon State University Press, Corvallis, Oregon, USA.

McAuley, D. G., J. R. Longcore, D. A. Clugston, R. B. Allen, A. Weik, S. Williamson, J. Dunn, B. Palmer, K. Evans, W. Staats, G. F. Sepik, and W. Halteman. 2005. Effects of hunting on survival of American woodcock in the Northeast. Journal of Wildlife Management 69: 1565–1577.

McCaffery, K. R., J. E. Ashbrenner, W. A. Creed, and B. E. Kohn. 1996. Integrating forest and ruffed grouse management: a case study at the Stone Lake Area. Wisconsin Department of Natural Resources Technical Bulletin No. 189. Wisconsin Department of Natural Resources, Madison, Wisconsin, USA.

Meunier, J., R. S. Lutz, K. E. Doherty, D. E. Andersen, E. Oppelt, and J. G. Bruggink. 2010. Fall diurnal habitat use by adult female American woodcock in the western Great Lakes region. Pages 83–94 *in* C. A. Stewart, and V. R. Frawley, editors. Proceedings of the Tenth American Woodcock Symposium. Michigan Department of Natural Resources and Environment, Lansing, Michigan, USA.

Millspaugh, J. J., G. C. Brundige, R. A. Gitzen, and K. J. Raedeke. 2000. Elk and hunter space-use sharing in South Dakota. Journal of Wildlife Management 64: 994–1003.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. American Midland Naturalist 37: 223–249.

Oppelt, E. J. 2006. Fall survival of American woodcock in the western Great Lakes region. Thesis. Northern Michigan University, Marquette, Michigan, USA.

Pinheiro, J. C., and D. M. Bates. 2000. Mixed-effects model in S and S-Plus. Springer-Verlag, New York, New York, USA.

Sauer, J. R., and J. B. Bortner. 1991. Population trends from the American woodcock Singing-ground Survey, 1970–88. Journal of Wildlife Management 55: 300–312.

Stedman, R., D. R. Dieffenbach, C. B. Swope, J. C. Finley, A. E. Luloff, H. C. Zinn, G. J. San Julian, and G. A. Wang. 2004. Integrating wildlife and human dimensions research methods to study hunters. Journal of Wildlife Management 68: 762–773.

Watson, A. E., D. N. Cole, D. L. Turner, and P. S. Reynolds. 2000. Wilderness recreation use estimation: a handbook of methods and systems. U.S. Department of Agriculture Forest Service, Rocky Mountain Research Station. General Technical Report RMRS-GTR-56. Ft. Collins, Colorado, USA.

Woehr, J. R. 1999. Declines in American woodcock populations: probable cause and management recommendations. Report to International Association of Fish and Wildlife Agencies.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164–168.

David E. Andersen is Leader of the Minnesota Cooperative Fish and Wildlife Research Unit, located in the Department of Fisheries, Wildlife, and Conservation Biology at the University of Minnesota in St. Paul, Minnesota. He received an M.S. in Wildlife Ecology and a Ph.D. in Wildlife Ecology and Zoology from the University of Wisconsin–Madison. His research expertise is in population ecology and conservation of wild birds, and he has conducted research on gamebirds, raptors, waterfowl, and songbirds.

Matthew E. Reiter received his B.A. from Boston College in 1998 and an M.S. and Ph.D. in Wildlife Conservation from the University of Minnesota in 2006 and 2009, respectively. He studied interactions among tundra-nesting geese and their shared nest predators in northern Canada. Prior to graduate school, he worked for the U.S. Geological Survey in Hawaii (2000–2003) studying avian disease management. Currently, Matt is a quantitative avian ecologist with PRBO Conservation Science and working to develop a large-scale monitoring program for wintering shorebirds throughout the Pacific Flyway.

Kevin E. Doherty is the science coordinator for the Prairie Pothole Joint Venture (PPJV) for the U.S. Fish and Wildlife Service. He is responsible for creation and integration of applied conservation research to address migratory bird issues within the PPJV. Dr. Doherty has published 23 scientific peer-reviewed papers and book chapters on topics including: landscape ecology, sage-grouse and sagebrush ecology, and conservation planning and mitigation policy in relation to energy development. Kevin received a Ph.D. in Wildlife Biology from the University of Montana in 2008, a M.S. in Wildlife Conservation with a minor in statistics from the University of Minnesota in 2004, and a B.S. in Wildlife Science from Virginia Tech in 1997.

David C. Fulton, U.S. Geological Survey, is Assistant Unit Leader at the Minnesota Cooperative Fish and Wildlife Research Unit. He received his Ph.D. in Human Dimensions of Natural Resources from Colorado State University. His research expertise is in the human dimensions of fisheries and wildlife management, with a focus on understanding what factors influence attitudes and behavior related to participation in wildlife-based recreation and preferences for management alternatives. He works closely with state and federal wildlife management agencies to identify and conduct applied human dimensions research to support agency decision-making and management.

IMPORTANT AREAS FOR MANAGING AMERICAN WOODCOCK IN THE MIDWESTERN AND NORTHEASTERN UNITED STATES

10th American Woodcock Symposium
Roscommon, Michigan, USA

WAYNE E. THOGMARTIN[1], USGS Upper Midwest Environmental Sciences Center, *2630 Fanta Reed Road, La Crosse, WI 54603, USA*

JASON J. ROHWEDER, USGS Upper Midwest Environmental Sciences Center, *2630 Fanta Reed Road, La Crosse, WI 54603, USA*

Abstract: Efficient application of conservation measures is especially desirable in a constrained economic climate. Mapped predictions of a species' abundance may allow the spatial targeting of focal areas for conservation, thereby increasing the efficiency of conservation efforts. Mapped predictions from a hierarchical spatial count model of the relative abundance of displaying male American woodcock (*Scolopax minor*, hereafter woodcock) during the breeding season provided an opportunity to identify focal areas for conservation in the midwestern and northeastern United States. We overlayed the mapped patterns in predicted relative abundance against digital data layers describing federal- and state-managed lands to identify the relative contribution of governmental agencies to the conservation of woodcock habitat. We found that governmental agencies, in a regional sense, have direct jurisdiction over woodcock habitat equal to that expected by chance. In total, 7% of predicted displaying male woodcock occurred on federally administered lands and 13% occurred on state-administered lands. Thus, the vast majority (80%) of the woodcock population occurs on private lands. We identified 10 peaks in relative woodcock abundance throughout the breeding range that may be focused on for future conservation action. Some of these peaks in predicted abundance, for instance, near Lake Superior State Forest in Michigan, are currently within the direct jurisdiction of governmental land management agencies, whereas other areas, such as peaks occurring in northwestern Pennsylvania, western New York, and northern Maine, largely occur in a private lands context. Thus, conservation of woodcock on their breeding grounds will require an array of management approaches largely dictated by their spatial context relative to current land ownership. With validation, these maps of predicted abundance relative to governmentally managed lands can be used to prioritize and focus management of woodcock in the United States portion of the breeding range.

Proceedings of the American Woodcock Symposium 10: 213–222

Key words: efficient conservation, hierarchical spatial count model, mapped predictions, *Scolopax minor,* Singing-ground Survey.

Populations of American woodcock (*Scolopax minor*) in the United States have exhibited a long-term decline of –0.9%/yr between 1968 and 2006 (Sauer et al. 2008). The reasons for this decline are unclear but may be associated with changes in successional habitats (Kelley et al. 2007). The nascent American Woodcock Conservation Plan called for, among other things, protecting and managing habitat needed to maintain or increase woodcock numbers. Implicit in this recommended action is the need for understanding the current distribution of woodcock populations relative to managed lands.

The efficiency of avian conservation increases when management action can be directed to the areas most suitable for a species. The use of models to predict distributions, occurrences, and abundances of species is common in ecological studies (Scott et al. 2002). These models can be used to assess species relationships to environmental variables and to locate areas with the greatest potential for management or protection.

Thogmartin et al. (2007) used a hierarchical spatial count model to map regional patterns in the predicted relative abundance of woodcock in their United States breeding range. This modeling approach related counts from the North American Woodcock Singing-ground Survey to environmental covariates, adjusting for nui-

---

[1] Email: wthogmartin@usgs.gov

Table 1. Source and a brief description of the data describing the federal- and state-managed lands occurring in the American woodcock breeding grounds of the midwestern and northeastern United States.

Management authority	Source	Brief description
Federal	National Atlas of the United States	Federally owned or administered lands of the United States; created October 2003
Illinois	Illinois Natural History Survey, Illinois Department of Natural Resources	Conservation areas, state forests, state parks, and fish and wildlife areas; based on report from June 1994
Indiana	Indiana Natural Heritage Data Center	Areas owned or managed by the Indiana Department of Natural Resources
Iowa	Iowa Department of Natural Resources	Land areas owned by the Iowa Department of Natural Resources
Maine	Maine State Planning Office	State and non-profit ownership with easements; created in 1989, updated in 1993
Michigan	Michigan Department of Natural Resources - Forest, Mineral and Fire Management Division, Resource Mapping and Aerial Photography	State land of ³40 ha
Minnesota	Minnesota Department of Natural Resources, Division of Wildlife; Division of Forestry - Forest Resource Assessment; Division of Parks and Recreation	Wildlife management areas, state forests, state parks, state recreation areas, and state waysides
New Hampshire	Complex Systems Research Center, University of New Hampshire	GRANIT Conservation/Public Lands of ³2 acres that are mostly undeveloped and are protected from future development
New York	New York State Office of Cyber Security and Critical Infrastructure Coordination	Recreation areas, campgrounds, and Adirondack and Catskill Parks
Ohio	U.S. Geological Survey - Water Resources Division	GAP conservation land stewardship; created December 2003
Pennsylvania	Pennsylvania Department of Conservation and Natural Resources, Bureau of State Parks; Department of Conservation and Natural Resources, Bureau of Forestry	State parks and forests
Vermont	Spatial Analysis Laboratory, University of Vermont	Vermont Conserved Lands Database; ³2-acre parcels managed by State entities; includes some privately owned easements
Wisconsin	Wisconsin Department of Natural Resources	Areas managed by Wisconsin Department of Natural Resources that are managed through fee ownership, easement, or lease rights

sances relating to spatial autocorrelation in survey counts and observer and year differences. Similar work has been conducted for landbirds in the upper midwestern United States using Breeding Bird Survey route counts (Thogmartin et al. 2004, 2006).

Federal and state natural resource agencies have greater ability in managing for species of conservation concern on land over which they have direct authority than on private lands. With mapped predicted relative abundances of woodcock as the basis for our research, we inferred the proportion of the United States breeding population of woodcock occurring on federal, state, and private lands. Further, we tested whether the proportion of the population on federal and state lands predicted by the species-habitat model exceeded that expected of a woodcock population distributed at random. We also tested whether areas of high predicted abundance were significantly more common on federal and state lands than would be expected by a random distribution of these population peaks. Understanding the spatial context of the breeding population relative to land management authorities capable of managing woodcock should facilitate targeting of specific locations and strategies for management, thereby increasing the economic efficiency and the scientific justification for this management.

STUDY AREA AND METHODS

We studied woodcock in their primary breeding range in the United States, an area comprised of 18 states in the northeast and north-central Midwest. This area is defined by the extent of the North American Woodcock Singing-ground Survey (Tautin et al. 1983, Sauer and Bortner 1991). We used the mapped predictions of a Bayesian hierarchical spatial count model (Thogmartin et al. 2007) as the basis for our inferences (Figure 1). North American Woodcock Singing-ground Survey counts were predicted with a log-linear function of explanatory variables describing habitat, year effects, and observer effects. The model also included a conditional autoregressive term representing potential correlation between adjacent route counts. The best model suggested woodcock counts were higher in landscapes with more forest, especially aspen (*Populus* spp.) and birch (*Betula* spp.) forest, and in locations with a high degree of interspersion among forest, shrubs, and grasslands. Woodcock counts were lower in landscapes with a high degree of human development. Data withheld from model construction and for the years 2002 and 2003 indicated the model $r^2 \geq 0.7$ and exhibited little if any bias in the predictions.

We overlaid this mapped prediction against federal- and state-administered lands in the geographic information system ArcGIS 9 (Environmental Systems Research, Inc., Redlands, California, USA; Table 1). Locations of federal lands were obtained from the National Atlas and consisted of federally administered lands of ≥640 ha in size; these lands included small private inholdings, which we were unable to discriminate. The state-administered lands were obtained from various state and academic sources (Table 1). States defined their administered lands differently, yielding little consistency on what constituted a state-administered land. Regardless, we used these data as the best available information for state-level inference. The proportion of the predicted population was calculated for federal, state, and private

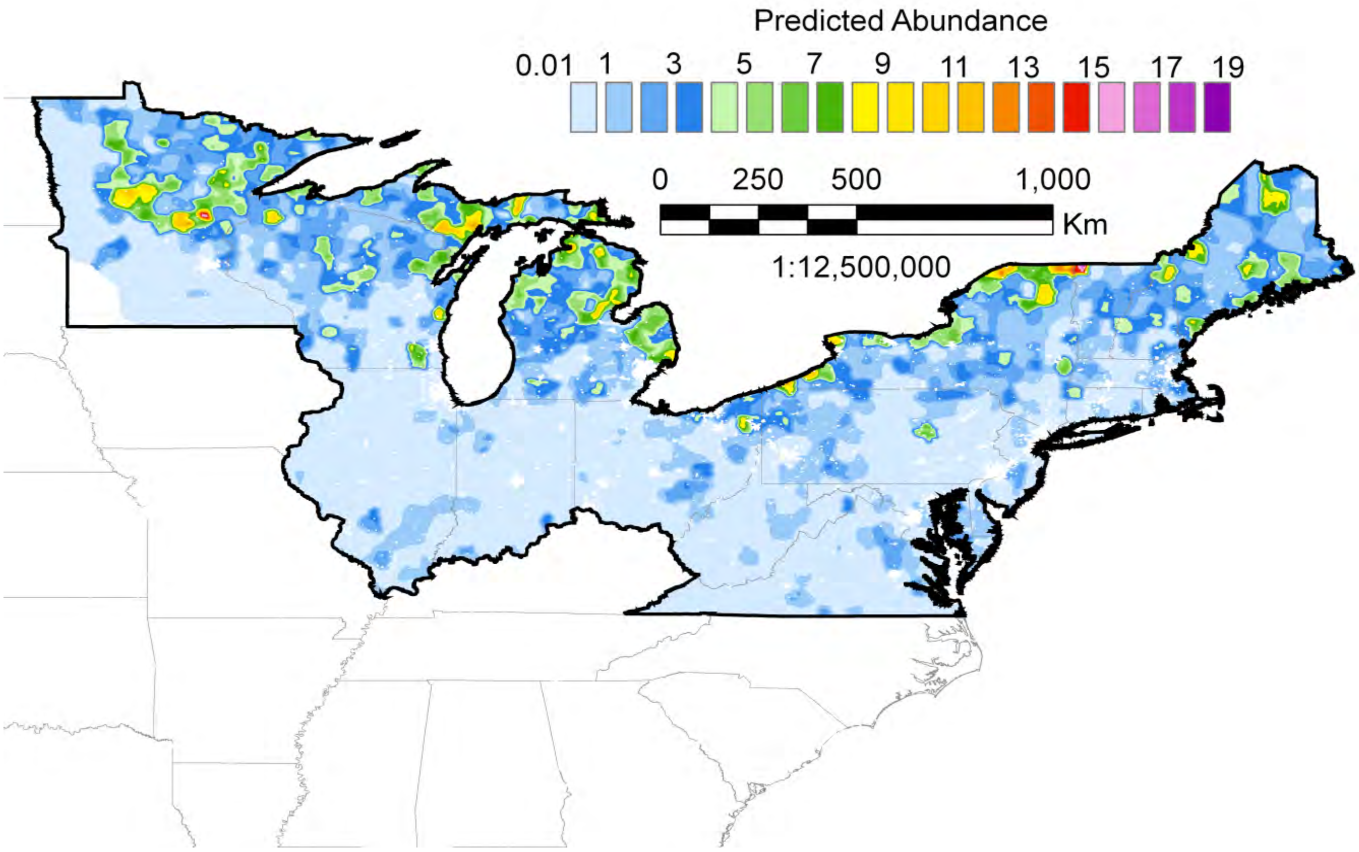


Figure 1. American woodcock abundance (birds/route) predicted for the upper midwestern and northeastern United States, as determined by a hierarchical Bayesian spatial count model of Singing-ground Survey counts. Reprinted with permission of The Wildlife Society.

Table 2. Proportion by state of the predicted American woodcock breeding population in the United States occurring on federal, state, and private lands. Summary relative abundances (minimum, mean, maximum, and range) by ownership category along with a weighted average across ownership categories are provided.

State	Land ownership	Area (km^2)	Area proportion	Population proportion	Relative abundance			
					Min	Mean	Max	Range
Maine								
	Federal	732	0.01	0.009	0.85	4.15	8.19	7.34
	State	4,210	0.05	0.050	0.26	2.89	8.54	8.28
	Private	82,979	0.94	0.941	0.23	3.03	9.01	8.78
Michigan								
	Federal	21,638	0.13	0.145	0.73	3.46	11.92	11.19
	State	19,199	0.11	0.128	0.25	4.16	12.07	11.81
	Private	127,982	0.76	0.727	0.24	3.43	12.13	11.89
Minnesota								
	Federal	22,169	0.09	0.109	0.12	3.00	8.23	8.11
	State	37,760	0.16	0.186	0.05	2.65	15.30	15.25
	Private	180,931	0.75	0.705	0.05	1.96	15.8	15.75
New York								
	Federal	957	0.01	0.008	0.02	1.74	9.04	9.01
	State	31,337	0.20	0.250	0.04	2.81	13.65	13.61
	Private	124,592	0.79	0.743	0.02	2.69	14.30	14.28
Pennsylvania								
	Federal	3,541	0.03	0.030	0.15	1.04	3.58	3.43
	State	9,635	0.08	0.082	0.14	0.77	8.45	8.31
	Private	113,787	0.90	0.888	0.14	1.18	15.39	15.25
Vermont								
	Federal	2,728	0.10	0.110	0.45	1.87	18.05	17.59
	State	1,511	0.06	0.061	0.51	2.32	16.58	16.06
	Private	22,173	0.84	0.830	0.45	2.37	18.10	17.65
Wisconsin								
	Federal	9,403	0.06	0.065	0.21	2.67	6.58	6.37
	State	5,877	0.04	0.041	0.13	1.96	10.34	10.21
	Private	135,576	0.90	0.895	0.13	2.06	10.71	10.58
Total		958,717	1.00	1.000	0.15	2.43	13.11	12.96

lands. Private lands were all lands not under federal or state management; we acknowledge that private lands span the gamut of management practices, up to and including highly managed private timberlands. We used Kolmogorov-Smirnov one-sample tests to determine whether, within each state, the proportion of the woodcock population under federal or state land management authority was more than would be expected given the proportion of federal and state land.

To focus management action on land units where peaks in predicted abundance occurred, we isolated peaks in predicted abundance by smoothing transitions in our model predictions. This smoothing was conducted with a spatial averaging of mapped predictions over the range of the woodcock based on a circular moving window with a radius of 13 cells (~7,000 m). We defined the highest 5% of cell values from the map of predicted abundance as hotspots. Consequently, areas defined as possessing a predicted relative abundance of ≥5.6 birds/route were identified. As with the population as a whole, we tested whether the proportion of the hotspots under federal- or state-management authority was more than could be expected given the proportion of land occupied by these management authorities within each state.

RESULTS

The vast majority (grand mean = 80%) of the displaying male American woodcock population in the United States was predicted to occur on private lands outside of the direct jurisdiction of federal or state land management (Table 2). The proportion of the population occurring on private lands varied from 71% in Minnesota to 94% in Maine. Seven percent of the predicted population occurred on federal land and 13% on state land, which was marginally higher than the proportion of the area under federal and state administration (6% and 11%, respectively). Neither federal- nor state-administered lands held jurisdiction over a greater proportion of the predicted population than expected by chance (Ds < 0.29, Ps > 0.96).

Ten areas were identified as hotspots (Figure 2). These occurred in central Minnesota, the upper and lower peninsulas of Michigan, northwestern Pennsylvania, western and northern New York (and the adjacent part of northern Vermont), and Maine. Nearly 3% of the areas predicted as hotspots of breeding woodcock abundance were under federal land management, whereas 21% of these areas were under state authority. Lake Superior State Forest in the Upper Peninsula of Michigan was especially noteworthy for containing 39% of 1 hotspot (hotspot 4), whereas Adirondack Park and Dead Creek Wildlife Management Area in northern New York contained about 40% of another hotspot (hotspot 8). Missisquoi National Wildlife Refuge, a Wildlife Management Institute woodcock best management practices demonstration area, appeared to be prime habitat for breeding woodcock, as predicted relative abundances at this location (range = 16–19 birds per route) were an order of magnitude higher than the regional mean (1.68 birds per route). The least governmentally managed hotspots were in northwestern Pennsylvania (hotspot 6), western New York (hotspot 7), and northern Maine (hotspot 10), each with <4% of their area under management. As with the population as a whole, federal and state land management agencies held jurisdiction over a proportion of the predicted hotspots equal to that expected by chance (Ds < 0.20, Ps $= 1.00$).

DISCUSSION

We summarized the predictions of a spatial model of woodcock breeding season relative abundance to infer the relative potential contribution of federal and state authorities to the management of this species on its breeding grounds. Our assessment suggested that conservation of this species as defined by the proportion of the population occurring on federal and state administered lands was equal to that predicted by chance. Given that federal and state administered lands constitute ~20% of the landscape, the vast majority of the woodcock population occurs in a private lands context. Further, whereas some areas of peak predicted abundance were well within federal and state lands, many areas where woodcock were abundant were privately held.

This private lands context has profound consequences for how this species may be managed. Managing species on private lands is more difficult because managers must partner with a wide and uncertain array of constituents, requiring a much greater investment of time and money to effect the same outcome that may be had on governmentally administered lands. The Northern Forest Woodcock Initiative, established by the Wildlife Management Institute in Bird Conservation Region 14 (the Atlantic Northern Forest), is a model program for directing woodcock conservation on private lands. The Northern Forest Woodcock Initiative is a coalition of 32 public and private conservation entities whose purpose includes outreach to private landowners. Replication of these initiatives in areas where we predict high abundance may be a useful means of focusing conservation efforts on private lands.

Admittedly, circumspect use of our results is required because the mapped model has not been field validated, and woodcock populations and habitats are dynamic and expected to change over time in contradiction to the implied static nature of the maps we produced. Internal model validation indicated the mapped model was unbiased and explained a majority of the variance in the counts (r^2s > 0.7), giving us confidence in its use here (Thogmartin et al. 2007). However, readers should be cognizant that this internal validation could not evaluate model performance everywhere it may be applied. Therefore, local managers are encouraged to use existing knowledge and assessments before acting on these results.

Further, local managers should understand that the value of these regional assessments cannot be used to identify specific parcels of land upon which to work for the benefit of woodcock. Regional models and maps and the assessments of the conservation estate that result from them are most useful for bringing regional resources to bear on a more localized portion of a region. Within these focal areas, because of the static nature of these mapped predictions and their limited resolution, managers with a better understanding of the local habitat will need to determine where these regional resources would be best used.

MANAGEMENT IMPLICATIONS

A benefit of mapping patterns in predicted abundance relative to governmentally administered lands is that areas may now be prioritized within states and across the region. We recommend focusing management efforts for woodcock in areas where they are most abundant in the breeding season because this represents an efficient approach to conserving this species (Figure 2). National wildlife refuges of the U.S. Fish and Wildlife Service may use the overlays of the predicted breeding season population relative to refuge boundaries to direct their private lands programs. For instance, the Missisquoi National Wildlife Refuge may direct its private lands program to conserve breeding habitat south and west of the Canadian border in northern New York and Vermont (Figure 2, hotspot 8). Rice Lake and Crane Meadows National Wildlife Refuges in Minnesota may coordinate conservation efforts with the state of Minnesota (specifically Mille Lacs, Snake River, Solana, Four Brooks, and Rum River wildlife management areas and state parks) to retain extant habitat south and east of their respective refuges (Figure 2, hotspot 2). Seney National Wildlife Refuge in Michigan occurs in the midst of a hotspot (Figure 2, hotspot 4) and may direct its private lands program to promoting the creation of new habitat in and among the areas north of the refuge.

Both federal and state authorities may use the overlays of predicted abundance and management boundaries to target conservation easements, land acquisition, and other conservation initiatives directed for the management of this species. We believe this spatial targeting of conservation effort represents an efficient, accountable, and scientifically justifiable approach to the management of this species.

ACKNOWLEDGMENTS

We thank the numerous biologists responsible for collecting woodcock data as part of the North American Woodcock Singing-ground Survey, without whose efforts this study would not be possible. This manuscript was made measurably better by the comments of J. G. Bruggink and anonymous reviewers.

LITERATURE CITED

Kelley, J. R., Jr., R. D. Rau, and K. Parker. 2007. American woodcock population status, 2007. U.S. Fish and Wildlife Service, Laurel, Maryland, USA.

Sauer, J. R., and J. B. Bortner. 1991. Population trends from the American woodcock singing-ground survey, 1970–88. Journal of Wildlife Management 55: 300–312.

Sauer, J. R., W. A. Link, W. L. Kendall, J. R. Kelley, and D. K. Niven. 2008. A hierarchical model for estimating change in American woodcock populations. Journal of Wildlife Management 72: 204–214.

Scott, J. M., P. J. Heglund, and M. L. Morrison. 2002. Predicting species occurrences: issues of accuracy and scale. Island Press, Washington, D.C., USA.

Tautin, J., P. H. Geissler, R. E. Munro, and R. S. Pospahala. 1983. Monitoring the population status of American woodcock. Transactions of the North American Wildlife and Natural Resources Conference 48: 376–388.

Thogmartin, W. E., M. G. Knutson, and J. R. Sauer. 2006. Predicting regional spatial patterns in rare grassland bird abundance with a hierarchical spatial count model. Condor 108: 25–46.

Thogmartin, W. E., J. R. Sauer, and M. G. Knutson. 2004. A hierarchical spatial count model of avian abundance with application to cerulean warbler. Ecological Applications 14: 1766–1779.

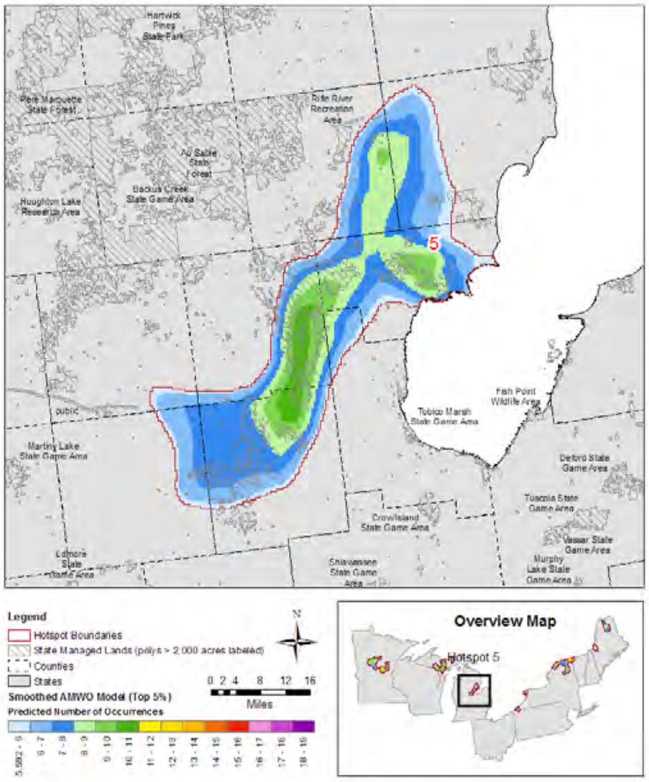
Thogmartin, W. E., J. R. Sauer, and M. G. Knutson. Modeling and mapping abundance of American woodcock across the midwestern and northeastern United States. Journal of Wildlife Management 71: 376–382.

For next figures:

Figure 2. Ten predicted peaks (hotspots) of American woodcock breeding season relative abundance associated with federal- and state-administered lands in the midwestern and northeastern United States. Note that the color ramp differs from Figure 1.

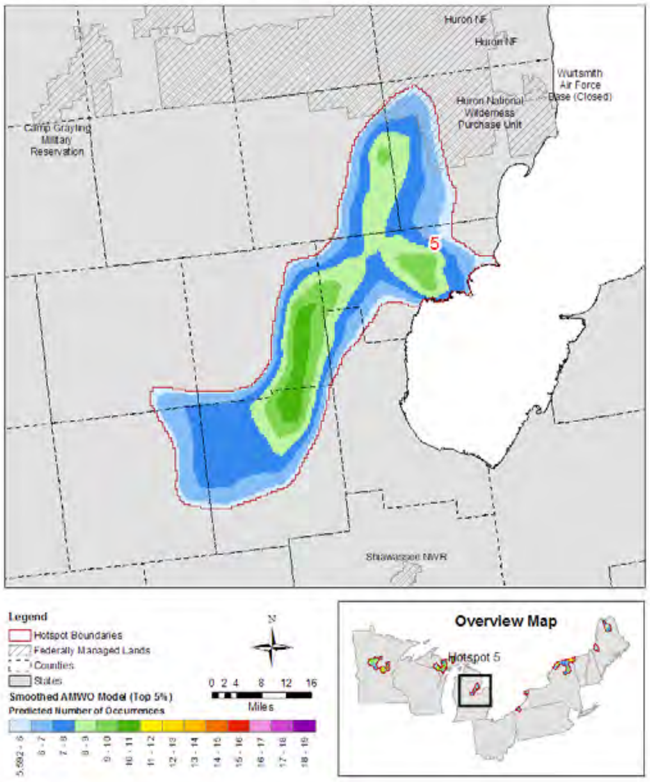
Smoothed American Woodcock (AMWO) Model Overlayed with State Lands

Hotspot 5



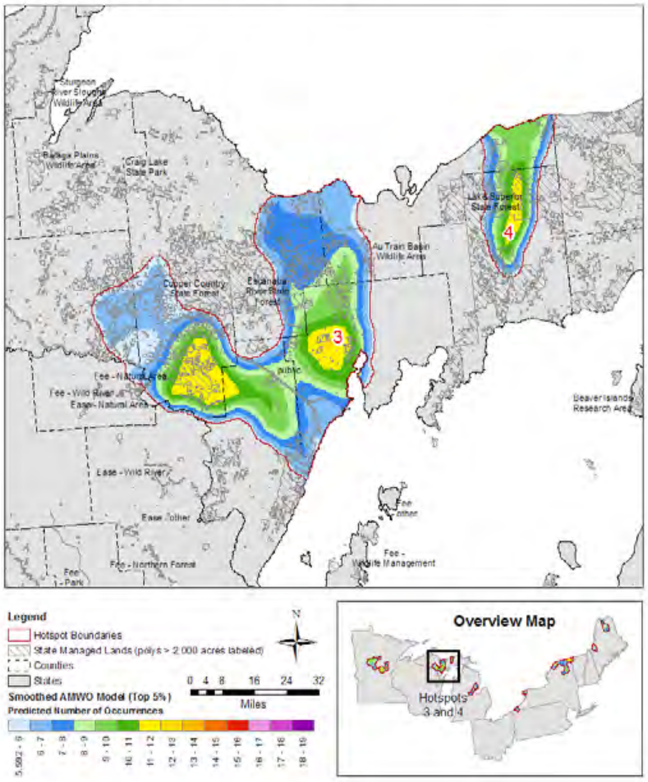
Smoothed American Woodcock (AMWO) Model Overlayed with Federal Lands

Hotspot 5



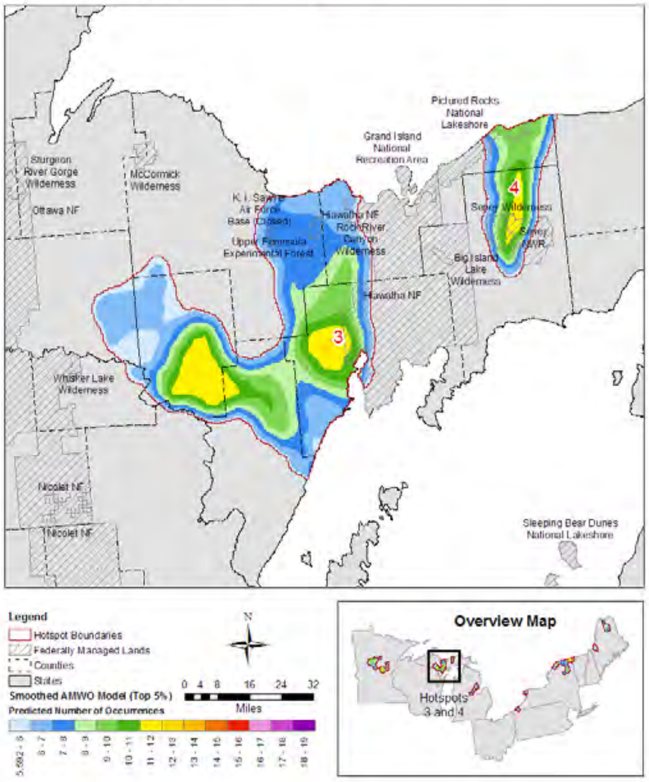
Smoothed American Woodcock (AMWO) Model Overlayed with State Lands

Hotspots 3 and 4



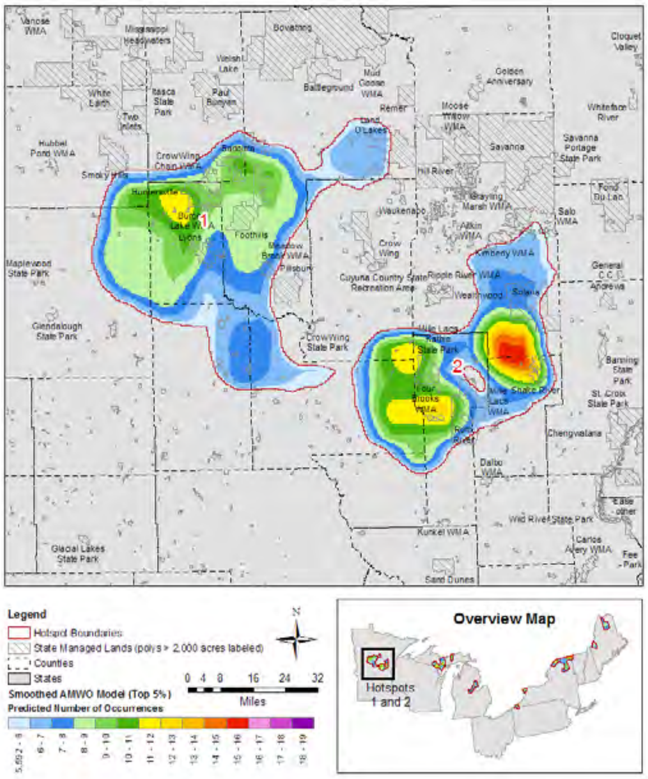
Smoothed American Woodcock (AMWO) Model Overlayed with Federal Lands

Hotspots 3 and 4



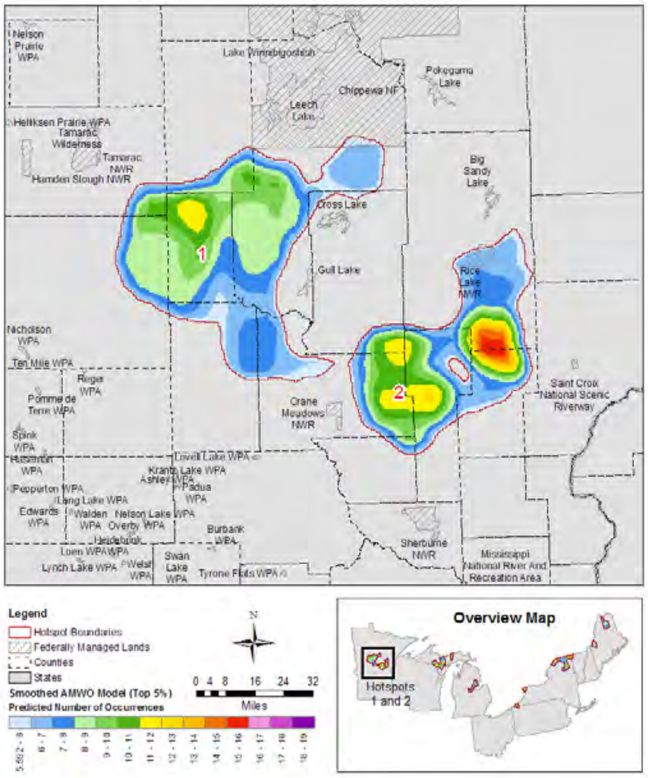
Smoothed American Woodcock (AMWO)
Model Overlayed with State Lands

Hotspots 1 and 2



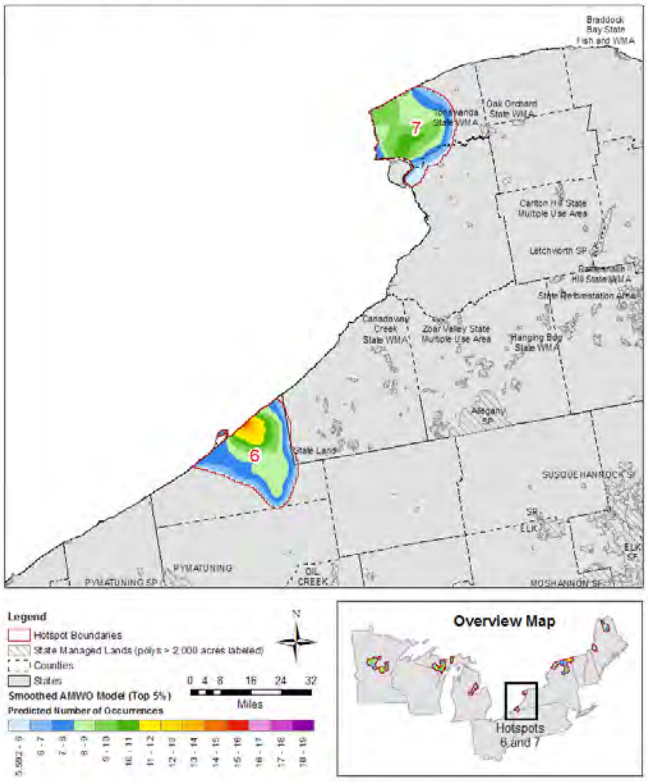
Smoothed American Woodcock (AMWO)
Model Overlayed with Federal Lands

Hotspots 1 and 2



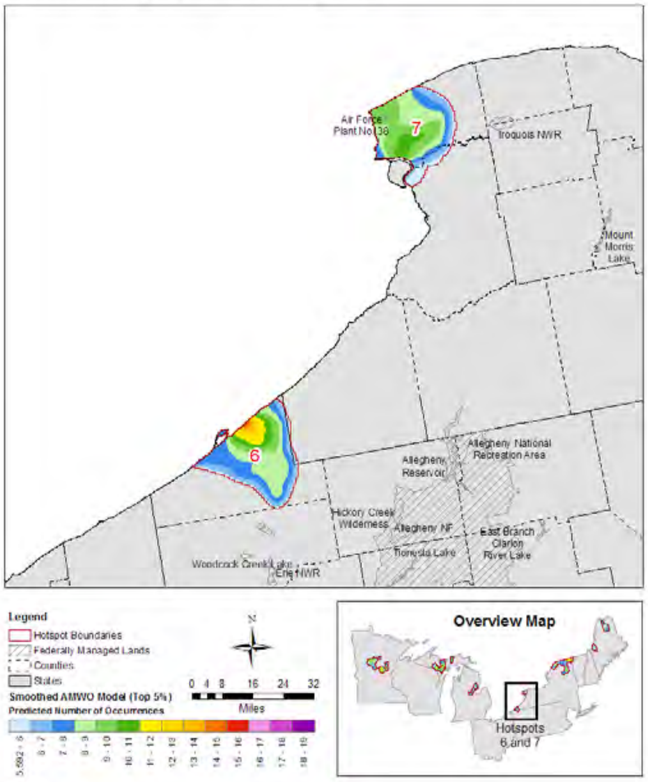
Smoothed American Woodcock (AMWO)
Model Overlayed with State Lands

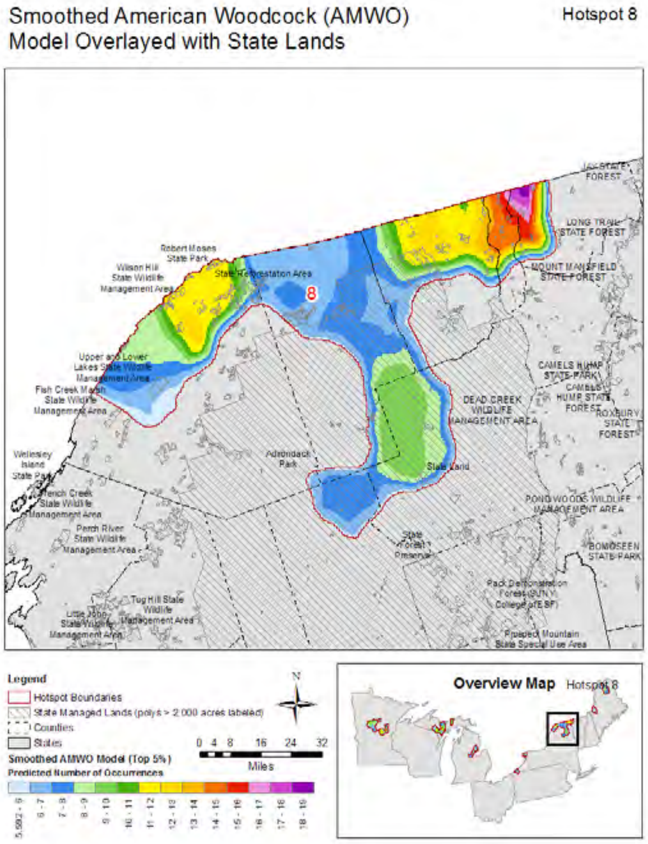
Hotspots 6 and 7



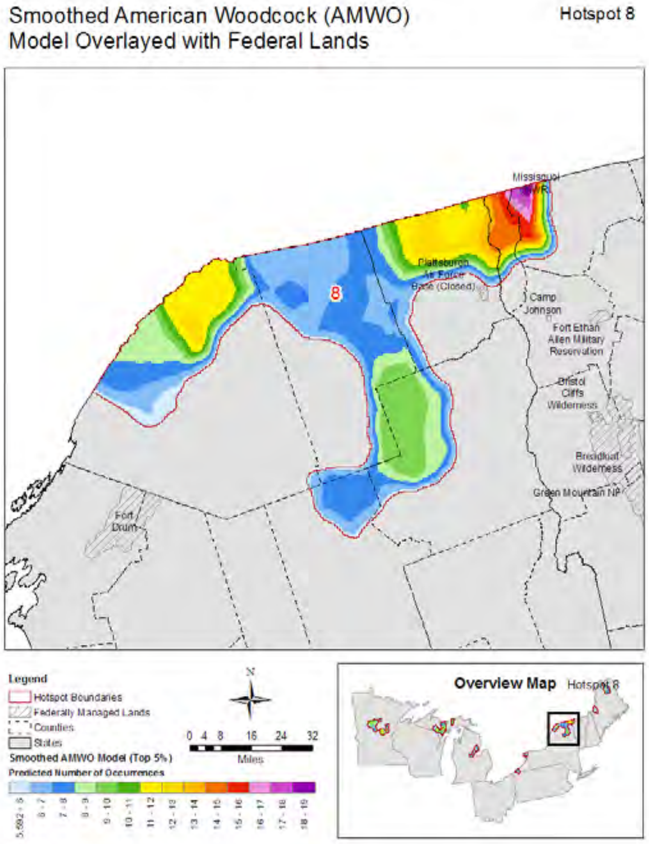
Smoothed American Woodcock (AMWO)
Model Overlayed with Federal Lands

Hotspots 6 and 7

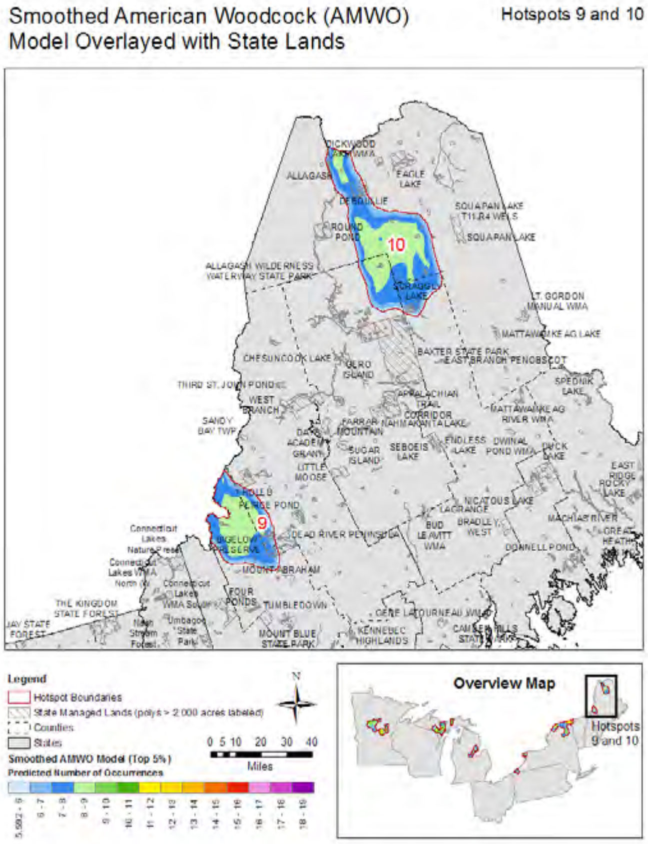



Smoothed American Woodcock (AMWO) Model Overlayed with State Lands

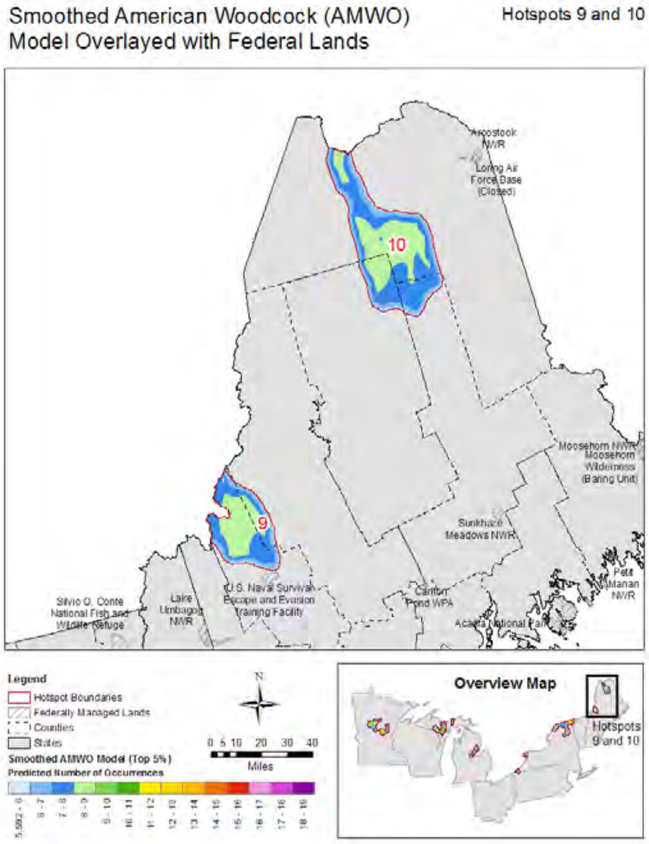
Hotspot 8


Smoothed American Woodcock (AMWO) Model Overlayed with Federal Lands

Hotspot 8


Smoothed American Woodcock (AMWO) Model Overlayed with State Lands

Hotspots 9 and 10


Smoothed American Woodcock (AMWO) Model Overlayed with Federal Lands

Hotspots 9 and 10

Both Wayne E. Thogmartin (left) and Jason Rohweder (right) are scientists with the United States Geological Survey, Upper Midwest Environmental Sciences Center in La Crosse, Wisconsin. Wayne is a research statistician (biology), working primarily at the intersection of avian ecology, spatial analysis, and statistics. He received a B.A. in Ecology/Behavior/Evolution from the University of California, San Diego, an M.S. in Zoology from the University of Arkansas, and a Ph.D. in Zoology from Southern Illinois University, Carbondale. Jason is a geographic information system analyst. He received a B.S. in Ecology from Winona State University and an M.S.in Resource Analysis from Saint Mary's University of Minnesota. His work emphasizes landscape ecology and the creation of flexible tools and models to assess species habitat.

AN EXAMINATION OF AMERICAN WOODCOCK POPULATION UNITS

JAMES R. KELLEY, JR.[1]**,** U.S. Fish and Wildlife Service, Division of Migratory Bird Management,
BHW Federal Building, 1 Federal Dr., Fort Snelling, MN 55111, USA

Abstract: Since 1977, American woodcock (*Scolopax minor*) have been managed on the basis of 2 populations, or regions, as recommended by an examination of banding data which indicated little interchange of birds between the Atlantic and Mississippi Flyways. Past examination of woodcock populations used state or province of banding as the smallest level of geographic unit. I examined the spatial distribution of 3,431 direct recoveries of woodcock grouped by 44 banding degree blocks using multi-response permutation procedures (MRPP). Cluster analysis of MRPP statistics was used to group degree blocks with similar recovery patterns. Results of clustering indicated general support for division of woodcock populations by flyway boundaries, but also provided information on locations of potential sub-populations of birds that may serve as reference areas for future banding studies.

Proceedings of the American Woodcock Symposium 10: 223

Key words: American woodcock, banding, MRPP, population units.

James R. Kelley, Jr. has been a biologist with the U.S. Fish and Wildlife Service, Division of Migratory Bird Management from 1991 to present. During 1991–2000 he served as a staff biologist focusing on waterfowl population dynamics and assessment. He served as the Eastern Webless Migratory Game Bird Specialist for the Division from 2000–2007. During this period he coordinated and was co-editor of the American Woodcock Conservation Plan. In 2007, he assumed duties as the Mississippi Flyway Representative where he serves as a liaison between the Service and the 14 state agencies within the Flyway. He received a B.S. in Wildlife Management from the University of Maine (1983) and an M.S. in Fisheries and Wildlife from the University of Missouri (1986).

---

[1] Email: james_r_kelley@fws.gov

AN EVALUATION OF WOODCOCK HARVEST REGULATIONS

JAMES R. KELLEY, JR.[1]**,** U.S. Fish and Wildlife Service, Division of Migratory Bird Management,
BHW Federal Building, 1 Federal Dr., Fort Snelling, MN 55111, USA

MICHAEL W. OLINDE, Louisiana Department of Wildlife and Fisheries,
P.O. Box 98000, Baton Rouge, LA 70898, USA

Abstract: Woodcock harvest regulations in the U.S. have gradually become more restrictive in response to continued population declines. We summarized woodcock hunting season frameworks in the U.S. from 1918–2005. Population trend estimates and seasonal patterns of woodcock wing receipts under various harvest regulation packages were examined for the Eastern and Central Regions. Similarly, hunter numbers and woodcock harvest from the Annual Questionnaire Survey of U.S. Waterfowl Hunters (1964–2001) and Harvest Information Program (1999–2004) were summarized for periods characterized by similar harvest regulations.

Proceedings of the American Woodcock Symposium 10: 225

Key words: American woodcock, harvest, hunting regulations, population trends.

James R. Kelley, Jr. has been a biologist with the U.S. Fish and Wildlife Service, Division of Migratory Bird Management from 1991 to present. During 1991–2000 he served as a staff biologist focusing on waterfowl population dynamics and assessment. He served as the Eastern Webless Migratory Game Bird Specialist for the Division from 2000–2007. During this period he coordinated and was co-editor of the American Woodcock Conservation Plan. In 2007, he assumed duties as the Mississippi Flyway Representative where he serves as a liaison between the Service and the 14 state agencies within the Flyway. He received a B.S. in Wildlife Management from the University of Maine (1983) and an M.S. in Fisheries and Wildlife from the University of Missouri (1986).

Michael (Mike) W. Olinde retired in 2010 as the Research Program Manager for the Wildlife Division of the Louisiana Department of Wildlife and Fisheries. He received his B.S. in Forestry and M.S. in Wildlife Management from Louisiana State University. After working for 2 years in south Florida for the Florida Game and Fresh Water Fish Commission, he returned to his home state and became the Upland Game Study Leader. American woodcock continues to be a species of special interest to him.

---

[1] Email: james_r_kelley@fws.gov

10th American Woodcock Symposium
Roscommon, Michigan, USA

AMERICAN WOODCOCK FALL MIGRATION USING CENTRAL REGION BAND RECOVERY AND WING-COLLECTION SURVEY DATA

NICK A. MYATT[1]**,** Arkansas Cooperative Fish & Wildlife Research Unit, Department of Biological Sciences, *University of Arkansas, Fayetteville, AR 72701, USA*

DAVID G. KREMENTZ, U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit, Department of Biological Sciences, *University of Arkansas, Fayetteville, AR 72701, USA*

Abstract: Band recovery and Wing-collection Survey data have the potential to provide information on American woodcock (*Scolopax minor)* fall migration ecology in the Central Region, yet these extensive data sets have not been analyzed recently. We analyzed all direct recoveries of woodcock banded in Michigan, Minnesota, and Wisconsin, as well as Wing-collection Survey data, to determine the progression of fall migration, the migration direction and final destination of woodcock migrating from these states. Migration initiation based on band recoveries was not observed until late October and early November, with most migration occurring during November. Wing receipt data showed a similar trend, with most change in mean receipt latitude occurring from 1 November–5 December. During November, wing receipts were spread through the entire Central Region. By 15–31 December, 92% (n = 26) of band recoveries were on the wintering grounds (south of 33º N latitude). Most banded woodcock from Michigan, Minnesota, and Wisconsin wintered in Louisiana. Because woodcock banded in these states remain in these states through November, they will be exposed to harvest for most of the hunting season. Should the population status of local birds be a concern, this migration pattern needs to be considered when setting season dates.

Proceedings of the American Woodcock Symposium 10: 227–228
Key words: American woodcock, band recovery, fall migration, *Scolopax minor*, Wing-collection Survey, phenology.

Printed with permission of The Wildlife Society and Allen Press Publishing Services. The abstract and manuscript were published here:

Myatt, N. A., and D. G. Krementz. 2007. American woodcock fall migration using Central Region band recovery and wing receipt data. Journal of Wildlife Management. 71: 336-344.

Nick Myatt received a B.S. in Natural Resources Management from Northland College in 2002 and a M.S. in Biology from University of Arkansas in 2004. Nick's thesis at the Arkansas Cooperative Fish and Wildlife Research Unit focused on the fall migration ecology of American woodcock. After completing his masters degree, he served as Program Coordinator of the "Access and Habitat Program" for the Oregon Department of Fish and Wildlife (ODFW) from 2004-2007. Currently, Nick is the District Wildlife Biologist for ODFW in Baker City, OR.

---

[1] Present address: Baker District Wildlife Biologist, Oregon Department of Fish and Wildlife, 2995 Hughes Lane, Baker City, OR 97814 USA

David Krementz David received a B.S. in Wildlife Management and Conservation, a M.S. in Zoology and Physiology from University of Wyoming in 1977 and 1980, respectively, and a Ph.D. in Zoology from University of Western Ontario in 1984. After completing his doctorate, he served as a wildlife biologist for the U.S. Fish and Wildlife Service and then the U.S. Geological Survey at the Patuxent Wildlife Research Center from 1986–1999 where he studied waterfowl, woodcock and songbird population biology and habitat use. Currently, David is the Unit Leader of the U.S. Geological Survey Arkansas Cooperative Fish and Wildlife Research Unit which he has held since 1999. David is a Past-President of the Arkansas State Chapter of the Wildlife Society.

INCUBATION BEHAVIOR OF THE AMERICAN WOODCOCK (*SCOLOPAX MINOR*) IN MAINE

DANIEL G. MCAULEY[1], U.S. Geological Survey, Patuxent Wildlife Research Center-Orono,
5768 S. Annex A, Orono, ME 04469-5768, USA

DAVID A. CLUGSTON[2], U. S. Geological Survey, Patuxent Wildlife Research Center-Orono,
5768 S. Annex A, Orono, ME 04469-5768, USA

JERRY R. LONGCORE, U. S. Geological Survey, Patuxent Wildlife Research Center-Orono,
5768 S. Annex A, Orono, ME 04469-5768, USA

WILLIAM HALTEMAN, Department of Mathematics and Statistics,
Neville Hall, University of Maine, Orono, Maine 04469 USA

Abstract: From April–June, 1987 and 1988, 12 radio-equipped female woodcock (*Scolopax minor*) were remotely monitored at their nest sites on Moosehorn National Wildlife Refuge to determine patterns and constancy of incubation behavior. Females spent 92% of their time on the nest, leaving for only 108.42 ± 3.77 (SE) min/day. The total time spent off the nest each day did not vary by year ($P = 0.39$), by daily high temperature ($P = 0.71$), or by precipitation ($P = 0.48$). There was some indication that renesting birds spent more time off of the nest/day than first nesters and that the amount of time woodcock hens spent off the nest at night was related to the phase of the moon. Nesting woodcock hens consistently left their nests during crepuscular periods, remaining on the nest for only 1 of 131 morning crepuscular periods and 3 of 131 evening crepuscular periods. Crepuscular movements of nesting hens accounted for 39% of the total time spent off the nest (258 episodes), 55% of time spent off the nest occurred during the daylight hours (294 episodes), and only 6% occurred at night (38 episodes). Nesting females spent 41% of all their time off the nest, active in the immediate vicinity of the nest.

Proceedings of the American Woodcock Symposium 10: 229–230

Key words: American woodcock, incubation constancy, nesting, Maine.

Dan McAuley is the Station Leader and Research Wildlife Biologist with the U.S. Geological Survey's Patuxent Wildlife Research Center, Orono, Maine field station. He has worked for Patuxent since 1978. Primary responsibility is to conduct field research on migratory bird issues identified by the U.S. Fish and Wildlife Service and other Department of Interior agencies. He has worked on American woodcock population ecology and conservation for the past 30 years, addressing issues related to population dynamics; ecology; spring, summer, and fall survival and habitat use; habitat change along woodcock Singing-ground Surveys routes; and the effects of hunting pressure on American survival of woodcock in Maine, New Hampshire, Vermont, and Pennsylvania. He is the Assessment and Research Coordinator for the American Woodcock Initiative and has helped to develop Best Management Practices for woodcock for the 4 regional woodcock initiatives. Current research includes studies on adaptive habitat management and habitat use of American woodcock in the Northeast, survival of American woodcock during fall migration using radio telemetry, as well as studies on survival and recruitment of common eiders using mark-recapture methods and band recovery analyses, and evaluating use of fixed-wing aircraft to survey red-necked phalaropes in the Bay of Fundy.

---

[1] E-mail:dan_mcauley@usgs.gov

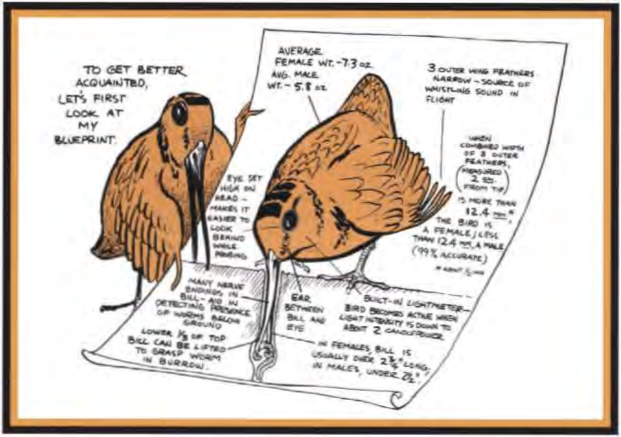
[2] Present address: Army Corps of Engineers, Environmental Resources Branch, P.O. Box 2946, Portland, OR 97208 USA.

David Clugston spent most of his career involved with large scale population and habitat management evaluations varying from wild horse censusing and behavioral studies in the high desert of Wyoming to New England harvest and habitat use of American woodcock. He has had the good fortune of having captured, handled, radio-tagged, and tracked a wide variety of species in some of the wildest parts of the United States. For the last 9 years he has been a Fishery Biologist with the Corps of Engineers, Northwest Division and Portland District Offices overseeing the RM&E programs dealing with fish passage and migration in the Columbia River Basin.

In 1971 ***Bill Halteman*** graduated from Oberlin College with a B.A. in Mathematics. After a 4-year interlude for military service, he began studies for the Ph.D. in Biostatistics at the University of Washington. He graduated in 1980 and joined the Mathematics faculty at the University of Maine where he continues to serve. His time is divided between teaching applied statistics courses to graduate students from the experimental sciences and providing statistical consulting for whomever needs help analyzing their data.

Jerry Longcore is a retired Wildlife Biologist (Research), U.S. Fish & Wildlife Service and former field station Leader, Patuxent Wildlife Research Center, Orono, Maine. He is a Certified Wildlife Biologist and fellow of The Wildlife Society with a continued interest in migratory bird research and management. He resides in Orono, Maine.

Index



This publication was sponsored by the Hal and Jean Glassen Memorial Foundation. This organization is a 501(c) (3) tax-exempt organization.

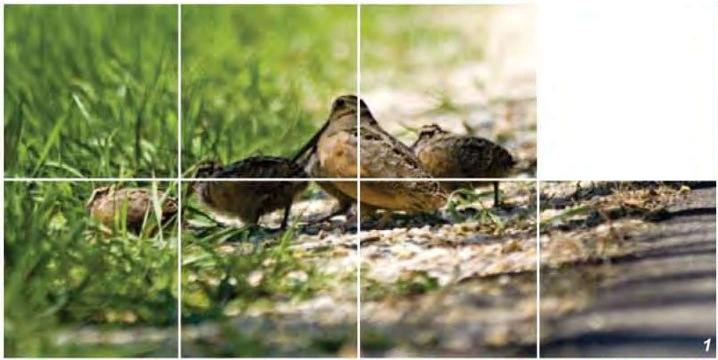
The foundation was established in 1992 to receive and administer funds for these charitable and educational purposes:

- To encourage firearms shooting skills competition
- To promote the lawful use and possession of firearms.
- To help fund game bird and animal research studies by schools of natural resources.
- To support research of animal diseases affecting dogs and cats.
- To provide for the welfare of animals through the American Humane Society or other organizations that are not anti-hunting.

The foundation provides financial assistance in the form of grants, scholarships, match funds and other support to 501 (c) (3) tax-exempt organizations whose mission statements are supportive of these objectives. Qualified 501 (c) (3) organizations are encouraged to contact:

The Hal & Jean Glassen
Memorial Foundation

6810 Nashway Drive E.
West Bloomfield, MI 48322


1


2

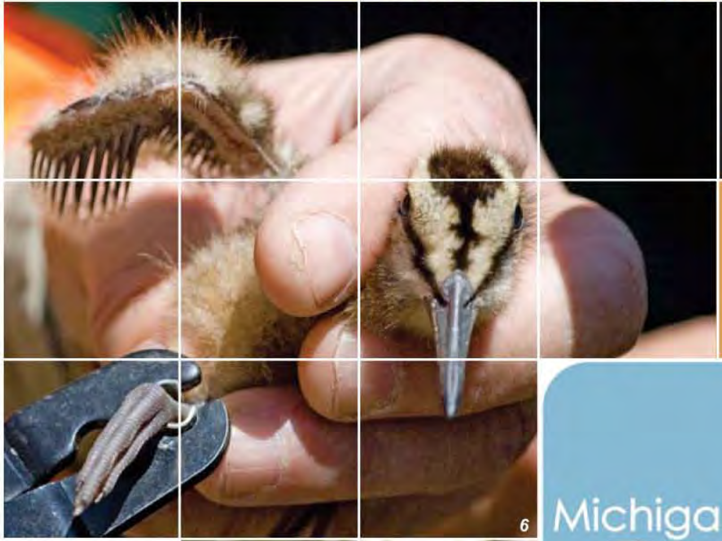

3


4


5

10th American Woodcock Symposium

Roscommon, Michigan, USA


6

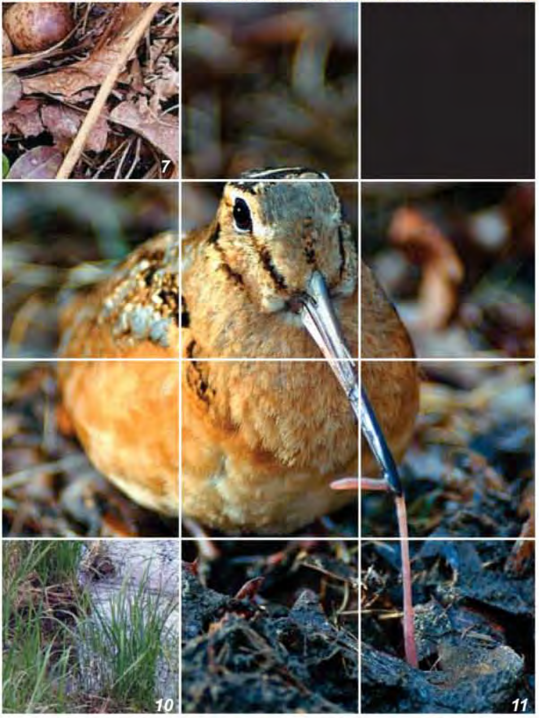

8


7

Michigan DNRE


9


10


11