HABITAT RELATIONSHIPS OF BIRD COMMUNITIES IN WISCONSIN PEATLANDS

by

STEPHANIE B. ZOLKOWSKI

A Thesis

Submitted in partial fulfillment of the requirements of the degree

MASTER OF SCIENCE

IN

NATURAL RESOURCES (WILDLIFE)

College of Natural Resources

UNIVERSITY OF WISCONSIN

Stevens Point, Wisconsin

August 2008

APPROVED BY THE GRADUATE COMMITTEE OF

Dr. Kevin R. Russell, Committee Chair
Assistant Professor of Wildlife Ecology and Management
College of Natural Resources

Mr. Loren Ayers
Terrestrial Ecologist
Wisconsin Department of Natural Resources

Dr. Tim F. Ginnett
Associate Professor of Wildlife
College of Natural Resources

Dr. Michael J. Hansen
Professor of Water Resources
College of Natural Resources

Dr. Robert H. Holsman
Associate Professor of Wildlife
College of Natural Resources

ABSTRACT

Effective conservation of biological diversity requires understanding of the influences of habitat composition and structure on species and community composition. Although patterns of bird richness and abundance in peatland natural communities have been studied in Canada, little is known about these relationships in the United States, especially within the Great Lakes region. Furthermore, environmental changes associated with global climate change could significantly impact many natural communities, including peatlands. Although potential impacts of climate change on birds are poorly understood, species composition and habitat use by peatland bird communities may be important to consider when monitoring peatlands for climate change impacts because of the sensitivity of birds to changes in vegetation composition and structure. In this study, I used several analytical methods to explain the distribution and habitat relationships of peatland birds in relation to a suite of habitat variables measured at a diverse array of peatland sites across Wisconsin.

In both 2006 and 2007, I surveyed peatland bird communities using standard unlimited-radius point counts at 14 intensive sites and 74 extensive sites previously selected by the WDNR. Intensive sites were non-randomly selected and surveyed ≥2 times each year of the study. Extensive sites were selected using a stratified random sampling design and surveyed only once during the study. At both intensive and extensive sites, point-count stations were established along a transect bisecting the midsection of each peatland site. Vegetation was sampled at each point-count station and the surrounding area following methods previously established by WDNR for the multi-taxa peatland study. To supplement these vegetation data, additional habitat

variables were measured in 2007. Vegetation was surveyed at each point within the intensive sites once per season in 2004, 2006, and 2007. Because extensive sites were surveyed only once during the study, vegetation at these sites was surveyed immediately after bird surveys. The area of each peatland site was determined using a Geographic Information System (GIS).

I grouped bird species into 3 habitat-use guilds (forest, open-shrub, peatland-associated) for analyses. Further, I grouped species as residents, short-distance migrants, and neotropical migrants. Bird species present at ≥5% of sampling stations were selected for individual analyses. I used three analytical methods to model bird habitat relationships: logistic and linear regression and canonical correspondence analysis (CCA). Data from both intensive and extensive sites previously collected by WDNR in 2004 and 2005 were included in analyses. I used stepwise logistic and linear regression to analyze habitat relationships of 42 species with sufficient detections. Dependent variables in models included species presence (logistic models) and mean abundance per site (linear models), stratified by habitat association and migratory strategy. I also analyzed habitat relationships of selected species that presently were near the edge of their distribution range within the study area. Because of different sampling intensities (i.e., years, number of point-count surveys/year) within intensive and extensive sites, I modeled data from intensive and extensive sites separately. I also analyzed the 2007 extensive sites separately to examine potential differences resulting from including additional habitat variables measured in 2007. I then examined bird community habitat relationships using CCA, stepwise logistic and linear regression, as well as *a priori*

logistic and linear regression models with Akaike's Information Criterion (AIC) model selection.

Generally, significant variables common among analytical approaches indicated that bird occurrence and relative abundance within peatlands increased in response to greater cover and structural diversity of shrub strata. Among logistic and linear regression models selected using AIC, models containing the variables snags, percent cover of low shrubs and high herbs, peatland area, and percent cover of all conifer trees received the strongest empirical support. Overall, foliage height diversity within peatlands appeared to be the most important structural attribute contributing to bird diversity and abundance within these habitats. In addition to providing a better understanding of peatland bird habitat relationships within the Great Lakes region, the results of this study may provide managers with important baseline data that could be used to monitor potential effects of climate change on peatland flora and fauna.

ACKNOWLEDGMENTS

I thank my graduate advisor, Dr. Kevin Russell for his guidance and encouragement throughout all stages of my graduate research. His enlightening words of wisdom and philosophies have made the past few years enjoyable for me. I am grateful for his dedication, editorship, mentorship, and friendship. I thank Mr. Loren Ayers for his cooperation and guidance throughout the course of this project. I appreciate the opportunity to work with the Wisconsin Department of Natural Resources (WDNR) on a project of this size and subject matter. I also thank other employees of the WDNR that have provided me with assistance in the office and the field including: Brian Bub, Dean Van Doren, Drew Feldkirchner, Archer Larned, Richard Staffen, Jill Rosenberg, Katy Werner, and Melissa Wolfe.

I also thank the other members of my committee: Drs. Tim Ginnett, Michael Hansen, and Robert Holsman, whose advice, feedback, teachings, and encouragement have been integral parts in the success of my research. Furthermore, I thank other faculty and staff of the University of Wisconsin – Stevens Point (UW-SP) in the College of Natural Resources (CNR). In particular, I am grateful to Christine Thomas, Shelli Dubay, Kevin Lawton, and Peggy Farrell, whose helpfulness and friendship have made me feel welcome and part of a great institution. I also thank my colleagues for their assistance, comments, and friendship including: Paul and Jen Bergman, Ben Rook, Janet King, Dan McFarlane, Les Dillard, and Chris Hamilton. I thank my technicians that helped me with the field work portion of my project including: Bill Frederickson, Shawn Wolfe, Terry Hamms, Cindy Kowalchuk, and David Heimann.

Finally, I thank my immediate and extended family: the Zolkowskis and Muellers for continued support and encouragement in all aspects of my personal and professional endeavors. I appreciate all of their efforts that made me realize that I have so many people in my life that care for me and the achievements that I reach in career and in life. Most of all, I thank my fiancé, Greg Mueller, for his limitless love, support and encouragement, as well as his helpful advice, assistance, and technical expertise with various computer programs. I am so thankful that I have such a great man in my life that loves me and encourages me to strive to achieve everything I desire in life.

TABLE OF CONTENTS

CHAPTER I: HABITAT RELATIONSHIPS OF BIRD COMMUNITIES IN WISCONSIN PEATLANDS

CHAPTER II: HABITAT RELATIONSHIPS OF THREE PEATLAND-ASSOCIATED BIRDS IN WISCONSIN

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

PREFACE

This thesis is comprised of two chapters consisting of separate, but related manuscripts submitted for publication that investigate the distribution and habitat relationships of bird communities within peatland natural communities of Wisconsin. Although the habitat relationships of birds have been extensively studied in both upland forest and grassland systems, relatively few studies have investigated these relationships in peatland ecosystems of North America. Furthermore, existing studies of peatland bird communities within North America have been largely conducted in the boreal regions of Canada because peatlands are common there. Despite the widespread distribution of peatland ecosystems within the Great Lakes region of the United States, including Wisconsin, the bird communities inhabiting these systems have previously been poorly characterized.

Both scientists and managers are increasingly concerned about the potential effects of global climate change on biological diversity. Environmental changes associated with global warming could significantly impact many natural communities in a number of ways. Animals and plants are expected to respond to climate change through changes in range (compression, extension, shifting), abundance, phenology, productivity, community composition, and biotic interactions. Plants are expected to exhibit changes in dispersal and physiology (photosynthetic rate, net primary production, water-use efficiency). The predicted response of acidic bog peatlands to climate change is increased shrub cover and reduced abundance of graminoids, whereas the predicted response of more alkaline fen peatlands to climate change will likely depend on changes in water-table elevation (Weltzin et al. 2003). Meanwhile, upland forest expansion (afforestation) into peatlands worldwide from both natural and anthropogenic disturbances is expected to negatively affect the biological diversity of peatlands (Lachance et al. 2005).

Distributional changes have been documented in some species of plants and animals (Schneider and Root 2002, Parmesan and Yohe 2003). Prior to European settlement, species range shifts resulting from periods of climate change were not constrained by artificial barriers such as roads, cities, reservoirs, and significant regions of altered or discontinuous habitats. Therefore, negative patterns in population dynamics and even species extinction rates could be more severe given the synergistic effects of climate change coupled with habitat loss and fragmentation. Responses of plant communities to potential changes in climate are exceedingly complex and difficult to predict (Schulze et al. 2002). For example, although the general effects of increasing CO_2 concentrations on plants and their responses are well documented and understood (Tjoelker et al. 1998, Tuba et al. 1998, Lloyd 1999, Norby et al. 2005, Johnson et al. 2006, Sherwood and Idso 2006), a large suite of regional and site-level influences on physiology and phenology decrease the predictability of plant responses to climate change within a given community.

The species composition, abundance, and habitat relationships of bird communities are important indicators of climate-change impacts on ecosystems because of the sensitivity of birds to changes in temperature, patterns of vegetative cover, and microhabitat structure (Walsberg 1985, Stockwell 1994). Birds are expected to track climate as a function of their physiological tolerances (Davis et al. 1986, Webb 1987, Pastor and Post 1988, Graham and Grimm 1990, Davis and Zabinski 1992, Hart and

Shaw 1995, Root and Schneider 1995), and bird species frequently segregate along microclimate gradients that reflect vegetation gradients (Smith 1977).

Specific impacts of global climate change on birds are not well understood (Hudson 1990, Marquiss and Newton 1990, Austin et al. 1993). Some monitoring programs have been initiated to examine bird distribution changes in response to climate change (Sauer and Droege 1992) and to use birds as bioindicators of these changes (Morrison 1986, Temple and Wiens 1989). Climate change could affect ecological traits of birds, including diet (Crick and Sparks 1999), habitat use (Zalakevicius and Zalakeviciute 2001, Travis 2003), body mass (Crick and Sparks 1999, Stevenson and Bryant 2000), and breeding density (Dunn and Winkler 1999). For example, both common yellowthroats (*Geothlypis trichas*) and Lincoln's sparrows (*Melospiza lincolnii*) would be expected to respond negatively to increased forest cover (afforestation) resulting from climate change because these species usually nest in copses of black spruce (*Picea mariana)* localized in transition areas between forested edges and open habitats (Gauthier and Aubrey 1995, Desrochers 2001).

Studies of climate change impacts on migratory patterns of short-distance and long-distance migratory birds have produced conflicting results (Saunders 1959, Huin and Sparks 1998, Sokolov et al. 1998, Huin and Sparks 2000, Lemoine and Bohning-Gaese 2003). Short-distance migrants in the United States are expected to respond more immediately to global climate change than long-distance migrants because the latter rely primarily on photoperiod rather than temperature for cueing migration (Butler 2003). In contrast, climate change models developed for Europe have predicted that warmer winters will cause a reduction in long-distance migrants because resident and short-distance migrants move less, thereby increasing competition for resources with long-distance migrants (Lemoine and Böhning-Gaese 2003).

Although the effects of climate change on breeding phenology of birds have not been studied extensively (Dunn and Winkler 1999, Schwartz and Reiter 2000, Visser et al. 2003), increasing temperatures are expected to influence the timing of initial reproduction in birds because warmer temperatures cause birds to breed earlier (Nice 1937, Jàrvinen 1994, Crick et al. 1997, Winkel and Hudde 1997, Forchhammer et al. 1998, McCleery and Perrins 1998, Brown et al. 1999, Crick and Sparks 1999, Dunn and Winkler 1999, Hussell 2003, Torti and Dunn 2005). Although relationships between climate change and bird reproduction are predicted to be complex and species- and region-specific (Torti and Dunn 2005), in general, niche specialists will likely respond more severely to climate change than generalist species because of changes in vegetation that alter or eliminate specific habitat and forage resources (Daan et al. 1988, Rotenberry and Wiens 1991).

Three important components for studies related to global climate change include 1) fine-scale temporal resolution to identify frequencies of biological change and to establish the relationship between biological changes and associated physiological events, 2) broad-scale spatial resolution to establish whether changes are occurring throughout the range of a species or at a smaller local scale, and 3) wide taxonomic resolution to help rule out alternate hypotheses (Sagarin 2002). A change across several or many taxonomic groups or life history strategies is more likely to be a general biological response to climatic change.

In 2003, the Wisconsin Department of Natural Resources (WDNR) initiated a study ("Biodiversity in Selected Natural Communities Related to Global Climate Change") to assess potential influences of climate change on wildlife and plant species associated with peatland natural communities of Wisconsin. Baseline data for birds, small mammals, herpetofauna, vascular plants, and invertebrates were collected by the WDNR and cooperators from 2004 to 2007 for comparisons with future studies. My specific objective in chapter 1 was to determine if avian richness and relative abundance within Wisconsin's peatlands could be explained by a suite of multivariate compositional and structural habitat variables. My specific objective was to determine if the presence and relative abundance of the three species within Wisconsin's peatlands could be explained logistic and linear regression modeling of compositional and structural habitat variables.

In both 2006 and 2007, I surveyed peatland bird communities using standard unlimited-radius point counts at 14 intensive sites and 74 extensive sites previously selected by the WDNR from across Wisconsin. Intensive sites were non-randomly selected and surveyed ≥2 times each year of the study. Extensive sites were selected using a stratified random sampling design and surveyed only once during the study. I also incorporated previous data on peatland birds and habitat variables collected by WDNR in 2004 and 2005. In the first chapter, I analyzed the bird point-count data and habitat variables using several analytical methods to create explanatory models of bird presence and abundance in Wisconsin peatlands. Specifically, I (1) explored the relationship between bird species, grouped by habitat and migratory guilds, and specific elements of microhabitat structure and landscape characteristics using canonical correspondence analysis (CCA); (2) examined the influence of habitat and landscape variables on bird presence using stepwise logistic regression; and (3) examined the influence of habitat and landscape variables on bird relative abundance using stepwise linear regression. I modeled data from intensive and extensive sites separately because of different sampling intensities (i.e., years, number of point-count surveys/year) within intensive and extensive sites. I also analyzed the 2007 extensive sites separately to examine any differences resulting from including additional habitat variables measured in 2007. Finally, I analyzed selected bird species that presently appear to be at the edge of their distributional range within the study area.

In the second chapter, I used the bird point-count data and habitat variables to model habitat relationships for 3 bird species, common yellowthroats, Nashville warblers (*Vermivora ruficapilla*), and palm warblers (*Dendroica palmarum*), that are considered strong peatland associates. Specifically, I determined if (1) habitat variables explained the probability of bird occurrence and (2) habitat variables explained variation in bird relative abundance.

LITERATURE CITED

Austin, A., N. A. Clark, J. J. D. Greenwood, and M. M. Rehfisch. 1993. An analysis of the occurrence of rare birds in Britain in relation to weather. BTO Research Report 99, British Trust for Ornithology, Thetford.

Brown, J. L., S. H. Li, and N. Bhagabati. 1999. Long-term trend toward earlier breeding in an American bird: A response to global warming? Proceedings of the National Academy of Sciences USA 96:5565-5569.

Butler, C. J. 2003. The disproportionate effect of global warming on the arrival dates of short-distance migratory birds in North America. Ibis 145:484-495.

Crick, H. Q. P. and T. H. Sparks. 1999. Climate change related to egg-laying trends. Nature 399:423.

Crick, H. Q. P., C. Dudley, D. E. Glue, and D. L. Thompson. 1997. U.K. birds are laying eggs earlier. Nature 388:526.

Daan, S., C. Dijkstra, R. Drent, and T. Meijer. 1988. Food supply and the annual timing of avian reproduction. *In* Acta XIX Congressus Internationalis Ornithologici. Vol. 19. Ottawa.

Davis, M. B., K. D. Woods, S. L. Webb, and R. P. Futuyma. 1986. Dispersal versus climate: Expansion of *Fagus* and *Tsuga* in the Upper Great Lakes region. Vegetatio 67:93-103.

Davis, M. B. and C. Zabinski. 1992. Changes in geographical ranges resulting from greenhouse warming effects on biodiversity of forests. *In* R. Peters and T. Lovejoy, editors. Global warming and biological diversity. Yale University Press, New Haven, Connecticut, USA.

Desrochers, A. 2001. Les oiseaux : diversité et répartition. *In* S. Payette and L. Rochefort (editors). Écologie des tourbières du Québec-Labrador. Presses de l'Université Laval, Saint-Nicolas, Québec.

Dunn, P. O. and D. W. Winkler. 1999. Climate change has affected the breeding date of tree swallows throughout North America. Proceedings of the Royal Society of London B 266:2487-2490.

Forchhammer, M. C., E. Post, N. C. Stenseth. 1998. Breeding phenology and climate.

Nature 391:29-30.

Gauthier, J. And Y. Aubry (editors). 1995. Atlas des oiseaux nicheurs du Québec méridional. Association québécoise de protection des oiseaux and Service canadien de la faune, Environnement Canada (région du Québec), Montréal, Québec.

Graham, R. W. and E. C. Grimm. 1990. Effects of global climate change on the patterns of terrestrial biological communities. Trends in Ecology and Evolution 5:289-292.

Hart, J. and R. Shaw. 1995. Shifting dominance within a montane vegetation community: results of a climate-warming experiment. Science 267:876-880.

Hudson, R. 1990. Implications of a 'greenhouse climate' for British birds. BTO Research Report 47, British Trust for Ornithology, Tring.

Huin, N. and T.H. Sparks. 1998. Arrival and progression of the swallow *Hirundo rustica* through Britain. Bird study 45:361-370.

Huin, N. and T. H. Sparks. 2000. Spring arrival patterns of the Cuckoo *Cuculus canorus*, Nightingale *Luscina megarhynchos*, and Spotted Flycatcher *Musciapa striata* in Britain. Bird Study 47:22-31.

Hussell, D. J. T. 2003. Climate change, spring temperatures, and timing of breeding of tree swallows (*Tachycineta bicolor*) in southern Ontario. Auk 120:607-618.

Jàrvinen, A. 1994. Global warming and egg size of birds. Ecography 17:108-110. USDA Forest Service Southern Region, Atlanta, GA.

Johnson, D. W., A. M. Hoylman, J. T. Ball, and R. F. Walker. 2006. Ponderosa pine responses to elevated CO_2 and nitrogen fertilization. Biogeochemistry 77:167-175.

Lachance, D., C. Lavoie, and A. Desrochers. 2005. The impact of peatland afforestation on plant and bird diversity in southeastern Quebec. Ecoscience 12:161-171.

Lemoine, N. and K. Böhning-Gaese. 2003. Potential impact of global climate change on species-richness of long-distance migrants. Conservation Biology 17:577-586.

Lloyd, J. 1999. The CO_2 dependence of photosynthesis, plant growth responses to elevated CO_2 concentrations and their interaction with soil nutrient status, II. Temperate and boreal forest productivity and the combined effects of increasing CO_2 concentrations and increased nitrogen deposition at a global scale. Functional Ecology 13:439-459.

Marquiss, M. and I. Newton. 1990. Birds *in* M.G.R. Cannell and M.D. Hooper (editors), The Greenhouse Effect and Terrestrial Ecosystems of the UK. ITE Research Publication, HMSO, London.

McCleery, R. H. and C. M. Perrins. 1998. Temperature and egg-laying trends. Nature 391:30-31.

Morrison, M. L. 1986. Bird populations as indicators of environmental change. Current Ornithology 3:429-51.

Nice, M. M. 1937. Studies in the life history of the Song Sparrow. I. A population study of the Song Sparrow. Transactions of the Linnaean Society of New York 4:1-247.

Norby, R. J., and 18 co-authors. 2005. Forest response to elevated CO_2 is conserved across a broad range of productivity. Proceedings of the National Academy of Sciences 102:18052-18056.

Parmesan, C. and G. Yohe. 2003. A globally coherent fingerprint of climate change impacts across natural systems. Nature 421:37-42.

Pastor, J. and W. M. Post. 1988. Response of northern forests to CO_2-induced climatic change: dependence on soil water and nitrogen availabilities. Nature 334:55-58.

Root, T. L. and S. H. Schneider. 1995. Ecology and climate: research strategies and implications. Science 269:334-341.

Rotenberry, J. T. and J. A. Wiens. 1991. Weather and reproductive variation in shrubsteppe sparrows: a hierarchical analysis. Ecology 72:1325-1335.

Sagarin, R. 2002. Historical Studies of Species' Responses to Climate Change: Promises and Pitfalls. Pages 127-163 *in* S. H. Schneider and T. L. Root (editors), Wildlife Response to Climate Change: North American Case Studies. Island Press.

Sauer, J. R. and S. Droege.1992. Geographic patterns of population trends of Neotropical migrants in North America. Pages 26-42 *in* J. M. Hagan, III, and D. W. Johnson, editors. Ecology and conservation of Neotropical migrant landbirds. Smithsonian, Washington, D. C.

Saunders, A. A. 1959. Forty years of spring migration in southern Connecticut. Wilson Bulletin 7:208-219.

Schneider, S.H. and T.L. Root (editors). 2002. Wildlife responses to climate change: North American case studies. Island Press, Washington, D. C.

Schulze, E. –D., E. Beck, and K. M. Müller-Hohenstein. 2002. Plant ecology. Springer Verlag, New York.

Schwartz, M. D. and B. E. Reiter. 2000. Changes in North American spring. International Journal of Climatology 20:929-932.

Sherwood, K. and C. Idso. 2006. The net primary productivity response of Earth's temperate forests to atmospheric CO_2 enrichment. CO_2 Science 9.

Smith, K. G. 1977. Distribution of summer birds along a forest moisture gradient in an Ozark watershed. Ecology 58:810-819.

Sokolov, L. V., M. Y. Markovets, A. P. Shapoval, and Y. G. Morozov. 1998. Long-term trends in the timing of spring migration of passerines on the Courish Spit of the Baltic Sea. Avian Ecology and Behavior 1:1-21.

Stevenson, I. R. and D. M. Bryant. 2000. Climate change and constraints on breeding. Nature 406:366-367.

Stockwell, S. S. 1994. Habitat selection and community organization of birds in eight peatlands of Maine. PhD thesis, University of Maine, Orono.

Temple, S. A. and J. A. Wiens. 1989. Bird populations and environmental changes: can birds be bio-indicators? American Birds 43:260-270.

Tjoelker, M. G., J. Oleksyn, and P. B. Reach. 1998. Seedlings of five boreal tree species differ in acclimation of net photosynthesis to elevated CO_2 and temperature. Tree Physiology 18:715-726.

Torti, V. M. and P. O. Dunn. 2005. Variable effects of climate change on six species of North American birds. Oecologia 145:486-495.

Travis, J. M. 2003. Climate change and habitat destruction: a deadly anthropogenic cocktail. Proceedings of the Royal Society of London B 270:467-473.

Tuba, Z., Z. Csintalan, K. Szente, Z. Nagy, and J. Grace. 1998. Carbon gains by dessication-tolerant plants at elevated CO_2. Functional Ecology 12:39-44.

Visser, M. E., F. Adriansen, J. H. van Balen, J. Blondel, A. A. Dhondt, S. van Dongen, C.

du Feu, E. V. Ivankina, A. B. Kerimov, J. de Laet, E. Matthysen, R. McCleery, M. Orell, and D. L. Thomson. 2003. Variable responses to large-scale climate change in European *Parus* populations. Proceedings of the Royal Society of London B 270:367-372.

Walsberg, G. E. 1985. Physiological consequences of microhabitat selection. Pages 389-413 *in* M. L. Cody, editor. Habitat selection in birds. Academic Press, Orlando, Florida, USA.

Webb, T. 1987. The appearance and disappearance of major vegetational assemblages: long-term vegetational dynamics in eastern North America. Vegetatio 69:177-187.

Weltzin, J. F., S. D. Bridgham, J. Pastor, J. Chen, and C. Harth. 2003. Potential effects of warming and drying on peatland plan community composition. Global Change Biology 9:141-151.

Winkel, W. and H. Hudde. 1997. Long term-trends in reproductive traits of tits (*Parus major*, *P. caeruelus*) and Pied Flycatchers *Ficedula hypoleuca*. Journal of Avian Biology 28:187-189.

Zalakevicius, M. and R. Zalakeviciute. 2001. Global climate change impact on birds: a review of research in Lithuania. Folia Zoologica 50:1-17.

CHAPTER I:
HABITAT RELATIONSHIPS OF BIRD COMMUNITIES IN WISCONSIN PEATLANDS

Abstract: Relatively little is known about relationships of birds to patch area and habitat characteristics in wetland-dominated landscapes of North America. In particular, patterns of bird occurrence and relative abundance within peatland ecosystems have been poorly characterized within the Great Lakes region of the United States. Bird communities were surveyed and habitat characteristics were measured between 2004 and 2007 at multiple points within 14 "intensive" peatland sites, sampled each year of the study, and at 74 additional "extensive" sites that were sampled once during the study. Using logistic and linear regression, and canonical correspondence analysis (CCA), I related the presence and relative abundance of individual species and habitat and migratory guilds to peatland area and habitat characteristics. Higher richness and relative abundance of peatland birds were generally positively associated with percent cover of: low shrubs to high herbs, trees, broadleaved shrubs, peatland area, and coniferous shrubs, and negatively associated with tree basal area. In particular, high foliage height diversity within peatlands appears critical for supporting diverse and abundant bird assemblages. Peatlands that possess these characteristics should support the greatest avian diversity and benefit most species. While my results provide important insights, continued research is needed in the conservation and management of birds in Great Lakes peatlands.

Key Words: area, canonical correspondence analysis, birds, Great Lakes, habitat relationships, peatlands, regression, wetlands, Wisconsin

INTRODUCTION

Two fundamental emphases in recent avian ecology research have been the importance of patch area and habitat characteristics on species richness and species composition (Swift et al. 1984, Cody 1985, Winter and Faaborg 1999, Riffell et al. 2001). Researchers have extensively documented that some bird species exhibit lower density and breeding success in small habitat patches or may be absent from such areas (Brown and Dinsmore 1986, Robbins et al. 1989, Vickery et al. 1994, Winter and Faaborg 1999). Numerous studies have documented the importance of habitat composition and structure on bird species (e.g., MacArthur and MacArthur 1961, James 1971, Willson 1974, Whitcomb et al. 1981, James and Wamer 1982, Erdelen 1984). In particular, diversity in the structure of live and dead vegetation (e.g., foliage height diversity; MacArthur and MacArthur 1961) exerts a significant influence on avian community composition because different resources are used by birds for foraging, nesting, and protection from the elements and predators (Cody 1985). For example, common yellowthroats (*Geothlypis trichas*) and Lincoln's sparrows (*Melospiza lincolnii*) decline in abundance as overhead forest canopy increases because both species typically nest in copses of black spruce (*Picea mariana*) localized in transition areas between forested edges and open patches (Gauthier and Aubrey 1995, Desrochers 2001). General theories of avian habitat relationships have evolved into the development of species-specific regression models (e.g., Gutzwiller and Anderson 1987, Naugle et al. 1999, Riffell et al. 2001) and predictive habitat suitability models to guide avian conservation and management (e.g., Prosser and Brooks 1998). However, much of this research has been conducted in terrestrial landscapes, whereas information concerning habitat relationships of wetland birds remains relatively scarce (Weller 1999, Riffell et al. 2001).

Avian habitat relationships have been investigated for some wetland ecosystems, including wet meadows (Riffell et al. 2001), depressional forested wetlands (Riffell et al. 2006), inland riparian wetlands (Inman et al. 2002), and prairie potholes (Naugle et al. 1999). However, information concerning species assemblages and habitat associations is lacking or limited for many wetland types, including peatlands. Ombrotrophic (bog) and minerotrophic (fen) peatlands are widespread ecosystems, covering approximately 3-4 x 10^6 km^2 worldwide (Lachance et al. 2005). Most peatlands have a boreal distribution, between 50° and 70° N in Canada, Russia, and northern Europe, although an estimated 3.7 million ha of peatlands occur in the temperate, coterminous United States (Hall et al. 1994). Although the overall biological diversity of peatlands is low when compared to other wetland ecosystems, these habitats often support distinctive flora and fauna. This is particularly true for peatlands at the southern extent of their distribution, where they support plant and animal species commonly found at more northern latitudes and are considered islands of boreal diversity in temperate ecosystems (Lachance et al. 2005). Consequently, the continued loss and degradation of peatlands from agriculture, forestry, urbanization, and harvest of peat moss may provide a significant threat to regional biological diversity. Additionally, potential changes in peatland vegetation composition and structure from anthropogenic climate change are expected to cause large changes in peatland flora and fauna (Weltzin et al. 2003, Lachance et al. 2005).

Recent work has documented the area and habitat associations of bird communities within boreal peatlands of Canada (Calmé and Desrochers 2000, Calmé et al. 2002, Lachance et al. 2005). However, species assemblages and habitat relationships of birds within peatlands of the Great Lakes Region of the United States have been poorly characterized. This is of particular concern because these peatlands serve as boreal refugia within surrounding temperate landscapes, and may provide critical migratory, breeding, and foraging habitat for a wide variety of bird species (Cutright et al. 2006).

My objective was to determine if avian richness and relative abundance within Wisconsin's peatlands could be explained by compositional and structural habitat variables. As part of a larger, long-term effort investigating potential effects of climate change on peatland ecosystems in Wisconsin, I sampled breeding bird communities and habitat characteristics in 2006 and 2007 within peatland wetlands distributed across the state. I also incorporated data previously collected at these and similar peatland sites in Wisconsin in 2004 and 2005. Information about these habitat relationships will help guide future research for Great Lakes peatlands, including establishment of baseline data for assessing changes in peatland bird communities resulting from future natural and anthropogentic disturbances. Without detailed knowledge about area and habitat relationships of birds using these wetlands, effective management and conservation of avian habitat is not possible in the Great Lakes region.

METHODS

Study Area

My study was conducted at individual peatland wetlands ("sites") scattered across Wisconsin that were selected by the WDNR for its broader multi-taxa climate change project. Study sites were selected to represent the geographic distribution of peatlands in

Wisconsin and to account for differences in topography, climate, and vegetation characteristics between the two ecological provinces (Keys et al. 1995) within the state. The Laurentian Mixed Forest Province covers the northern half of Wisconsin (Province 212), and the Eastern Broadleaf Forest Province (Province 222) covers southern Wisconsin (Fig. 1). The division between these two provinces is known as the "Tension Zone," along which the northern coniferous-deciduous forest changes gradually into southern oak forests and savannas and the former prairie region. In Wisconsin, peatland natural communities include black spruce (*Picea mariana*) swamps, bog relicts, boreal rich fens, muskegs, open bogs, poor fens (including central poor fens), tamarack (*Larix laricina*) poor swamps, tamarack rich swamps, northern wet-mesic forests including white cedar (*Thuja occidentalis*) swamps, southern sedge meadows, and northern sedge meadows.

Selection of study sites was based on two levels of survey intensity. The WDNR used Natural Heritage Inventory (NHI) data for Wisconsin natural communities, state natural areas, and other sources to select 14 peatland complexes as intensive survey sites (Fig. 2). These sites were subjectively determined by the WDNR to have experienced minimal human disturbance and to have a high likelihood of future stability (i.e., protected from direct anthropogenic influences). The 14 sites were also selected to ensure broad geographic representation within each province in Wisconsin. Intensive sites were designated for repeated sampling during each year of the study to account for temporal variation in bird populations.

A stratified random sampling design was used to select additional individual peatlands, distributed statewide and within both ecological provinces, as potential extensive survey sites. New extensive sites were randomly selected to survey each year and were surveyed only once during the study. From 2004 to 2007, 74 extensive sites were surveyed (Fig. 3). The purpose of extensive sites was to provide broad spatial resolution across peatland wetlands of Wisconsin. Intensive site peatlands ranged 16-792 ha in area ($\bar{x}$ = 336 ha ± 67 SE), whereas extensive site peatlands ranged 16-607 ha in area ($\bar{x}$ = 126 ha ± 15).

Bird Sampling

Point counts (Ralph et al. 1995, Howe et al. 1997a) were used to assess presence and relative abundance of breeding passerine birds (Robbins 1991) within both intensive and extensive peatland sites. Point-count stations were established along a transect running through the midsection of each peatland site. Because sites varied in size, I attempted to ensure that the number of points was proportional to peatland area (i.e., more points at larger sites). For peatlands ≥100-ha, the number of points was limited to nine to ensure that all points within a site could be surveyed during one visit (Bub and Werner 2004). Stations were located ≥250-m apart in forested peatlands and ≥300-m apart in open peatlands to ensure independence of detections among points (Ralph et al. 1995, Howe et al. 1997a). Point-count stations were established ≥125-m from habitat edges (i.e., the mapped boundaries of each site) to minimize detection of birds associated with non-peatland habitat types (Howe et al. 1997a).

Unlimited-radius point counts were conducted at each station for 10 minutes from 0400 to 0930 Central Daylight Time. Point count surveys were conducted from late May to mid-July between 2004 and 2007. This start date minimized detection of non-breeding migrant species (i.e., transients). Unlimited-radius counts were used because differences in vegetation among sites make judgment of exact distances difficult (Ralph et al. 1995). To minimize potential effects of seasonal variation in bird activity, intensive sites were surveyed in reverse order during the second visit. Because multiple individuals surveyed point counts, observers were rotated among intensive sites to minimize observer bias. Each year, a different set of ≤50 extensive sites, which were randomly selected by the WDNR, were surveyed once. Thus, point-count stations within extensive sites were only surveyed once during the study (Bibby et al. 1992, Ralph et al. 1995). Surveys were not conducted during periods of rain, heavy fog, or high winds (i.e., Beaufort >3; Table 1) because these conditions are known to decrease detectability of birds. Wind code (Table 1), sky code (Table 2), and temperature (°C) were recorded at each point-count station prior to initiating a survey.

Species and sex (if known) of all birds heard or seen during counts were recorded. Counts were recorded within three intervals (0-3 min, 3-5 min, 5-10 min) during which each bird was first detected. Birds that flew over the point during surveys (i.e., “flyovers”) or were detected before and after the 10-min period were recorded separately. Although exact distances to each bird could not be measured, horizontal detection distances from the point center to each bird were mapped in classes. Within forested (closed-canopy) peatlands, bird distances were mapped at either 0-50 m or >50 m. Distances to birds in open habitats are easier to estimate (Ralph et al. 1995, Howe et al. 1997a), so bird detections at these sites were mapped at either 0-50 m, 50-100 m, or >100 m.

Habitat Sampling

I sampled vegetation surrounding each point-count station following methods previously established by the WDNR for the multi-taxa peatland study (Table 3). Vegetation was surveyed at each point within intensive sites once per season in 2004, 2006, and 2007. Extensive sites were surveyed only once during the study, so vegetation at these sites was surveyed immediately after bird surveys. The point-centered quarter method (Cottam and Curtis 1956) was used to estimate tree species composition, size, and density (Krebs 1989) at each point-count station. At each point, species, diameter at breast height (dbh; cm), height (measured with a clinometer; m), and distance (m) of the nearest ≥7.5-cm tree in each quarter was measured. Within open peatlands, N/A was recorded for each quadrant in which no trees were encountered within 50 m of the point center.

Habitat characteristics were measured using several different methods previously established by the WDNR. Within a 10-m radius plot surrounding each point-count station, using visual estimation, percent cover classes (≤1%, 2-5%, 6-25%, 26-50%, 51-75%, 76-95%, 96-100%) of 5 vegetation height strata were recorded: trees (>10 m), trees-high shrubs (2-10m), low shrubs and high herbs (0.5-2 m), low herbs (0-0.5 m), and moss (0 m). For tree and tree-high shrub strata, percent cover was recorded separately for total cover, conifer cover, and broadleaf cover. The number of snags was tallied within each plot. Ocular estimates of the structural position and relative abundance of tree, shrub, sub-shrub, and herbaceous plant species were obtained for each plot using structure and relative abundance codes (CNPS 1998). Structural codes included canopy dominant, canopy associate, subcanopy-sapling, seedling, shrub dominant, and shrub associate. To categorize relative abundance, based on visual assessment, a designation of “rare” was used for species with few individuals, “uncommon” was used for species that were infrequently encountered, “common” was used for species that were locally abundant or frequently encountered, and “abundant” was used for species that were dominant within their strata in the plot.

Additional Vegetation Sampling in 2007.—To further quantify vegetation characteristics within intensive and extensive sites, additional vegetation measurements were recorded at all point-count stations surveyed in 2007. Within the 10-m radius plot, tree species, tree height, and tree dbh were recorded for three additional randomly-selected trees in each quarter. The dbh of snags within the 10-m radius plot was also measured. Percent canopy closure in each plot was estimated with a spherical densiometer in each cardinal direction and averaged for the plot. I measured ground cover at the center of the 10-m radius plot with a 1-m^2 Daubenmire frame (Daubenmire 1959) and recorded the percent cover of herbaceous vegetation, woody ground cover, and leaf litter. Sapling height was measured with a meter-stick or clinometer for the three tallest saplings and averaged for the plot. Canopy height was measured with a clinometer for the three tallest canopy trees and averaged (Moorman and Guynn 2001). Visual obscurity was measured using a 2.5 × 150-cm cover pole (Robel et al. 1970), marked in 10-cm sections. The pole was placed in the center of the plot and the total number of sections ≥75% obscured from each cardinal direction was recorded, measured at eye level. The mean of the four readings was used to estimate percent shrub obscurity for each plot. Using GIS, I determined the total area (ha) of each peatland site. I traced the edge of peatland sites from digital orthophotos and calculated the total area (ha) of the peatland.

Data Analyses

Prior to data analysis, bird point-count and habitat data was tested for significant year effects between 2004 and 2007 using analysis of variance (ANOVA) and t-tests. Overall, no significant year effects were found in the data and therefore bird relative abundance and habitat variables were averaged within each site and then across all years.

*Modeling and analysis overview***.** I grouped bird species into 3 habitat-use guilds (forest, open-shrub, peatland-dependent) and 3 migratory guilds (residents, short-distance migrants, neotropical migrants) (Robbins 1991, Calmé et al. 2002, Cutright et al. 2006) for analysis. Bird species present at ≥5% (e.g., Bulin 2005, Lachance et al. 2005, Heltzel and Leberg 2006) of bird survey stations were selected for individual analyses (*n* = 42). Flyovers and birds detected before and after the 10-min sampling period at each point were excluded from analyses to avoid double-counting individuals.

For analyses, I combined data that I collected during 2006-2007 with those previously collected by WDNR during 2004-2005. I used three analytical methods to model bird habitat relationships: canonical correspondence analysis (CCA; Ter Braak 1986, McGarigal et al. 2000), stepwise logistic regression (Nur et al. 1999), and stepwise linear regression (Nur et al. 1999). Dependent variables included average bird relative abundance, presence by species per site stratified by habitat association and migratory strategy, and relative abundances of selected species that were near the edge of their distribution range (Cutright et al. 2006). Prior to analyses, square-root transformations of point-count data were used to normalize distributions. I included area in all datasets to account for variation in peatland size. Because of different sampling intensities (i.e., years, number of point-count surveys per year) within intensive and extensive sites, I modeled data from these sites separately. The full set of habitat variables, including those measured in 2007, was used in analyses of intensive sites. However, because a different set of extensive sites was visited each year, I also analyzed the 2007 extensive sites separately to determine if differences in results related to additional habitat variables measured in 2007. Species that may be of conservation concern in Wisconsin because they are currently at the edge of their distribution range were analyzed using the dataset of all extensive sites because of the larger sample size. Stepwise linear and stepwise logistic regressions were performed using SAS software (SAS Institute, Cary, NC).

Canonical Corresondence Analysis (CCA). I used canonical correspondence analysis (CCA; Ter Braak 1986, 1988, McGarigal et al. 2000) to examine relationships between peatland bird communities and environmental variables. This method has been widely used to relate avian communities to ecological gradients (e.g., Bolger et al. 1997, Calmé and Desrochers 2000, MacFaden and Capen 2002). The CCA is a multivariate direct ordination technique that is useful for summarizing divergent associations of members of a community to specific environmental variables. Species are ordered on axes constrained to be linear combinations of the independent variables, and CCA assumes a unimodal relationship between speciesaverage relative abundance and relevant environmental variables (Ter Braak 1986). This method creates synthetic variables (axes) that maximally separate (ordinate) unimodal distributions of species. If species abundance is related to environmental variables measured and species differ in their response to these variables, then CCA can order their distributions along the axes created from these variables. Eigenvalues associated with each axis give a relative indication of the ability of the axis to separate species distributions.

I used CCA to ordinate species average relative abundance at each site using environmental variables described above. Bird species data were square-root transformed as described above. I used CCA for bird species that were detected at >5% of point count stations and for each habitat-association and migratory strategy guild. Ideally, rare species would be examined in gradient analysis, but these species tend to obscure community patterns (Ter Braak 1986, MacFaden and Capen 2002).

CCA is robust to multicollinearity in environmental data. It may be disadvantageous to eliminate correlated variables prior to analyses because redundancy in environmental data may average out measurement errors (Palmer 1993). However, I performed limited variable reduction by examining Variance Inflation Factors (VIF) for each environmental variable in a CCA because initial data analysis produced models with seemingly large number of variables. A VIF >20 indicates that a variable is highly correlated with other variables and does not provide a unique contribution to the ordination (Ter Braak 1988). For each CCA, I eliminated variables from analyses if their VIF was >20, and re-ran the CCA with the revised set of variables.

I used biplots of species and environmental scores from each CCA to interpret relationships between species and environmental variables. For each CCA run, tests of significance of the first canonical axis and all canonical axes were made using Monte Carlo tests with 99 permutations ($\alpha = 0.01$). The significance test for the first axis is particularly important because this axis explains the highest proportion of variation in the data and is usually one of two axes shown in an ordination diagram (Ter Braak 1988). If an ordination biplot was unclear or significance tests indicate that ordination axes were not significant, additional variables were removed to improve results of CCA runs (MacFaden and Capen 2002). I used the program CANOCO (Ter Braak 1988) for all CCA analyses.

The first run of the CCA using intensive sites bird and habitat data produced high cumulative percentages of variance of species-environment relationship, but the first canonical axis and all canonical axes were not significant according to Monte Carlo tests ($p=1.0$) and many habitat variables were redundant (VIF > 20). The dataset was then analyzed using CCA with automatic forward selection and the best explanatory variables were used in all subsequent runs of intensive sites. Explanatory variables used in subsequent runs were PCTT, PCTB, PCSB, SDBH, OBSC, BA, and SAPH (Table 3). Additional CCA runs were performed for each of the six habitat and migratory guilds.

Stepwise Logistic and Linear Regression. I used stepwise selection with multiple logistic and linear logistic regression in SAS (PROC REG, PROC LOGISTIC, SELECTION=STEPWISE; SAS Institute, Cary, NC) to create explanatory models for 42 bird species detected at >5% of point count stations. I also used forward stepwise logistic regression (PROC LOGISTIC, SELECTION=FORWARD) for intensive site data because of difficulties analyzing data using stepwise regression in SAS. Transformed average relative abundance of each species at each site was used as the dependent variable in stepwise linear regressions. Presence of each bird species at each site was used as the dependent variable in stepwise and forward stepwise logistic regressions. Models were created separately for each bird species at intensive sites and extensive sites. Prior to model specification, I examined correlations among habitat variables, and the most easily measured variable (i.e., most likely to be measured during peatland inventories) of a correlated pair (Spearman's $r^2 \geq 0.70$) was retained. In stepwise linear regressions, remaining variables were entered using SLENTRY=0.15 and were retained using SLSTAY=0.05 so retained variables were most explanatory. Few models were created for stepwise forward logistic regression with default values because of the nature of the data, specifically, species that were observed at all or nearly all sites in the dataset as well as the distribution of the habitat variable measurements at each site. To resolve this problem, I used SLENTRY=0.15 and SLSTAY=0.15 to enter and retain variables, respectively.

RESULTS

Over a four-year period, 15,054 individuals were detected of 138 different species (Appendix A) during 188 census visits to 88 peatland sites. Species richness within peatlands ranged from 9 to 45 species/peatland. The most common species was the common yellowthroat, followed by Nashville warblers, white-throated sparrows, red-winged blackbirds, and blue jays (Appendix A).

Canonical Correspondence Analysis

Intensive Sites. Habitat variables explained most variation in bird community structure within peatlands of Wisconsin. These results were significant according to Monte Carlo tests (Table 4). Among individual habitat guilds, a large amount of variation in resident bird relative abundance was explained (Table 5), and residents were typically positively associated with snags and snag diameter (Table 3, Fig. 4). Variation in short-distance migrants was largely explained with CCA (Table 5) and this guild was positively correlated with percent cover of broadleaf trees (Table 3, Fig. 4). Neotropical migrants had less variation explained (Table 5), however, birds in this guild were negatively correlated with snag diameter, percent cover of broadleaf trees, and sapling height (Table 3, Fig. 4). Open-shrub birds had even less variance explained (Table 5), but were positively correlated with percent cover of low shrubs to high herbs, leaf litter, and percent cover of high shrubs (Table 3, Fig. 4). Forest birds had almost 75% variation explained by CCA (Table 5) and were positively correlated with percent cover of trees and basal area (Table 3, Fig. 4). A large amount of variation in peatland-associated bird relative abundance was explained (Table 5) and negatively correlated with vertical cover, sapling height, and percent cover of broadleaf trees (Table 3, Fig. 4).

All Extensive Sites Combined (2004-2007). Results including all extensive sites were similar to those from 2007 alone (see below). Much of the variance of average relative abundance of all bird species at extensive sites was explained by CCA (Table 4). Variation in resident birds was largely explained by four canonical axes (Table 6) and were positively correlated with percent cover of high shrubs and tree density (Table 3, Fig. 5). As with previous analyses, short-distance migrants produced the highest explanation of variance, and showed negative association with percent cover of broadleaf trees (Table 3, Fig. 5). Neotropical migrants had less variance explained by CCA compared to other guilds (Table 6), but were positively correlated with peatland area, percent cover of broadleaf trees, and percent cover of conifer trees (Table 3, Fig. 5). Open-shrub species had an amount of variation similar to neotropical migrants explained (Table 5), and were positively associated with percent cover of low shrubs to high herbs and percent cover of shrubs (Table 3, Fig. 5). Similarly, forest birds had 75% of variance explained in four canonical axes (Table 5), and were positively associated with percent cover of shrubs and percent cover of low herbs (Table 3, Fig. 5). Peatland-associates also produced strong explanatory results (Table 5) and were positively correlated with moss ground cover, percent cover of broadleaf shrubs, and percent cover of broadleaf trees (Table 3, Fig. 5).

2007 Extensive Sites. The initial CCA of 2007 extensive sites produced strong explanatory. Much of the variation in average relative abundance of all bird species in 2007 extensive sites was explained (Table 4). Resident birds had lower amount of variation explained by CCA than other guilds (Table 5), but were positively associated with percent cover of all trees and peatland area (Table 3, Fig. 6). Short-distance migrants had the most variation explained (Table 5), and were negatively associated with percent cover of coniferous high shrubs, percent cover of conifer trees, and percent cover of broadleaved high shrubs (Table 3, Fig. 6). Little variation of average relative abundance of neotropical migrants at 2007 extensive sites was explained by CCA (Table 5), but species in this guild were positively associated with percent cover of low shrubs to high herbs and percent cover of broadleaf trees (Table 3, Fig. 6). Open-shrub species had similar amounts of variance explained (Table 5), but were negatively associated with percent cover of low shrubs to high herbs, percent cover of broadleaf trees, and canopy height (Table 3, Fig. 6). Forest birds also had a low amount of variation explained by CCA (Table 5), but were positively correlated with basal area, percent canopy closure, snags, and percent cover of high shrubs (Table 3, Fig. 6). In contrast, peatland-associates performed strongly with much variance explained by the first four canonical axes (Table

5), and were negatively associated with peatland area, moss ground cover, and woody ground cover (Table 3, Fig. 6).

Species currently at the edge of their distribution range. Species currently at the edge of their distributional range in Wisconsin (Table 6) were analyzed with data collected at all extensive sites from 2004 to 2007. Slightly more than half of variation in average relative abundance was explained within the first two canonical axes (Table 7). In particular, blue-winged warblers were negatively correlated with increasing peatland area , whereas mourning warblers were negatively influenced by percent cover of conifer trees (Table 3, Fig. 7). Swainson's thrushes exhibited a negative correlation with peatland area (Table 3, Fig. 7). Yellow-bellied flycatchers had a negative correlation with several variables including snags, percent cover of low herbs, and percent cover of low shrubs to high herbs (Table 3, Fig. 7).

Stepwise Logistic and Linear Regression Modeling

At intensive sites, the probability of occurrence of many species was associated with shrub and conifer habitat features. In general, forest guild species were negatively associated with percent cover of conifer trees and positively associated with percent cover of conifer shrubs (Table 8). Similarly, open-shrub birds were negatively associated with snag diameter and basal area (Table 8). Presence of birds in the forested peatland guild was typically associated with conifer habitat features including percent cover of conifer shrubs and percent cover of conifer trees (Table 8).

Among all extensive sites (2004-2007), the probability of occurrence of forest birds was positively associated with percent cover of trees and tree density, but negatively associated with percent cover of low shrubs to high herbs (Table 9). Presence of open-shrub birds (e.g., sedge wrens) was generally negatively associated with percent cover of conifer trees but positively associated with peatland area and percent cover of low shrubs to high herbs (Table 9). In many of the models for forested-peatland associates, species presence was positively associated with percent cover of conifer trees, percent cover of low herbs, and snags, and negatively associated with percent cover of broadleaf shrubs (Table 9). Presence of open-shrub peatland birds generally was positively associated with peatland area and negatively with snags (Table 9). Peatland area was positively correlated with the presence of nine species and negatively correlated with the presence of two species (brown-headed cowbird, ovenbird) (Tables 8-10).

Stepwise logistic models for 2007 extensive sites indicated significant variation with respect to variables included for individual species within habitat guilds. Models for presence of forest birds generally indicated positive associations with percent cover of trees, percent cover of broadleaf shrubs and percent cover of low herbs (Table 10). Open-shrub bird presence was generally negatively associated with snags, tree density, and percent cover of trees in all three categories (total, broadleaf, and conifer; Table 10). Presence of forested-peatland species (e.g., hermit thrushes) generally was negatively associated with percent cover of low shrubs to high herbs and tree density, and positively correlated with snag diameter (Table 10). At the 2007 extensive sites, presence of open-shrub peatland-associated birds was generally positively associated with peatland area, vertical cover, and negatively associated with percent canopy closure (Table 10).

At intensive sites, average relative abundance of many forest-associated bird species was positively correlated with conifer shrubs and snag diameter (Table 11). Models of average relative abundance of open-shrub species (e.g, sedge wrens) generally included negative associations with basal area, snag diameter, and percent cover of conifer shrubs (Table 11). In contrast, forested-peatland birds exhibited few general trends with regard to habitat relationships.

Stepwise linear regression of data from all extensive sites (2004-2007) produced models with shrubs, low herbs, and trees as important microhabitat components (Table 12). Average relative abundance of several species, including blue-winged warblers, common yellowthroats, and palm warblers was positively correlated with peatland area (Table 12). Generally, average relative abundance of forest birds (e.g., red-eyed vireos) was negatively associated with percent cover of low shrubs to high herbs, and positively associated with percent cover of low herbs and percent cover of trees (Table 12). At all extensive sites, average relative abundance of open-shrub species (e.g., yellow warblers) was typically positively related to percent cover of low shrubs to high herbs and negatively related to percent cover of conifer trees (Table 12). Average relative abundance of forested peatland-associated birds was positively related to percent cover of conifer trees and snags (Table 12). Average relative abundance of open-shrub peatland species (e.g., common yellowthroats) was generally negatively related to percent cover of trees and positively related to peatland area and percent cover of low shrubs to high herbs (Table 12).

Vertical cover and canopy closure, measured only in 2007, were included in stepwise linear regression models of 2007 extensive sites. Forest bird average relative abundance at 2007 extensive sites generally were negatively associated with vertical cover and percent cover of low shrubs to high herbs (Table 13). Vertical obscurity was positively related to average relative abundance of open-shrub species (Table 13).

Average relative abundance of forested peatland species (e.g., yellow-shafted flickers) generally were positively related to percent cover of low herbs and canopy (Table 13). Average relative abundance of open-shrub peatland species (e.g., Lincoln's sparrows) was generally positively associated with peatland area and woody ground cover but negatively associated with canopy closure (Table 13).

Stepwise logistic and linear regression models were produced for most of the 18 species currently at the edge of their distribution range (Table 6). Models were not created for two species using stepwise linear regression (Le Conte's Sparrow and olive-sided flycatcher) or for two species using stepwise logistic regression (olive-sided flycatcher and Swainson's Thrush) because none of the variables measured met the requirements for inclusion in stepwise regression models. Variables representing shrub and tree microhabitat characteristics were commonly included in models created for the other 16 species (Tables 14 and 15).

DISCUSSION

Peatland Bird-Habitat Relationships

My research is among the first quantitative assessments of factors potentially influencing the distribution and abundance of peatland birds in the Great Lakes Region of the United States. Significant correlations of bird species with individual habitat variables were generally consistent with what is known about these species' general cover type associations in the state and region (Howe et al. 1997b, Cutright et al. 2006). Additionally, variation in important habitat variables among habitat and migratory guilds of peatland birds generally supports previous groupings of these species (Robbins 1991, Calmé et al. 2002, Cutright et al. 2006) and highlights their often unique ecological requirements.

Overall, the results of habitat relationship modeling for peatland birds were surprisingly congruent between intensive and extensive sites given the differences in site selection methodology, spatial resolution, and sampling intensity. However, I found that analyses of intensive and extensive sites produced somewhat different suites of habitat variables for some species and guilds. Further, models of peatland bird habitat relationships from intensive sites tended to explain a larger percentage of variation in species presence and abundance. Repeated visits to intensive sites may be beneficial for long-term studies of presence and abundance of individual species, but results from single visits to extensive sites appeared to be sufficiently similar to those from intensive sites for adequately explaining bird habitat relationships in peatlands of Wisconsin.

Multiple habitat variables were shown to influence peatland bird presence and relative abundance in my research. Similarly, previous research has demonstrated that a variety of factors influence avian diversity and abundance, with responses to habitat characteristics often species specific (Marzluff and Sallabanks 1998). In both terrestrial and wetland landscapes, the distribution of particular microhabitats like treefall openings in forests (e.g., Terborgh et al. 1990), rocky outcrops in shrub-steppe habitats (e.g., Wiens and Rotenberry 1981), percent cover of forest canopy (Wiens and Rotenberry 1981, Lachance et al. 2005), tree species diversity (e.g., James and Wamer 1982), shrub structural diversity (Riffell et al. 2001), and the distribution of specific plant taxa (e.g., Rice et al. 1984) all have been correlated with variation in the presence or abundance of individual bird species.

I found that bird species previously documented to be associated with forest cover types in both upland and wetland habitats of the Great Lakes region (Howe et al. 1997b, Cutright et al. 2006) were also positively correlated with forest habitat characteristics of peatlands in Wisconsin. Similar results have been documented for forest-associated birds in peatlands of Quebec (Lachance et al. 2005) and terrestrial (Ross et al. 2001) and riparian forests (Hanowski et al. 2005), whereas other species may be negatively correlated or unrelated with forest canopy cover and basal area (Ross et al. 2001, Loehle et al. 2005). High avian diversity within mixed conifer-deciduous forests has been previously documented in a wide variety of landscapes (e.g., Johnston and Odum 1956, Kerpez and Stauffer 1989, Hagan et al. 1997). Abundance of forest-associated birds also was related to the presence of specific cover types within peatlands. For example, the abundance of rose-breasted grosbeaks within peatlands was positively correlated with patches of deciduous trees containing abundant saplings and low herbaceous vegetation, similar to habitat relationships previously reported by Smith et al. (2007).

As expected, models for species generally associated with open-shrub cover types (e.g., alder flycatchers, common yellowthroats, American goldfinches, golden-winged warblers, Lincoln’s sparrows, yellow-bellied flycatchers) commonly included specific habitat characteristics including high amounts of shrub cover but low basal area, smaller snag diameters, and lower density of trees. My modeling results agree with those from previous studies in Canadian peatlands (Lachance et al. 2005), Great Lakes wet meadows (Riffell et al. 2001), and other habitat types (e.g., Murkin et al. 1997, Klaus and Buehler 2001, Renfrew and Ribic 2008). For example, within coastal wet meadows of the Great Lakes region, higher richness and abundance of wetland birds were generally associated with more robust and dense grass and sedge vegetation, structural diversity in the horizontal and vertical planes, and increased frequency of shrubs (Riffell et al. 2001).

Characteristic nesting and breeding habitat features included in the models for most neotropical migrants in my study, including snag diameter, percent cover of deciduous trees, and sapling height, correspond with previously documented habitat relationships for these species. Habitat patches with lower tree basal areas and increased vegetation cover 1-2-m in height are typically occupied by neotropical migrants (Bisson and Stutchbury 2001). Some neotropical species observed in this study share these general habitat preference characteristics, such as alder flycatchers, common yellowthroats, savannah sparrows, and red-winged blackbirds. In this study and others (e.g., Keller et al. 2003, Estrada and Coates-Estrada 2005), the most important factors related to high richness and abundance of neotropical migrant species are the height and structural diversity of foliage.

Species considered residents in Wisconsin typically vary in their habitat preferences. Species in this guild include American goldfinches, black-capped chickadees, blue jays, golden-crowned kinglets, northern cardinals and red-breasted nuthatches. My logistic and linear modeling results for these species were similar and also in agreement with the results of previous research. For example, blue jays typically prefer hardwood and mixed forests (Cutright et al. 2006) and in this study they were positively associated with percent cover of trees and conifer trees. Chickadees typically use moss to line these nest cavities (Smith 1993). Accordingly, I found that black-capped chickadee average relative abundance and presence were positively related to both snag diameter and moss ground cover. Another Wisconsin resident, the golden-crowned kinglet, often nests high in conifer trees (Ingold and Galati 1997). Models for this species included positive correlations with percent cover of conifer trees and canopy height.

Modeling results for short-distance migrants in this study were also similar to previous research. Species in this migratory guild, including American robins, brown-headed cowbirds, red-breasted nuthatches, and winter wrens, demonstrate a strong affinity for mixed-conifer forests with diverse vegetation structure for foraging (Adams and Morrison 1993). In my study, variables associated with the presence and average relative abundance of short-distance migrants within peatlands included percent cover of conifer trees, percent cover of conifer shrubs, vertical cover, and percent cover of low shrubs to high herbs, which correspond with previous research from other regions demonstrating that short-distance migrants generally use a greater proportion of early-successional habitats and younger forests than long-distance migrants or residents (Kirk et al. 1996, Hagan et al. 1997).

Species previously identified as peatland associates (Gauthier and Aubry 1995, Cutright et al. 2006) that were present at my study sites included palm warblers, Nashville warblers, yellow-bellied flycatchers, common yellowthroats, Lincoln's sparrows, and savannah sparrows. Among these species, the palm warbler is considered most strongly and perhaps exclusively associated with peatlands, at least in temperate regions where upland coniferous forests are scarce (Desrochers 2001, Lachance et al. 2005). This species is associated with small copses of black spruce surrounded by open areas, an ecotone with intermediate canopy cover (Lachance et al. 2005). Palm warblers typically nest on the ground but use trees within the copse for singing and surveillance

(Welsh 1971). Therefore, shrub and sphagnum moss cover, dominant habitat characteristics within peatlands, were primary factors correlated with the presence and average relative abundance of palm warblers and other peatland-associated species.

Recent research investigating patterns of avian distribution and abundance within the peatlands of Quebec has suggested that bird richness increases with habitat heterogeneity (Gauthier and Aubry 1995, Calmé and Desrochers 2000, Lachance et al. 2005), with avian diversity highest in peatlands exhibiting an interspersion of forested and open/shrub patches (Lachance et al. 2005). In particular, the ecotones between forested and open patches appear linked to the presence of several species, including palm warblers, common yellowthroats, winter wrens, and Lincoln's sparrows within Canadian peatlands (Gauthier and Aubry 1995, Lachance et al. 2005). Most of the models for peatland-associated birds in my study included a variety of vegetation structural attributes, especially those for Lincoln's sparrows and savannah sparrows, supporting the contention that spatial heterogeneity in both macrohabitats (i.e., open versus forested patches) and microhabitat structure is a critical factor influencing avian diversity within peatlands (Calmé and Desrochers 2000, Lachance et al. 2005). In fact, regardless of region or ecosystem type, foliage height diversity and spatial heterogeneity of habitat patches appear to be among the most important factors influencing avian distribution and abundance (Steele 1992, Keller et al. 2003, Estrada and Coates-Estrada 2005).

Species currently at the edge of their range could potentially be among the first to exhibit changes in their distribution or abundance as a result of habitat perturbation (Valiela and Bown 2003). In my study area, species in this category included alder flycatchers, black-throated green warblers, blue-winged warblers, Lincoln's sparrows, and veerys. Presence of alder flycatchers was positively correlated with the percent cover of shrubs, which agrees with previously published habitat associations of this species (Cutright et al. 2006). Black-throated green warblers typically use hardwood and mixed-hardwood forests, but coniferous trees are important for territory and nest locations (Morse 1993, Robichaud and Villard 1999). In this study, black-throated green warblers demonstrated a strong affinity for habitats with a high percent cover of trees. An open-shrub species in this group, the blue-winged warbler, is associated with early- to mid-successional habitats with brushy shrub components (Cutright et al. 2006). Likewise, I found that the presence and abundance of blue-winged warblers was positively associated with increasing percent cover of low herbs.

In this study, the presence or abundance of several bird species was positively correlated with increasing peatland area. In contrast, only 2 of 21 species of birds breeding in peatlands of Quebec, palm warblers and upland sandpipers, were positively correlated with peatland area as reported by Calmé and Desrochers (2000). Among open-shrubland species, I found that blue-winged warblers, Sandhill cranes, and yellow warblers were more abundant as peatland area increased. Previous studies in Wisconsin and elsewhere showed that several species of upland grassland birds were present in larger numbers within larger openings (Winter et al. 2006, Renfrew and Ribic 2008). I also found that the presence of sedge wrens was more likely in larger than in smaller peatlands. Similarly, a positive relationship between sedge wren occurrence and increasing size of Great Lakes wet meadows has been reported (Riffell et al. 2001).

Increasing peatland area also was positively correlated with the abundance of several peatland-associated species in Wisconsin, including common yellowthroats, Lincoln's sparrows, palm warblers, and yellow-shafted flickers. Similar area relationships have been reported for these species in Quebec peatlands (Calmé and Desrochers 2000), prairie potholes (Fairbairn and Dinsmore 2001), isolated depressional wetlands (Riffell et al. 2006), and Peruvian bogs (Telleria et al. 2006). Likewise, I found positive area relationships for several neotropical migrant species, including blue-winged warblers, common yellowthroats, eastern wood-pewees, Lincoln's sparrows, palm warblers, and sandhill cranes. The area sensitivity of these and other species of neotropical migratory birds is well documented (e.g., Brown and Dinsmore 1986, Robbins et al. 1989, Vickery et al. 1994, Brenner and Berad 1998, Edwards and Otis 1999, Fauth et al. 2000). Larger forest tracts appear to be sources in which surpluses of offspring are produced and can potentially colonize new fragments including areas where reproduction fails to balance adult mortality (Fauth et al. 2000). Smaller patch sizes resulting from upland forest fragmentation negatively affect neotropical migrants via higher rates of brood parasitism from edge species such as brown-headed cowbirds and increased predation near forest edges (Gentry et al. 2006). Accordingly, in my study, the abundance of brown-headed cowbirds was negatively correlated with peatland area, suggesting that this species was associated with smaller peatland fragments exhibiting higher edge-area ratios (Robbins et al. 1989, Riffell et al. 2001).

However, Riffell et al. (2001) identify several problems associated with interpreting area sensitivity of wetland birds. First, many wetland birds also breed in terrestrial habitats where studies of area-sensitivity are more common (e.g., common yellowthroats in forest gaps [Robbins et al. 1989]), and species that are insensitive to area in terrestrial habitats may be sensitive in wetland habitats and vice versa. Also, area-sensitivity may be apparent in regions of low or moderate breeding densities (i.e., near the fringes of a species' range) but not be apparent in regions of high density where even smaller, lower quality habitat patches are occupied by breeding individuals. Area-sensitive species observed in this study that are currently near the edge of their range include blue-winged warblers, Lincoln's sparrows, mourning warblers, and palm warblers. Third, birds in naturally fragmented landscapes may not be as sensitive to patch area, but these ideas have not been tested in wetland-dominated landscapes (Riffell et al. 2001).

Relevance to Conservation Planning

Although declines in bird populations are evident in many regions, the extent or causes of such changes are not obvious (e.g., see Hagan and Johnston 1992, Marzluff and Sallabanks 1998). Differences in annual variation in abundance between migratory groups (neotropical and short-distance migrants) have led some to suggest that declines in abundance of long-distance migrants are tied to events on wintering grounds (e.g. Robbins et al. 1989) whereas others attribute population declines to breeding ground effects (e.g. Böhning-Gaese et al. 1993). Part of the disagreement may stem from the scale at which these studies were conducted (Sauer and Droege 1992). Trends observed in bird populations at a single study site often differ from trends observed at larger, more regional scales (Holmes and Sherry 1988, Witham and Hunter 1992). Similarly, changes observed in one part of a species' range are not always evident in other regions, indicating that population trends are not spatially uniform (James et al. 1992). My study indicates that peatlands of Wisconsin currently support diverse and abundant bird assemblages, and these ecosystems contribute significantly to avian diversity within the Great Lakes region. However, this study represents only a "snapshot" of peatland bird assemblages. Individual species may alter their habitat selection criteria as wetland habitat conditions change, often on an annual basis (Riffell et al. 2001). Therefore, long-term stability of these communities in the region, and critical habitat characteristics, can only be gauged through long-term monitoring and development of predictive habitat models involving a range of environmental fluctuations (Gutzwiller and Barrow 2001, Riffell et al. 2001).

Based on habitat relationships I observed, conservation efforts should focus on large peatland complexes. Many species in the peatlands I sampled were more abundant or more likely to occur in large peatlands, so large peatlands would potentially be more likely to contain the habitat heterogeneity and suite of microhabitat features related to greater avian diversity (Gauthier and Aubry 1995, Calmé and Desrochers 2000, Lachance et al. 2005). My results indicate that some of these required habitat features may include (1) presence and interspersion of both forested and open-shrub patches, (2) diversity in height and structure of foliage, particularly within a well-developed shrub layer, (3) presence of both coniferous and deciduous trees in various stages of succession, and (4) scattered snags and woody ground cover. Management for these features, however, may come at the expense of others, so active management to promote these features should also consider possible negative impacts. For example, encouraging tree cover within peatlands may enhance habitat quality for some species (e.g., hermit thrushes, Nashville warblers) while simultaneously degrading habitat quality for species that require open habitats or forest-opening ecotones (e.g., palm warblers, Lincoln's sparrows) (Gauthier and Aubry 1995, Calmé and Desrochers 2000, Lachance et al. 2005). Therefore, a landscape or regional conservation approach that includes a wide variety of vegetative cover and structural conditions (Weller and Spatcher 1965, VanRees-Siewert and Dinsmore 1996) would be most appropriate because habitat requirements vary among species and can be highly specific (e.g., palm warblers). Management plans that focus on only one habitat characteristic or that attempt to maintain all habitat features in a single wetland would most likely fail (Riffell et al. 2001).

Although the habitat relationship models I developed for peatland birds in Wisconsin generally agree with previously published information on habitat requirements of these species in the region (Howe et al. 1997b, Cutright et al. 2006) region, many factors that I did not consider may have an important influence on avian diversity within peatlands. For example, the degree of urbanization (Friesen et al. 1995), road density (Forman and Alexander 1998), or other differences in the landscape context (Naugle et al. 1999) can influence habitat selection and distribution of birds in wetlands (Riffell et al. 2001). Although intensive sites in my study are protected from development and disturbance by Wisconsin's state natural area program, most peatlands within the state, including most of the extensive sites I studied, are imbedded within a matrix of private lands that are potentially subject to timber harvest, conversion for agriculture, and other anthropogenic disturbances. Afforestation (increase in tree cover) is among the primary vegetative changes recently observed in North American peatlands, most likely in response to wetland drainage (Lachance et al. 2005). These and other anthropogenic disturbances may significantly alter the future vegetative structure of peatlands, and therefore their associated avian communities.

In addition to direct anthropogenic alteration, peatland ecosystems and associated biological diversity may be at risk of changes or loss from climate change (Weltzin et al. 2003). The actual effects of climate change on peatlands via increased carbon dioxide and increased variance in temperature and precipitation are currently unknown but potentially include increased densities of shrub cover and decreased amounts of graminoid species (Weltzin et al. 2003). These or other changes in the vegetative composition and structure of peatlands certainly could be expected to alter the distributions and habitat relationships of peatland-associated birds (Lachance et al. 2005). How avian communities within peatlands and other ecosystems will react or adapt to such changes is difficult to predict, as responses are expected to be complex and often species-specific (Root and Schneider 1993). Species that are currently at the edge of their distributional range may be among the first to exhibit changes in their populations as a result of climate change. Predicting avian responses to climate change requires linking large-scale models of bird distribution with climate change models (Root and Schneider 1993). The results of my study provide an important baseline from which the Wisconsin Department of Natural Resources will monitor future changes in peatland bird diversity as a function of both natural and anthropogenic disturbance.

ACKNOWLEDGMENTS

I thank my graduate advisor, Dr. Kevin Russell for his support and guidance throughout the course of this research. His editorship, mentorship, and friendship were greatly appreciated. I thank Loren Ayers and other employees of the Wisconsin

Department of Natural Resources for their cooperation in organizing, implementing and concluding this work. I would also like to thank members of my graduate committee, Drs. Tim Ginnett, Michael Hansen, and Robert Holsman for their advice, feedback and encouragement. Furthermore, I would like to thank other faculty at the University of Wisconsin – Stevens Point in the College of Natural Resources.

LITERATURE CITED

Adams, E. M. and M. L. Morrison. 1993. Effects of forest stand structure and composition on red-breasted nuthatches and brown creepers. Journal of Wildlife Management 57:616-629.

Bibby, C. J., N. D. Burgess, and D. H. Hill. 1992. Bird census techniques. Academic Press, London.

Bisson, I. A. and B. J. M. Stutchbury. 2001. Nesting success and nest-site selection by a neotropical migrant in a fragmented landscape. Canadian Journal of Zoology 78:858-863.

Böhning-Gaese, K., M. L. Taper, and J. H. Brown. 1993. Are declines in North American insectivorous songbirds due to causes on the breeding range? Conservation Biology 7:76-86.

Bolger, D. T., T. A. Scott, and J. T. Rotenberry. 1997. Breeding bird abundance in an urbanizing landscape in coastal southern California. Conservation Biology 11:406-421.

Brenner, F. J. and R. Berad. 1998. Relationship between forest fragmentation and woodlot characteristics on breeding birds. Journal of the Pennsylvania Academy of Science 71:73-77.

Brown, M. and J. J. Dinsmore. 1986. Implications of marsh size and isolation for marsh bird management. Journal of Wildlife Management 50:392-397.

Bub, B. and K. Werner. 2004. Bird survey protocol: peatlands bird survey – May 2004. Unpublished report. Wisconsin Department of Natural Resources, Madision, WI, USA.

Bulin, B. A. 2005. Avian diversity in relation to lakeshore development in Portage County, Wisconsin. M. S. Thesis, University of Wisconsin – Stevens Point, Stevens Point, WI, USA.

California Native Plant Society (CNPS). 1998. Releve protocol, CNPS Vegetation Committee. Retrieved May 20, 2002 from http://www.cnps.org/vegetation/protocol.htm.

Calmé, S. and A. Desrochers. 2000. Biogeographic aspects of the distribution of bird species breeding in Quebec's peatlands. Journal of Biogeography 27:725-732.

Calmé, S., A. Desrochers, and J.-P. L. Savard. 2002. Regional significance of peatlands for avifaunal diversity in southern Quebec. Biological Conservation 107:273-281.

Cody, M. L. (editor) 1985. Habitat Selection in Birds. Academic Press, Inc., California.

Cottam, G. and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

Cutright, N. J., B. R. Harriman, and R. W. Howe (editors). 2006. Atlas of the breeding birds of Wisconsin. Wisconsin Society for Ornithology, Inc. Waukesha, WI.

Daubenmire, R. K. 1959. A canopy coverage method of vegetational analysis. Northeast Science 43:43-64.

Desrochers, A. 2001. Les oiseaux : diversité et répartition. *In* S. Payette and L. Rochefort (editors). Écologie des tourbières du Québec-Labrador. Presses de l'Université Laval, Saint-Nicolas, Québec.

Edwards, N. T. and D. L. Otis. 1999. Avian communities and habitat relationships in South Carolina Piedmont beaver ponds. American Midland Naturalist 141:158-171.

Erdelen, M. 1984. Bird communities and vegetation structure: I. Correlations and comparisons of simple and diversity indices. Oecologia 61:277-84.

Estrada, A. and R. Coates-Estrada. 2005. Diversity of Neotropical migratory landbird species assemblages in forest fragments and man-made vegetation in Los Tuxtlas, Mexico. Biodiversity and Conservation 14:1719-1734.

Fairbairn, S. E. and J. J. Dinsmore. 2001. Local and landscape-level influences on wetland bird communities of the prairie pothole region of Iowa, USA. Wetlands 21:41-47.

Fauth, P. T., E. J. Gustafson, and K. N. Rabenold. 2000. Using landscape metrics to model source habitat for Neotropical migrants in midwestern US. Landscape Ecology 15:621-631.

Forman, R. T. T. and Alexander, L. E. 1998. Roads and their major ecological effects. Annual Review of Ecology and Systematics 29:207–231.

Friesen, L. E., P. F. Eagles, and R. J. MacKay. 1995. Effects of residential development on forest-dwelling Neotropical migrant songbirds. Conservation Biology 9:1408–1414.

Gauthier, J. And Y. Aubry (editors). 1995. Atlas des oiseaux nicheurs du Québec méridional. Association québécoise de protection des oiseaux and Service canadien de la faune, Environnement Canada (région du Québec), Montréal, Québec.

Gentry, D. J., D. L. Swanson, and J. D. Carlisle. 2006. Species richness and nesting success of migrant forest birds in natural river corridors and anthropogenic woodlands in Southeastern South Dakota. Condor 108:140-153.

Gutzwiller, K. J. And S. H. Anderson. 1987. Multi-scale associations between cavity-nester birds and features of Wyoming streamside woodlands. Condor 89:534-548.

Gutzwiller, K. J. and W. C. Barrow, Jr. 2001. Bird-landscape relations in the Chihauhaun Desert: coping with uncertainties about predictive models. Ecological Applications 11:1517–1532.

Hagan, J. M. and D. W. Johnston (editors). 1992. Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Washington, DC.

Hagan, J. M., P. S. McKinley, A. L. Meehan, and S. L. Grove. 1997. Diversity and abundance of landbirds in a northeastern industrial forest landscape. Journal of Wildlife Management 61:718-735.

Hall, J. V., W. E. Frayer, and B. O. Wilen. 1994. Status of Alaska wetlands. U. S. Fish and Wildlife Service, Alaska Region, Anchorage, AK. 32 pp.

Hanowski, J., N. Danz, J. Lind, and G. Niemi. 2005. Breeding bird response to varying amounts of basal area retention in riparian buffers. Journal of Wildlife Management 69:689-698.

Heltzel, J. M. and P. L. Leberg. 2006. Effects of selective logging on breeding bird communities in bottomland hardwood forests in Louisiana. Journal of Wildlife Management 70:1416-1424.

Holmes, R. T. and T. W. Sherry. 1988. Assessing population trends of New Hampshire forest birds: local vs. regional patterns. Auk 105:756-768.

Howe, R. W., G. J. Niemi, S. J. Lewis, and D. A. Welsh. 1997a. A standard method for monitoring songbird populations in the Great Lakes Region. Passenger Pigeon 59(3):183-194.

Howe, R. W., G. Niemi, and J. R. Probst. 1997b. Management of western Great Lakes forests for the conservation of Neotropical migratory birds. Pages 144-167 *in* F. Thompson, III, editor. *Management of Midwestern landscapes for the conservation of Neotropical migratory birds.* U.S. Forest Service General Technical Report NC-187, North Central Forest Experiment Station, St. Paul, Minnesota, USA.

Ingold, J. L. and R. Galati. 1997. Golden-crowned Kinglet (Regulus satrapa). *In* A. Poole and F. Gill (editors), The Birds of North America., no. 301. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, D.C.

Inman, R. L., H. H. Prince, and D. B. Hayes. 2002. Avian communities in forested riparian wetlands of southern Michigan, USA. Wetlands 22:647-660.

James, F. C. 1971. Ordinations of habitat relationships among breeding birds. Wilson Bulletin 83:215-236.

James, F. C. and N. O. Wamer. 1982. Relationships between temperate forest bird communities and vegetation structure. Ecology 63:159-171.

James, F. C., D. A. Wiedenfeld, and C. E. McCulloch. 1992. Trends in breeding populations of warblers: declines in the southern highlands and increases in the lowlands. Pages 43-56 *in* J. M. Hagan and D. W. Johnston (editors), Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Washington, DC.

Johnston, D. W. and E. P. Odum. 1956. Breeding bird populations in relation to plant succession on the piedmont of Georgia. Ecology 37:50-62.

Keller, J. K., M. E. Richmond, and C. R. Smith. 2003. An explanation of patterns of breeding bird species richness and density following clearcutting in northeastern USA forests. Forest Ecology and Management 174:541-564.

Kerpez, T. A. and D. F. Stauffer. 1989. Avian communities of pine-hardwood forests in the southeast: characteristics, management, and modeling. Pages 156-169 *in* Proceedings of pine-hardwood mixtures: a symposium on management and ecology of the type. (T. A. Waldrop, editor). U. S. Forest Service General Technical Report SE-58.

Keys, J. Jr., C. Carpenter, S. Hooks, F. Koenig, W. H. McNab, W. Russell, and M. L. Smith. 1995. Ecological units of the eastern United States: first approximation. USDA Forest Service Southern Region, Atlanta, GA.

Kirk, D. A., A. W. Diamond, K. A. Hobson, and A. R. Smith. 1996. Breeding bird communities of the western and northern Canadian boreal forest: Relationship to forest type. Canadian Journal of Zoology 74:1749-1770.

Klaus, N. A. and D. A. Buehler. 2001. Golden-winged warbler breeding habitat characteristics and nest success in clearcuts in the southern appalachian mountains. Wilson Bulletin 113:297-301.

Krebs, C. J. 1989. Ecological Methodology. New York, Harper and Row.

Lachance, D., C. Lavoie, and A. Desrochers. 2005. The impact of peatland afforestation on plant and bird diversity in southeastern Quebec. Ecoscience 12:161-171.

Loehle, C., T. B. Wigley, S. Rutzmoser, J. A. Gerwin, P. D. Keyser, R. A. Lancia, C. J. Reynolds, R. E. Thill, R. Weih, D. White, and P. B. Wood. 2005. Managed forest landscape structure and avian species richness in the southeastern US. Forest Ecology and Management 214:279-293.

MacArthur, R. H. and J. W. MacArthur. 1961. On bird species. Ecology 42:594-598.

MacFaden, S. W. and D. E. Capen. 2002. Avian habitat relationships at multiple scales in a New England forest. Forest Science 48:243-253.

Marzluff, J. M., and R. Sallabanks. 1998. Avian Conservation: Research and Management. Island Press, Washington, D.C.

McGarigal, K., S. Cushman, and S. Stafford. 2000. Multivariate Statistics for Wildlife and Ecology Research. Springer-Verlag, New York.

Moorman, C. E., and D. C. Guynn, Jr. 2001. Effects of group selection opening size on breeding bird habitat use in a bottomland forest. Ecological Applications 11:1680-1691.

Morse, D. H. 1993. Black-throated Green Warbler (Dendroica virens). *In* A. Poole and F. Gill (editors), The Birds of North America, no. 55. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington, D.C.

Murkin, H. R., E. J. Murkin, and J. P. Ball. 1997. Avian habitat selection and prairie wetland dynamics: A 10-year experiment. Ecological Applications 7:1144-1159.

Naugle, D. E., K. F. Higgins, S. M. Nusser, and W. C. Johnson. 1999. Scale-dependent habitat use in three species of prairie wetland birds. Landscape Ecology 14:267-276.

Nur, N., S. L. Jones, and G. R. Geupel. 1999. Statistical guide to data analysis of avian monitoring programs. USDI Fish and Wildlife Service Biological Technical Publication BTP-R6001-1999, Washington, D.C.

Palmer, M. W. 1993. Putting things in even better order: the advantages of canonical correspondence analysis. Ecology 74:2215–2230.

Prosser, D. J. and R. P. Brooks. 1998. A verified habitat suitability index for the Louisiana Waterthrush. Journal of Field Ornithology 69:288-298.

Ralph, C. J., J. R. Sauer, and S. Droege (editors). 1995. Monitoring bird populations by point counts. General Technical Report PSW-GTR-149. Pacific Southwest Research Station, USDA Forest Service, Albany, CA.

Renfrew, R. B. and C. A. Ribic. 2008. Multi-scale models of grassland passerine abundance in a fragmented system in Wisconsin. Landscape Ecology 23:181-193.

Rice, J. R., B. W. Anderson, and R. D. Ohmart. 1984. Comparison of the importance of different habitat attributes to avian community organization. Journal of Wildlife Management 48:895-911.

Riffell, S. K., B. E. Keas, and T. M. Burton. 2001. Area and habitat relationships of birds in Great Lakes coastal wet meadows. Wetlands 21:492-507.

Riffell, S. K., T. M. Burton, and M. Murphy. 2006. Birds in depressional forested wetlands: Area and habitat requirements and model uncertainty. Wetlands 26:107-118.

Robbins, C. S., D. K. Dawson, and B. A. Dowell. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic States. Wildlife Monographs 103.

Robbins, S. D., Jr. 1991. Wisconsin birdlife: Population and distribution past and present. University of Wisconsin Press, Madison, WI, USA.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Robichaud, I. and M. A. Villard. 1999. Do Black-throated Green Warblers prefer conifers? Meso- and microhabitat use in a mixedwood forest. Condor 101: 262-271.

Root, T. L. and S. H. Schneider. 1993. Can large-scale climatic models be linked with multi scale ecological studies? Conservation Biology 7:256-270.

Ross, B. D., M. L. Morrison, W. Hoffman, T. S. Fredericksen, R. J. Sawicki, E. Ross, M. B. Lester, J. Beyea, and B. N. Johnson. 2001. Bird relationships to habitat characteristics created by timber harvesting in Pennsylvania. Journal of the Pennsylvania Academy of Science 74:71-84.

Sauer, J. R. and S. Droege. 1992. Geographic patterns in population trends of Neotropical migrants in North America. Pages 26-42 *in* J. M. Hagan and D. W. Johnston (editors), Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Washington, DC.

Smith, L. A., E. Nol, D. M. Burke, and K. A. Elliott. 2007. Nest-site selection of rose-breasted grosbeaks in southern Ontario. Wilson Journal of Ornithology 119:151-161.

Smith, S. M. 1993. Black-capped chickadee (Parus atricapillus). *In* A. Poole, P. Stettenheim, and F. Gill (editors), The Birds of North America, no. 39. Academy of Natural Sciences, Philadelphia, PA, and American Ornithologists' Union, Washington,D.C.

Steele, B. B. 1992. Habitat selection by breeding black-throated blue warblers at two spatial scales. Ornis Scandinavica 23:33-42.

Swift, B. L., J. S. Larson, and R. M. DeGraaf. 1984. Relationship of breeding bird density and diversity to habitat variables in forested wetlands. Wilson Bulletin 96: 48-59.

Telleria, J. L., J. L. Venero, and T. Santos. 2006. Conserving birdlife of peruvian highland bogs: Effects of patch-size and habitat quality on species richness and bird numbers. Ardeola 53:271-283.

Terborgh, J., S. K. Robinson, T. A. Parker, C. A. Munn, and N. Pierpont. 1990. Structure and organization of an Amazonian forest bird community. Ecological Monographs 60:213-238.

Ter Braak, C. J. F. 1986. Canonical correspondence analysis: a new eignvector technique for multivariate direct gradient analysis. Ecology 67:1167-1179.

Ter Braak, C. J. F. 1988. CANOCO: A FORTRAN program for canonical community ordination. Version 2.1. Microcomputer Power, Ithaca, NY.

Valiela, I. and J. L. Bowen. 2003. Shifts in winter distribution in birds: Effects of global warming and local habitat change. Ambio 32:476-480.

VanRees-Siewert, K. L. and J. J. Dinsmore. 1996. Influences of wetland age on bird use of restored wetlands in Iowa. Wetlands 16:577-582.

Vickery, P. D., M. L. Hunter, and S. M. Melvin. 1994. Effects of habitat area on the distribution of grassland birds in Maine. Conservation Biology 8:1087-1097.

Weller, M. W. and C. S. Spatcher. 1965. Role of habitat in the distribution and abundance of marsh birds. Iowa Agriculture and Home Economics Experiment Station, Ames, IA, USA. Special Report 43.

Weller, M. W. 1999. Wetland Birds. Cambridge University Press, Cambridge, UK.

Welsh, D. A. 1971. Breeding and territoriality of the palm warbler in a Nova Scotia bog. Canadian Field-Naturalist 85:31-37.

Weltzin, J. F., S. D. Bridgham, J. Pastor, J. Chen, and C. Harth. 2003. Potential effects of warming and drying on peatland plan community composition. Global Change Biology 9:141-151.

Whitcomb, R. F., O. S. Robins, J. F. Lynch, B. L. Bystrak, M. K. Klimkiewitz, and D. Bystrak. 1981. Effects of forest fragmentation on avifauna of the eastern deciduous forest. Pages 125-205 *in* Forest Island Dynamics in Man-dominated Landscapes (R. L. Burgess and D. M. Sharpe, editors), Springer-Verlag, Berlin and New York.

Wiens, J. A. and J. T. Rotenberry. 1981. Habitat associations and community structure of birds in shrubsteppe environments. Ecological Monographs 51:21-41.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017-29.

Winter, M. and J. Faaborg. 1999. Patterns of area sensitivity in grassland birds.

Conservation Biology 13:1424-1436.

Winter, M., D. H. Johnson, J. A. Shaffer, T. M. Donovan, and W. D. Svedarsky. 2006. Patch size and landscape effects on density and nesting success of grassland birds. Journal of Wildlife Management 70:158-172.

Witham, J. W. and M. L. Hunter. 1992. Population trends of Neotropical migrant landbirds in northern coastal New England. Pages 85-95 *in* J. M. Hagan and D. W. Johnston (editors), Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Washington, DC.

Table 1. Beaufort Wind Scale codes used to describe wind conditions for bird surveys in Wisconsin peatlands, 2004-2007.

Beaufort Code	**mph**	**km**	**Description**	**Surroundings**
0	< 1	< 1	Calm	Smoke rises vertically
1	1-3	1-5	Light Air	Smoke drift shows wind direction
2	4-7	6-11	Light Breeze	Leaves rustle, wind felt on face
3	8-12	12-19	Gentle Breeze	Leaves, small twigs in constant motion
4	13-18	20-28	Moderate Breeze	Raises dust, leaves, small branches in motion
5	19-24	23-38	Fresh Breeze	Small trees in leaf sway
6	25-31	39-49	Strong Breeze	Larger branches in motion
7	32-38	50-61	Moderate Gale	Whole trees in motion
8	39-46	62-74	Fresh Gale	Walking impeded, broken branches
9	> 47	> 75	Strong Gale	

Table 2. List of sky codes used to describe weather conditions for bird surveys in Wisconsin peatlands, 2004-2007.

Sky	Description	Cloud Cover
0	Clear	0-15%
1	Partly cloudy	16-50%
2	Mostly cloudy	51-75%
3	Overcast	76-100%
4	Wind-driven sand, dust,	-
5	Fog or haze	-
6	Drizzle	-
7	Rain	-
8	Snow	-
9	Thunderstorm, w or w/out	-

Table 3. List of variables measured in vegetation surveys in Wisconsin peatlands, 2004-2007.

Variable	**Units**	**Abbreviation**	**Description**
Overstory canopy	%	PCAN	Canopy closure of overstory trees
Basal area	sq m/ha	BA	Basal area of plot
DBH	cm		Diameter Breast Height of tree in plot
Tree Height	m		Height of tree in plot
Snag abundance	#	SNAG	number of snags within 10-m radius
Snag diameter	Cm	SDBH	Diameter Breast Height of snags in plot
Absolute Percent Cover	%	PCTT	Absolute percent cover of strata: tree (total)
		PCTC	Absolute percent cover of strata: tree (conifer)
		PCTB	Absolute percent cover of strata: tree (broadleaf)
		PCST	Absolute percent cover of strata: shrubs (total)
		PCSC	Absolute percent cover of strata: shubs (conifer)
		PCSB	Absolute percent cover of strata: shrubs (broadleaf)
		PCHH	Absolute percent cover of strata: low shrubs/high herbs
		PCLH	Absolute percent cover of strata: low herbs
		MOSS	Absolute percent cover of strata: moss
Structural Position (of tree, shrub, sub-shrub, and herbaceous plants)		CD	Canopy dominant
		CA	Canopy associate
		SC/SA	Sub-canopy/Sapling
		SD	Seedling
		DS	Dominant shrub
		AS	Associate shrub
Abundance	1, 2, 3, 4		Rare (1), Uncommon (2), Common (3), Abundant (4)
Distance	m		Distance to nearest ≥7.5cm tree
Ground cover	%	HERB	Cover of herbaceous vegetation
		WOOD	Cover of woody ground cover
		LEAF	Cover of leaf litter
Sapling height	m	SAPH	Average height of 3 tallest saplings per plot
Canopy height	m	CANH	Height of overstory canopy
Vertical cover	%	OBSC	Index of understory vegetation structure
Peatland Area	ha	AREA	Total size of peatland area
Temperature	ºC		Air temperature
PCQ Density	trees/ac	PDEN	Average PCQ density per site
PCQ Dominance	BA/ac	PDOM	Average PCQ dominance per site

Table 4. Cumulative percentage of variance of species-environment relationship for canonical correspondence analysis ordinations based on a subset of birds (species detected at ≥5% of survey stations) by site types in Wisconsin peatlands, 2004 – 2007.

Dataset	No.*	Cumulative % Variance Of Species-Environment Relation				Monte Carlo Test *p* 1st Axis	Monte Carlo Test *p* All Axes	Total Inertia CCA
		Ax.† 1	Ax. 2	Ax. 3	Ax. 4			
2007 Extensive	22	70.8	83.9	95.1	99.6	0.0100	0.0100	0.066
All Extensive	13	69.3	89.0	97.5	99.8	0.0100	0.0100	0.076
Intensive	7	74.7	93.7	97.4	99.8	0.0100	0.0100	0.018

* Number of habitat variables included in the ordination.

† CCA ordination axis

Table 5. Cumulative percentage of variance of species-environment relationship for canonical correspondence analysis ordinations based on a subset of birds (species detected at ≥5% of survey stations) by migratory and habitat groups at intensive and extensive sites in Wisconsin peatlands, 2004 – 2007.

Dataset	No.[*]	Cumulative % Variance Of Species-Environment Relation				Monte Carlo Test *p* 1st Axis	Monte Carlo Test *p* All Axes	Total Inertia CCA
		Ax.[†] 1	Ax. 2	Ax. 3	Ax. 4			
Intensive Sites								
Neotropical migrants	7	49.9	70.0	81.4	89.7	0.0100	0.0100	0.302
Short-distance migrants	7	80.4	96.4	100.0	0.0	0.0200	0.0800	0.339
Residents	7	66.5	81.3	91.8	97.2	0.3100	0.3100	0.194
Forest	7	54.1	74.9	84.1	92.2	0.0100	0.0100	0.236
Open-shrub	7	32.0	60.0	80.4	88.7	0.0800	0.0100	0.235
Peatland-associated	7	60.7	85.8	94.6	97.5	0.0100	0.0100	0.431
All Species	7	47.3	67.8	77.6	86.3	0.0100	0.0100	0.292
All Extensive Sites								
Neotropical migrants	13	41.8	55.3	67.2	75.7	0.0100	0.0100	1.959
Short-distance migrants	13	54.7	93.0	100.0	0.0	0.0800	0.0300	1.360
Residents	13	46.0	66.2	82.7	93.3	0.0100	0.0100	1.086
Forest	13	39.7	54.6	64.2	73.2	0.0100	0.0100	1.701
Open-shrub	13	31.0	52.4	66.9	75.7	0.0100	0.0100	1.666
Peatland-associated	13	52.6	76.1	87.9	92.5	0.0100	0.0100	1.409
All Species	13	39.0	53.9	64.3	72.7	0.0100	0.0100	1.818
2007 Extensive Sites								
Neotropical migrants	22	26.7	42.1	54.8	63.3	0.0100	0.0100	1.809
Short-distance migrants	22	58.5	89.6	100.0	0.0	0.0500	0.0100	1.079
Residents	22	37.8	61.2	77.0	89.2	0.0100	0.0100	1.020
Forest	22	28.4	41.3	53.5	62.6	0.0100	0.0100	1.596
Open-shrub	22	25.4	45.2	60.0	68.6	0.0100	0.0100	1.463
Peatland-associated	22	43.4	65.1	80.9	88.0	0.0100	0.0100	1.303
All Species	22	25.8	40.8	53.4	60.9	0.0100	0.0100	1.656

[*] Number of habitat variables included in the ordination.

[†] CCA ordination axis

Table 6. Species near the edge of their distribution range, observed in Wisconsin peatlands, 2004-2007, to be considered for separate analyses.

Alder Flycatcher	Olive-sided Flycatcher
Black-throated Green Warbler	Palm Warbler
Blue-gray Gnatcatcher	Red-bellied Woodpecker
Blue-headed Vireo	Red-breasted Nuthatch
Blue-winged Warbler	Swainson’s Thrush
Hermit Thrush	Veery
Le Conte’s Sparrow	White-throated Sparrow
Lincoln’s Sparrow	Yellow-bellied Flycatcher
Mourning Warbler	
Nashville Warbler	

Table 7. Cumulative percentage of variance of species-environment relationship for canonical correspondence analysis ordinations based on a subset of birds (species currently near the edge of their distribution range) by site types in Wisconsin peatlands, 2004 – 2007.

Dataset	No.*	Cumulative % Variance Of Species-Environment Relation				Monte Carlo Test *p* 1st Axis	Monte Carlo Test *p* All Axes	Total Inertia CCA
		Ax.† 1	Ax. 2	Ax. 3	Ax. 4			
Intensive Sites	7	30.6	56.2	75.3	85.9	0.0300	0.0100	0.621
All Extensive Sites	13	34.5	53.2	64.7	73.2	0.0100	0.0100	2.565
2007 Extensive Sites	22	20.4	36.7	52.5	64.3	0.0100	0.0100	2.593

* Number of habitat variables included in the ordination.

† CCA ordination axis

Table 8. Habitat models using forward stepwise logistic regression analyses for 42 bird species in intensive site peatlands, Wisconsin, 2004-2007 (n = 14) . Habitat variables entered regressions at $P \leq 0.15$ and were retained when $P \leq 0.15$. (+) or (-) indicates the directions of the relationship between that variable and bird species. Max-rescaled R^2 is included in the table.

Species	Habitat Model	R^2
Forest Associated Species		
American Crow†		
Black-capped Chickadee	- PCTC	0.999
Black-throated Green Warbler	- PCTC, + PCSB, - PCHH	0.905
Blue-headed Vireo	- PCHH, - WOOD	0.999
Blue Jay†		
Cedar Waxwing†		
Common Raven	- PCST, - SNAG, + HERB	0.999
Eastern Wood-Pewee	+ PCSB, - PCHH	0.997
Great Crested Flycatcher†		
Ovenbird	+ CANH	0.997
Red-breasted Nuthatch	- HERB, - WOOD	0.999
Red-eyed Vireo†		
Rose-breasted Grosbeak†		
Veery*	- BA	0.999
White-throated Sparrow	- SDBH	0.999
Winter Wren	+ PCSC, + WOOD	0.902
Yellow-bellied Flycatcher	+ PCSC, + SDBH	0.422
Yellow-rumped Warbler	- PCSB, - MOSS	0.999
Open-Shrub Associated Species		
Alder Flycatcher	- PCLH, - BA, + HERB	0.999
American Goldfinch†		
American Robin†		
Blue-winged Warbler*	- LEAF	0.999
Brown-headed Cowbird	- PCTC, - AREA	0.560
Chipping Sparrow	- SDBH	0.999
Eastern Towhee	+ PCST	0.375
Golden-winged Warbler*	+ PCTC, - PCHH, - SDBH, - BA	0.999
Mourning Dove†		
Red-winged Blackbird	- BA	0.999
Sandhill Crane	+ PCHH, - WOOD	0.999
Sedge Wren	- SDBH	0.999
Song Sparrow	- BA	0.999
Swamp Sparrow	- SDBH	0.999
Yellow Warbler	- BA	0.999
Forested Peatland Associated Species		
Golden-crowned Kinglet	+ PCSC, + CANH	0.999
Hermit Thrush	+ PCTC, - PCST, + PCHH	0.999
Nashville Warbler	- SDBH	0.999
Yellow-shafted Flicker†		
Open-Shrub Peatland Associated Species		
Common Yellowthroat	- BA	0.999
Lincoln's Sparrow	- SDBH, - HERB, - WOOD	0.999
Northern Cardinal	+ PCSB, + PCLH, + CANH	0.918
Palm Warbler	- PCSB, + PCSC, - PCAN, + CANH	0.998
Savannah Sparrow	- PCSC, + PCLH	0.999

* Species of greatest conservation need, as listed in Wisconsin's Wildlife Action Plan

† No model created for species because species was detected at all intensive sites

Table 9. Habitat models using stepwise logistic regression analyses for 42 bird species in all extensive site peatlands in Wisconsin, 2004-2007 (*n* = 74). Habitat variables entered regressions at $P \leq 0.15$ and retained when $P \leq 0.15$. (+) or (-) indicates directions of the relationship between that variable and bird species. Max-rescaled R^2 is included.

Species	Habitat Model	R^2
Forest Associated Species		
American Crow	+ PCHH, - MOSS	0.245
Black-capped Chickadee	+ PCTC, + PCSB, - PCLH, + MOSS	0.353
Black-throated Green Warbler	+ PCTT, - PCHH	0.352
Blue-headed Vireo	- PCST, + SNAG, + PDEN	0.393
Blue Jay	+ PCTT, - PCST	0.261
Cedar Waxwing	+ PCLH, + SNAGS, + AREA	0.243
Common Raven	- PCTB, + PCSB, - PCHH, - PCLH, + PDEN, + AREA	0.462
Eastern Wood-Pewee	+ PCLH	0.647
Great Crested Flycatcher	+ PCHH, + PCLH, + SNAG	0.340
Ovenbird	+ PCLH, - AREA	0.146
Red-breasted Nuthatch	+ PCTT, - MOSS	0.169
Red-eyed Vireo	- PCHH	0.399
Rose-breasted Grosbeak	- PCTC, - PCHH, + PCLH	0.372
Veery[*]	+ PCST, - MOSS, - SNAG	0.369
White-throated Sparrow	- PCTT, + PCTC, - PCSB, + SNAG, + PDEN	0.620
Winter Wren	+ PCTT, - PCHH, + SNAG	0.444
Yellow-bellied Flycatcher	- PCTT, + PCTC, - PCHH, + AREA	0.444
Yellow-rumped Warbler	- PCTT, + PCTC, - PCHH, + MOSS	0.497
Open-Shrub Associated Species		
Alder Flycatcher	- PCTC, + PCST, + PCLH	0.166
American Goldfinch	- PCHH	0.073
American Robin	- PCHH, + PCLH, - MOSS, + PDEN	0.537
Blue-winged Warbler[*]	+ PCLH, + PDEN	0.218
Brown-headed Cowbird	+ PCHH	0.257
Chipping Sparrow[†]		
Eastern Towhee[†]		
Golden-winged Warbler[*]	+ PCTT	0.042
Mourning Dove	+ PCST, + PCHH, - MOSS	0.376
Red-winged Blackbird	+ PCHH	0.206
Sandhill Crane	+ PCST, - PCSB, + PCHH, - PCLH, - SNAG, + PDEN, + AREA	0.615
Sedge Wren	- PCTC, + AREA	0.291
Song Sparrow	- PCTC	0.091
Swamp Sparrow	- PCSB, - MOSS, + SNAG	0.188
Yellow Warbler	+ PCTB, - PCTC, + PCLH, + MOSS, + AREA	0.514
Forested Peatland Associated Species		
Golden-crowned Kinglet	+ PCTC, - PCHH	0.267
Hermit Thrush	- PCSB, + PCHH, + PCLH, + SNAG	0.554
Nashville Warbler	+ PCTC, + PCLH, + SNAG	0.451
Yellow-shafted Flicker	- PCSB, - PCHH, + PCLH, + PDEN	0.321
Open-Shrub Peatland Associated Species		
Common Yellowthroat	- PCTB, - PCTC, + PCST, - PCSB, + PCHH, - MOSS, - SNAG, + PDEN, + AREA	0.832
Lincoln's Sparrow	+ MOSS, + AREA	0.323
Northern Cardinal	+ PCTT, - PCTB, - PCTC, + PCST, + PCHH, - MOSS	0.519
Palm Warbler	- PCHH, + AREA	0.279
Savannah Sparrow	- PCTT, + PCTC, - PCST, + PCSB, - SNAG	0.362

[*] Species of greatest conservation need, as listed in Wisconsin's Wildlife Action Plan

[†] No variables met requirements for inclusion in model using stepwise selection

Table 10. Habitat models using stepwise logistic regression analyses for 42 bird species in extensive site peatlands in Wisconsin, 2007 (*n* = 50). Habitat variables entered regressions at $P \leq 0.15$ and were retained when $P \leq 0.15$. (+) or (-) indicates the directions of the relationship between that variable and bird species. Max-rescaled R^2 included.

Species	Habitat Model	R^2
Forest Associated Species		
American Crow	+ PCHH, - AREA	0.327
Black-capped Chickadee	+ PCST, + SDBH, - WOOD	0.513
Black-throated Green Warbler	+ PCTT, + PCSB, + PCLH, + PDEN	0.745
Blue-headed Vireo[†]		
Blue Jay	+ PCTT, - PCST	0.283
Cedar Waxwing	- PCHH, + OBSC, + WOOD, + AREA	0.464
Common Raven	+ PCTT, - PCTB, - PCAN, - LEAF, + PDEN	0.747
Eastern Wood-Pewee	+ PCLH	0.621
Great Crested Flycatcher	- PCTC, + PCLH, + PERCAN, - LEAF	0.498
Ovenbird	+ PCTB, + PCST, + PCSB, - PCHH, - SDBH, - OBSC, + SAPH, + LEAF	0.971
Red-breasted Nuthatch	- PCST, + SDBH	0.236
Red-eyed Vireo	+ MOSS, + SNAG, - OBSC, + PCAN	0.893
Rose-breasted Grosbeak	+ PCSB, + PCLH, + MOSS, + SDBH, + WOOD	0.716
Veery[*]	+ PCSB, + SDBH, + OBSC, - LEAF, - AREA	0.726
White-throated Sparrow	- PCTT, + PCTC, - PCSB, - PCHH, - PCLH, + SNAG, + WOOD	0.834
Winter Wren	+ PCAN	0.738
Yellow-bellied Flycatcher	+ PCTC, - PDEN	0.830
Yellow-rumped Warbler	+ PCTB, + PCTC, - PDEN	0.974
Open-Shrub Associated Species		
Alder Flycatcher	- PCTT, - PCTC, - SNAG, + PCAN, - LEAF, - PDEN	0.819
American Goldfinch	+ WOOD, + PDEN	0.299
American Robin	- PCHH, + PDEN	0.926
Blue-winged Warbler[*]	+ PCLH	0.133
Brown-headed Cowbird	+ OBSC, + LEAF	0.499
Chipping Sparrow	- PCTB, - PCTC, + PCSB, - SAPHT, + HERB, + WOOD	0.858
Eastern Towhee	- PCTT, - PCTC, + SDBH	0.293
Golden-winged Warbler[*]	- PCST, - PCHH, - PCLH, - MOSS, - SNAG, + SDBH, + OBSC, - HERB, + WOOD	0.870
Mourning Dove	+ PCHH, - WOOD	0.475
Red-winged Blackbird	+ PCHH	0.119
Sandhill Crane	- SNAG, + OBSC	0.400
Sedge Wren	- MOSS, - PCAN, - HERB, - PDEN	0.667
Song Sparrow	+ SDBH, - PCAN, - PDEN	0.373
Swamp Sparrow	+ PCTT, - PCSB, - PCHH, - PCLH, - MOSS, + OBSC, - PDEN	0.587
Yellow Warbler	+ PCTB, + PCLH, - SNAG, + WOOD, + AREA	0.785
Forested Peatland Associated Species		
Golden-crowned Kinglet	- PCHH, - PCLH, - SNAG, + SDBH, + PCAN, - PDEN	0.654
Hermit Thrush	- PCHH, - PCLH, + SDBH, + PCAN, + LEAF, - PDEN	0.863
Nashville Warbler	+ PCLH, + SDBH, + HERB	0.824
Yellow-shafted Flicker	+ PCLH, - OBSC	0.548
Open-Shrub Peatland Associated Species		
Common Yellowthroat	- SNAG, + OBSC, - SAPH, - PDEN	0.484
Lincoln's Sparrow	+ PCLH, + MOSS, - PCAN, + AREA	0.718
Northern Cardinal	- MOSS, + OBSC, - HERB, + WOOD	0.473
Palm Warbler	- PCHH, + WOOD, + AREA	0.660
Savannah Sparrow	- PCAN, - LEAF, + PDEN	0.753

[*] Species of greatest conservation need, as listed in Wisconsin's Wildlife Action Plan

[†] No variables met requirements for inclusion in model using stepwise selection

Table 11. Habitat models using stepwise linear regression analyses for 42 bird species in intensive site peatlands, Wisconsin, 2004-2007 (*n* = 14). Bird count data was square-root transformed. Habitat variables entered regressions at *P*≤0.15 and were retained when *P*≤0.05. (+) or (-) indicates the directions of the relationship between that variable and bird species. Abbreviations correspond to model variables in Table 3.

Species	Habitat Model	R^2
Forest Associated Species		
American Crow	+ PCHH, - SNAG, + SDBH, - WOOD, - LEAF	0.94
Black-capped Chickadee	- PCLH	0.31
Black-throated Green Warbler	+ BA	0.58
Blue-headed Vireo	- WOOD	0.43
Blue Jay	+ CANH	0.41
Cedar Waxwing	- MOSS, + LEAF	0.65
Common Raven	- PCSB, + PCHH, + HERB	0.71
Eastern Wood-Pewee	+ SDBH	0.49
Great Crested Flycatcher	+ SDBH	0.50
Ovenbird	+ PCSC, + PCHH, + SNAG, + CANH	0.84
Red-breasted Nuthatch	- WOOD	0.48
Red-eyed Vireo	+ SDBH	0.29
Rose-breasted Grosbeak	- PCST, + SDBH	0.62
Veery*	+ SDBH, - BA	0.84
White-throated Sparrow	+ PCSC	0.32
Winter Wren	+ PCSC	0.58
Yellow-bellied Flycatcher	+ PCSC	0.47
Yellow-rumped Warbler	- PCSB, + PCAN	0.72
Open-Shrub Associated Species		
Alder Flycatcher	- BA	0.39
American Goldfinch†		
American Robin†		
Blue-winged Warbler*	- PCLH, - MOSS, - SDBH, - LEAF	0.90
Brown-headed Cowbird	- PCSC	0.38
Chipping Sparrow	- SDBH	0.61
Eastern Towhee	+ PCST	0.43
Golden-winged Warbler*	- SDBH	0.29
Mourning Dove	+ PCST, - SNAG	0.65
Red-winged Blackbird	- PCSC, + MOSS, - CANH	0.77
Sandhill Crane	- PCSC, - SNAG	0.51
Sedge Wren	- SDBH, - BA	0.81
Song Sparrow	- BA, - WOOD	0.80
Swamp Sparrow	- SDBH	0.73
Yellow Warbler	- PCTC, - BA	0.78
Forested Peatland Associated Species		
Golden-crowned Kinglet	+ BA	0.40
Hermit Thrush	- PCSB	0.46
Nashville Warbler	+ PCSC	0.49
Yellow-shafted Flicker†		
Open-Shrub Peatland Associated Species		
Common Yellowthroat	- SNAG, - BA	0.74
Lincoln's Sparrow	+ PCST, - PCAN	0.75
Northern Cardinal†		
Palm Warbler	- PCSB	0.30
Savannah Sparrow	+ PCSB, - PCAN	0.77

* Species of greatest conservation need, as listed in Wisconsin's Wildlife Action Plan

† No variables met requirements for inclusion in model using stepwise selection

Table 12. Habitat models using stepwise linear regression analyses for 42 bird species in all extensive site peatlands, Wisconsin, 2004-2007 (*n* = 74). Bird count data was square-root transformed. Habitat variables entered regressions at $P \leq 0.15$ and were retained when $P \leq 0.05$. (+) or (-) indicates the directions of the relationship between that variable and bird species.

Species	Habitat Model	R^2
Forest Associated Species		
American Crow	+ PCHH	0.18
Black-capped Chickadee	+ PCTT, + PCTC	0.15
Black-throated Green Warbler	+ PCTT, - PCHH	0.25
Blue-headed Vireo	+ SNAG, + PDEN	0.20
Blue Jay	+ PCTT, + PCTC	0.21
Cedar Waxwing	+ PCLH	0.06
Common Raven	- PCHH, + PDEN, + AREA	0.29
Eastern Wood-Pewee	+ PCLH, + AREA	0.19
Great Crested Flycatcher	+ PCLH, + SNAG	0.15
Ovenbird	+ PCLH	0.10
Red-breasted Nuthatch	+ PCTC, - MOSS	0.24
Red-eyed Vireo	- PCHH, + PCLH	0.33
Rose-breasted Grosbeak	- PCTC, - PCHH, + PCLH	0.30
Veery*	+ PCSB, + PCHH	0.31
White-throated Sparrow	+ PCTC, + MOSS, + SNAG	0.38
Winter Wren	- PCHH	0.15
Yellow-bellied Flycatcher	- PCTT, + PCTC, - PCHH	0.31
Yellow-rumped Warbler	- PCHH, + SNAG	0.25
Open-Shrub Associated Species		
Alder Flycatcher†		
American Goldfinch†		
American Robin	+ PCTC, - PCHH, - MOSS	0.37
Blue-winged Warbler*	+ PCLH, + AREA	0.13
Brown-headed Cowbird	+ PCHH	0.10
Chipping Sparrow†		
Eastern Towhee†		
Golden-winged Warbler*†		
Mourning Dove	+ PCSB, + PCHH	0.41
Red-winged Blackbird	+ PCHH	0.23
Sandhill Crane	+ PCHH, + AREA	0.28
Sedge Wren	- PCTC, - SNAG	0.20
Song Sparrow	- PCTC	0.07
Swamp Sparrow	- PCSB, - MOSS	0.15
Yellow Warbler	- PCTC, + PCLH	0.23
Forested Peatland Associated Species		
Golden-crowned Kinglet	+ PCTC, - PCHH	0.21
Hermit Thrush	+ PCTC, - PCSB, + SNAG	0.43
Nashville Warbler	+ PCTC, + SNAG	0.28
Yellow-shafted Flicker	- PCHH, + PCLH	0.16
Open-Shrub Peatland Associated Species		
Common Yellowthroat	- PCTT, + PCHH, - SNAG, + AREA	0.53
Lincoln's Sparrow	- PCTT, + PCLH, + MOSS, + AREA	0.35
Northern Cardinal	+ PCHH	0.13
Palm Warbler	- PCST, + MOSS, + SNAG, + AREA	0.32
Savannah Sparrow	- PCTT, - PCST, + PCSB, - SNAG	0.28

* Species of greatest conservation need, as listed in Wisconsin's Wildlife Action Plan

† No variables met requirements for inclusion in model using stepwise selection

Table 13. Habitat models using stepwise linear regression analyses for 42 bird species in extensive site peatlands in Wisconsin, 2007 (*n* = 50). Bird count data was square-root transformed. Habitat variables entered regressions at *P*≤0.15 and retained when *P*≤0.05. (+) or (-) indicates the directions of the relationship between that variable and species.

Species	Habitat Model	R^2
Forest Associated Species		
American Crow	- HERB, - WOOD	0.34
Black-capped Chickadee	+ SDBH, + PDEN	0.32
Black-throated Green Warbler	+ PCTT, - PCHH	0.41
Blue-headed Vireo†		
Blue Jay	+ SDBH, + HERB	0.29
Cedar Waxwing	+ WOOD	0.13
Common Raven	+ PDEN, + AREA	0.42
Eastern Wood-Pewee	+ PCLH	0.15
Great Crested Flycatcher	+ SNAG	0.13
Ovenbird	- OBSC	0.23
Red-breasted Nuthatch	+ SDBH, - OBSC, + HERB	0.38
Red-eyed Vireo	- PCHH, - OBSC	0.47
Rose-breasted Grosbeak	+ PCLH, + WOOD	0.34
Veery*	+ PCSB, + SDBH, + OBSC	0.46
White-throated Sparrow	- PCHH, - LEAF	0.45
Winter Wren	- PCTT, + PCAN	0.45
Yellow-bellied Flycatcher	- PCTT, + PCTC, + PCAN, - PDEN	0.71
Yellow-rumped Warbler	+ PCTC, - PCHH, - PCLH, + SAPH, - PDEN	0.60
Open-Shrub Associated Species		
Alder Flycatcher	- PDEN	0.20
American Goldfinch	+ WOOD	0.14
American Robin	- OBSC, - LEAF, + PDEN	0.49
Blue-winged Warbler*	+ PCLH	0.09
Brown-headed Cowbird	+ OBSC	0.25
Chipping Sparrow	- PCAN	0.10
Eastern Towhee†		
Golden-winged Warbler*	- SNAG, + SDBH, + WOOD	0.39
Mourning Dove	+ PCHH, + HERB	0.46
Red-winged Blackbird	- SDBH, + OBSC, - SAPH	0.46
Sandhill Crane	+ OBSC, + AREA	0.34
Sedge Wren	- PCTC	0.19
Song Sparrow	- PCAN, - PDEN	0.22
Swamp Sparrow	- SAPH	0.12
Yellow Warbler	+ PCTB, + PCLH, - SNAG, + WOOD, + AREA	0.50
Forested Peatland Associated Species		
Golden-crowned Kinglet	- PCSB, + PCAN, - LEAF	0.40
Hermit Thrush	- PCHH, + PCAN, - PDEN	0.49
Nashville Warbler	+ PCLH, + SDBH	0.42
Yellow-shafted Flicker	+ PCLH, - OBSC, + AREA	0.39
Open-Shrub Peatland Associated Species		
Common Yellowthroat	+ PCHH, - PCAN, + AREA	0.53
Lincoln's Sparrow	- OBSC, + WOOD, + AREA	0.43
Northern Cardinal	+ OBSC, - HERB	0.31
Palm Warbler	+ WOOD	0.36
Savannah Sparrow	- PCTC, - PCLH, - OBSC, - PCAN, + SAPH, + HERB, + PDEN	0.69

* Species of greatest conservation need, as listed in Wisconsin's Wildlife Action Plan

† No variables met requirements for inclusion in model using stepwise selection

Table 14. Habitat models using stepwise logistic regression analyses for 18 bird species currently at the edge of their distribution range. Data collected in all extensive site peatlands from 2004 to 2007 (*n* = 74). Habitat variables entered regressions at $P \leq 0.15$ and were retained when $P \leq 0.15$. (+) or (-) indicates the directions of the relationship between that variable and bird species. Max-rescaled R^2 included in the table.

Species	Habitat Model	R^2
Alder Flycatcher	- PCTC, + PCST, + PCLH	0.166
Black-throated Green Warbler	+ PCTT, - PCHH	0.352
Blue-gray Gnatcatcher	- PCST	0.480
Blue-headed Vireo	- PCST, + SNAG, + PDEN	0.393
Blue-winged Warbler*	+ PCLH, + PDEN	0.218
Hermit Thrush	- PCSB, + PCHH, + PCLH, + SNAG	0.554
Le Conte's Sparrow	+ PCTT	0.136
Lincoln's Sparrow	+ MOSS, + AREA	0.323
Mourning Warbler	+ PCTT	0.362
Nashville Warbler	+ PCTC, + PCLH, + SNAG	0.451
Olive-sided Flycatcher†		
Palm Warbler	- PCHH, + AREA	0.279
Red-bellied Woodpecker	+ SNAG	0.286
Red-breasted Nuthatch	+ PCTT, - MOSS	0.169
Swainson's Thrush†		
Veery*	+ PCST, - MOSS, - SNAG	0.369
White-throated Sparrow	- PCTT, + PCTC, - PCSHB, + SNAG, + PDEN	0.620
Yellow-bellied Flycatcher	- PCTT, + PCTC, - PCHH, + AREA	0.444

* Species of greatest conservation need, as listed in Wisconsin's Wildlife Action Plan

† No variables met requirements for inclusion in model using stepwise selection

Table 15. Habitat models using stepwise linear regression analyses for 18 bird species currently at the edge of their distribution range. Data collected in all extensive site peatlands from 2004 to 2007 (*n* = 74). Bird count data was square-root transformed. Habitat variables entered regressions at $P \leq 0.15$ and were retained when $P \leq 0.05$. (+) or (-) indicates the directions of the relationship between that variable and bird species.

Species	Habitat Model	R^2
Alder Flycatcher†		
Black-throated Green Warbler	+ PCTT, - PCHH	0.25
Blue-gray Gnatcatcher	- PCST, + PCHH	0.10
Blue-headed Vireo	+ SNAG, + PDEN	0.20
Blue-winged Warbler*	+ PCLH, + AREA	0.13
Hermit Thrush	+ PCTC, - PCSB, + SNAG	0.43
Le Conte's Sparrow†		
Lincoln's Sparrow	- PCTT, + PCLH, + MOSS, + AREA	0.35
Mourning Warbler	+ PCTT, - PCSB, + AREA	0.28
Nashville Warbler	+ PCTC, + SNAG	0.28
Olive-sided Flycatcher†		
Palm Warbler	- PCST, + MOSS, + SNAG, + AREA	0.32
Red-bellied Woodpecker	- PCTC, + PCLH, + SNAG	0.15
Red-breasted Nuthatch	+ PCTC, - MOSS	0.24
Swainson's Thrush	+ MOSS, - SNAG	0.08
Veery*	+ PCSB, + PCHH	0.31
White-throated Sparrow	+ PCTC, + MOSS, + SNAG	0.38
Yellow-bellied Flycatcher	- PCTT, + PCTC, - PCHH	0.31

* Species of greatest conservation need, as listed in Wisconsin's Wildlife Action Plan

† No variables met requirements for inclusion in model using stepwise selection

Figure 1. The Laurentian Mixed Forest (212) and Eastern Broadleaf Forest (222) Ecological Provinces in Wisconsin.

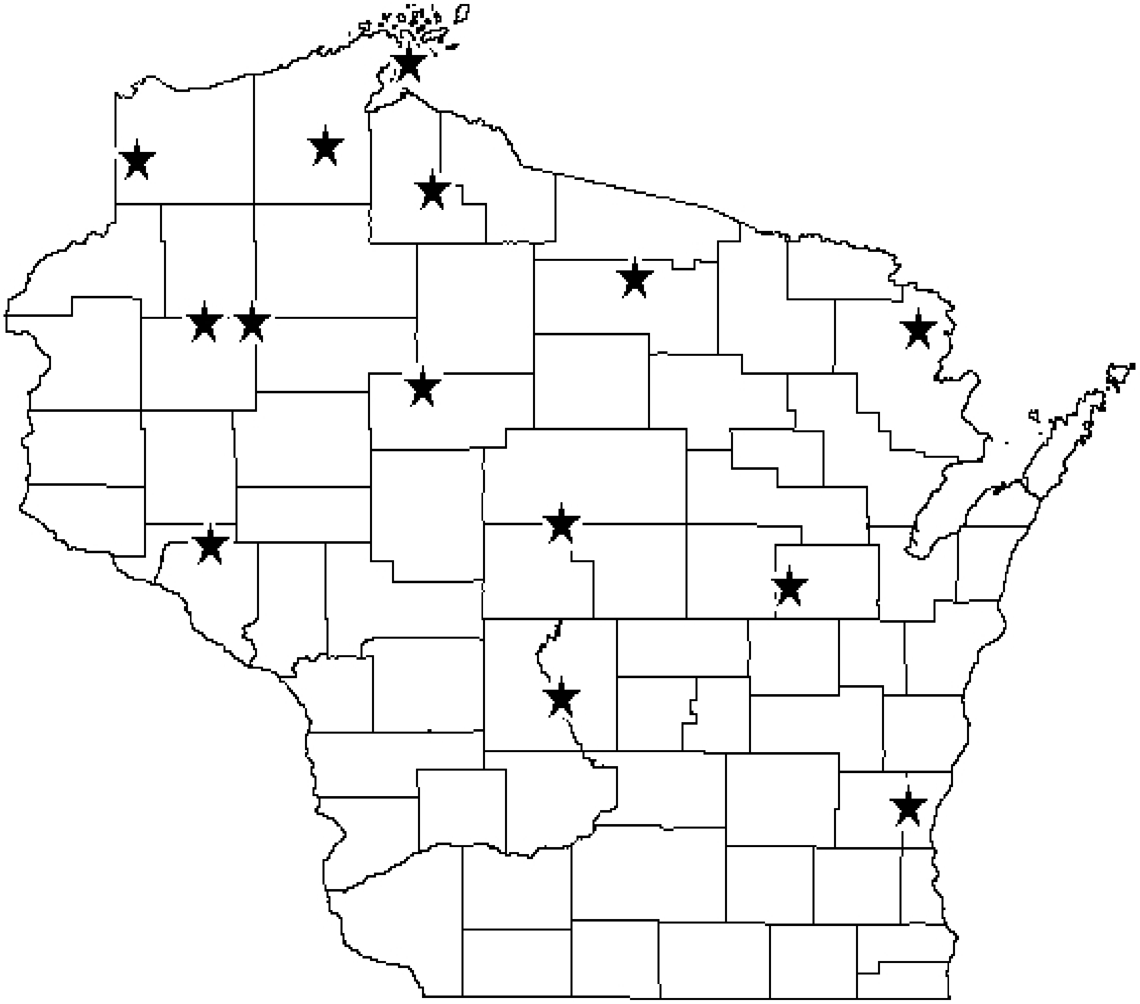


Figure 2. Locations of peatland intensive survey sites, 2004-2007, Wisconsin.

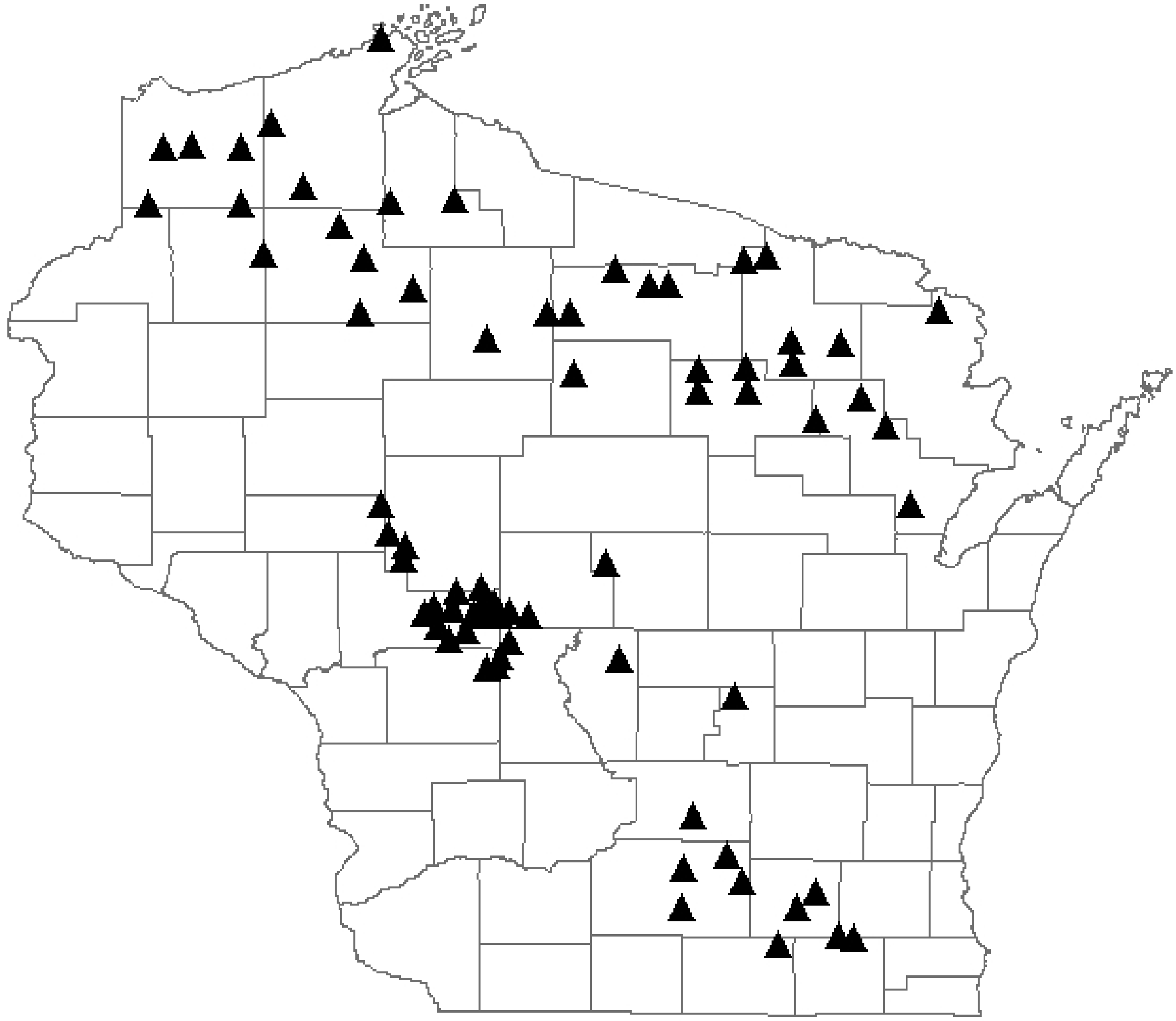


Figure 3. Locations of peatland extensive sites surveyed in 2004 – 2007, Wisconsin.

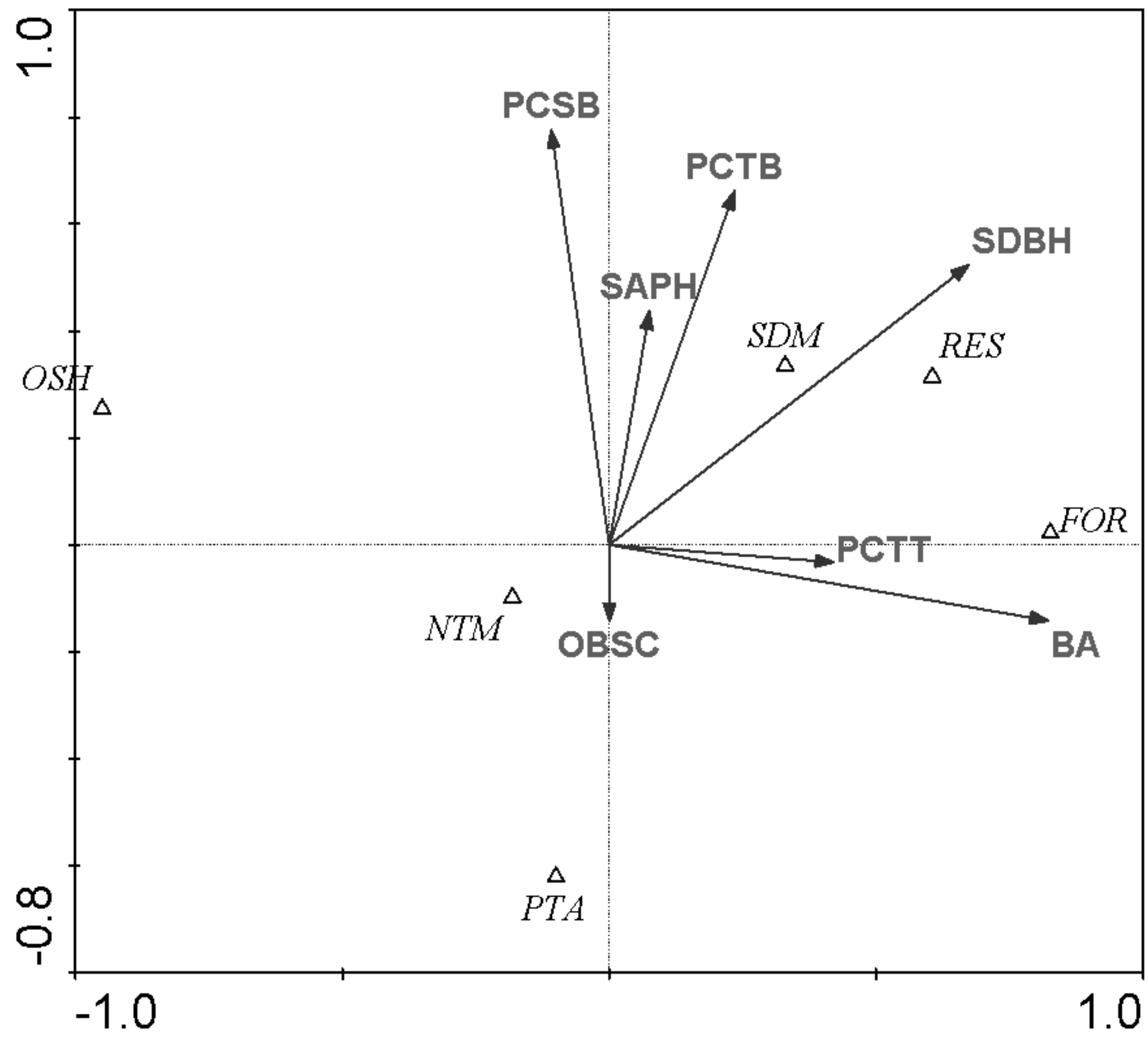


Figure 4. Canonical correspondence biplot of variables from the intensive sites dataset for a subset of birds (species detected at ≥5% of survey stations) in Wisconsin peatlands 2004 – 2007. Neotropical migrants (NTM), short-distance migrants (SDM), resident birds (RES). Forest-associates (FOR), open-shrubland associates (OSH), peatland-associated species (PTA).

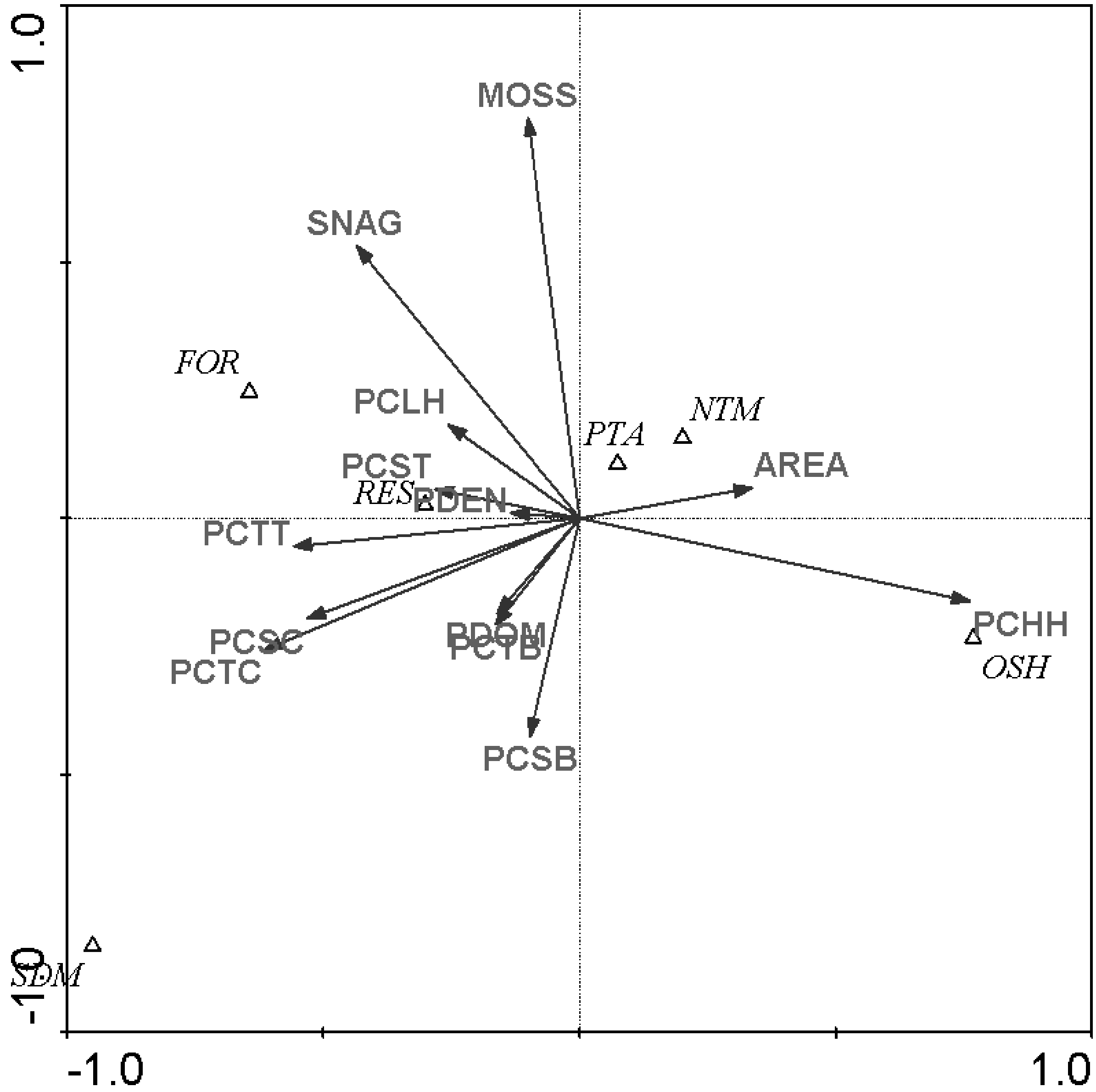


Figure 5. Canonical correspondence biplot of variables from all 2004-2007 extensive sites dataset for a subset of birds (species detected at ≥5% of survey stations) in Wisconsin peatlands. Forest-associates (FOR), open-shrubland associates (OSH), peatland-associated species (PTA).

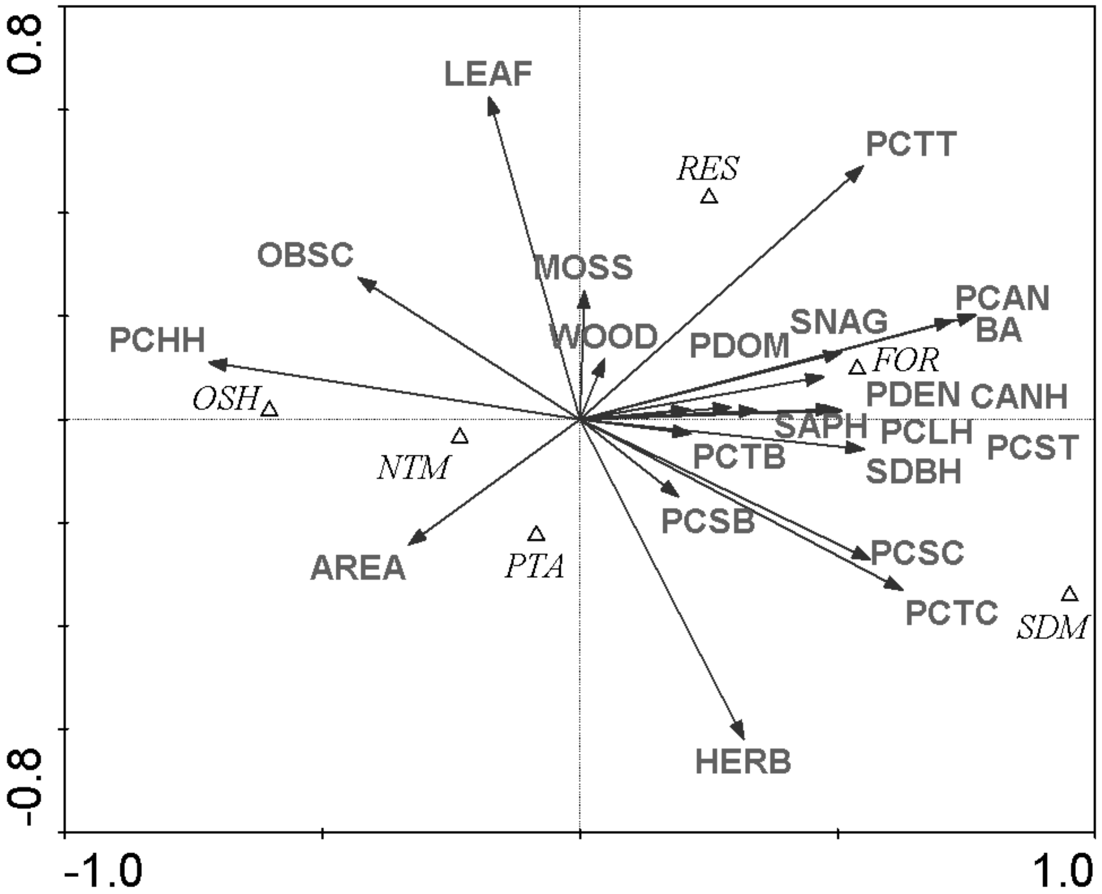


Figure 6. Canonical correspondence biplot of variables from the 2007 extensive sites dataset for a subset of birds (species detected at ≥5% of survey stations) in Wisconsin peatlands. Forest-associates (FOR), open-shrubland associates (OSH), peatland-associated species (PTA).

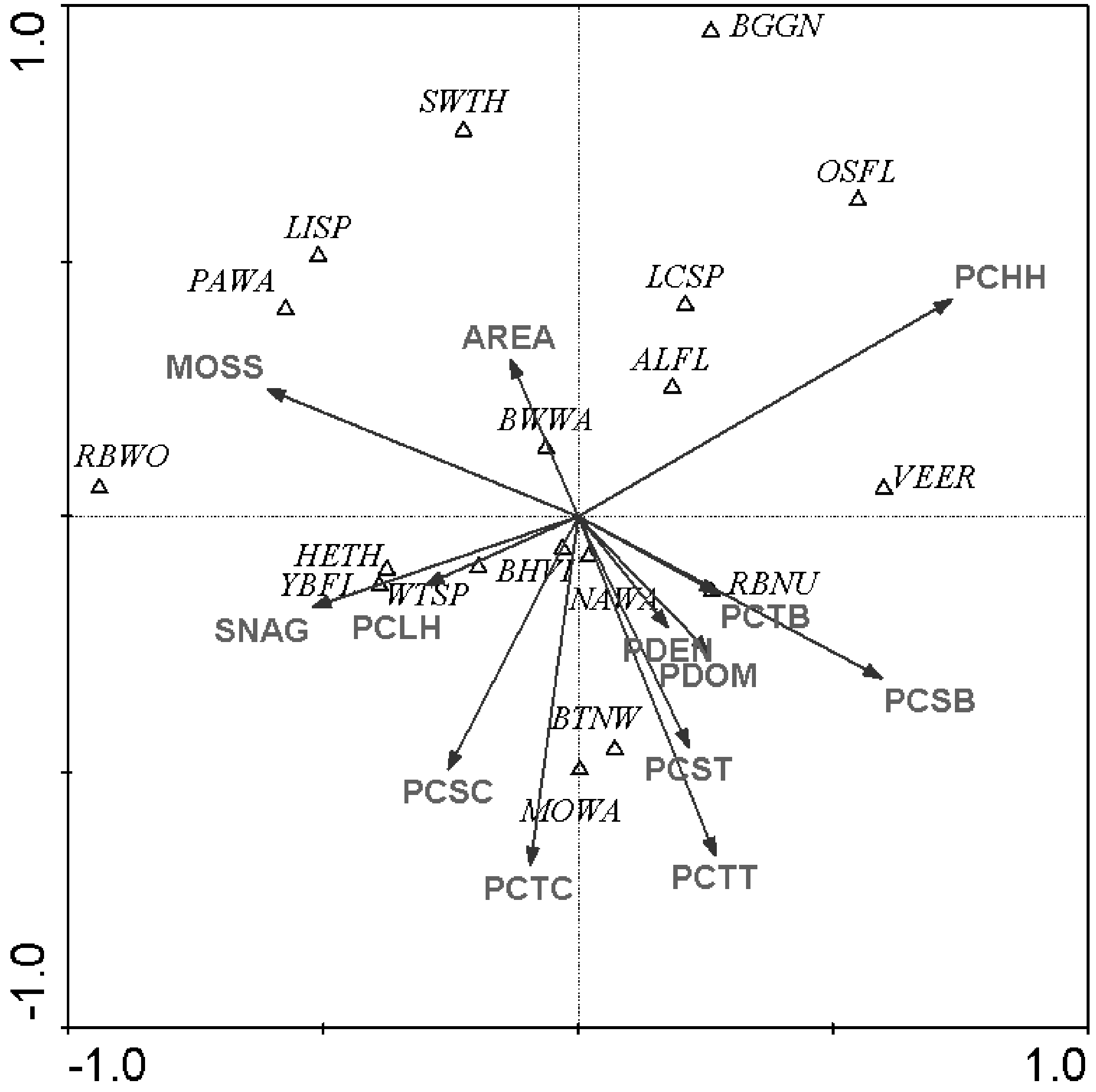


Figure 7. Canonical correspondence biplot of variables from all 2004-2007 extensive sites dataset for a subset of birds (species currently at the edge of their distribution range) in Wisconsin peatlands.

CHAPTER II:
HABITAT RELATIONSHIPS OF THREE PEATLAND-ASSOCIATED BIRDS IN WISCONSIN

Abstract. Relationships of upland bird species to patch area and habitat characteristics have been predominant themes in avian ecology over the past few decades, although, relatively little is known about these relationships in many wetland-dominated habitats, especially within peatlands of the Great Lakes region of the United States. I examined habitat relationships of Palm warblers (*Dendroica palmarum*), Nashville warblers (*Vermivora ruficapilla*), and common yellowthroats (*Geothylpis trichas*) across a range of peatland types, compositions, and structures in Wisconsin using point count data on bird presence and average relative abundance, and measurements of 22 explanatory habitat variables obtained from 88 peatland sites between 2004-2007. Habitat relationships of the three species were examined using *a priori*, logistic and linear regression models with Akaike's Information Criterion (AIC) model selection. Overall, results indicated percent cover of shrubs and foliage height diversity were the most important habitat characteristics explaining the presence and average relative abundance of all three species in Wisconsin peatlands. Individually, probability of occurrence and average relative abundance of common yellowthroats were negatively associated with canopy height, percent cover of broadleaf shrubs, and sapling height. Probability of occurrence and average relative abundance of Nashville warbers were positively associated with percent cover of conifer trees, low herbs, and all shrubs. Probability of occurrence and average relative abundance of palm warblers were positively associated with percent cover of moss, conifer trees, and woody ground cover. Information gained from my study should increase the capacity of managers to plan for continued persistence and conservation of these and other peatland-associated birds in Wisconsin.

Key words: AIC, common yellowthroat, *Dendroica palmarum, Geothylpis trichas,* habitat relationships, Nashville warbler, palm warbler, peatlands, regression, *Vermivora ruficapilla,* Wisconsin

INTRODUCTION

Ombrotrophic (bog) and minerotrophic (fen) peatlands are widespread ecosystems, covering approximately 3-4 x 10^6 km^2 worldwide (Lachance et al. 2005). Most peatlands have a boreal distribution between 50° and 70° N in Canada, Russia, and northern Europe, although an estimated 3.7 million ha of peatlands occur in the temperate, coterminous United States (Hall et al. 1994). Although the overall biological diversity of peatlands is low when compared to other wetland ecosystems, these habitats often support distinctive flora and fauna (Moore 2002). This is particularly true for peatlands at the southern extent of their distribution, where they support plant and animal species commonly found at more northern latitudes and can be considered islands of boreal diversity in temperate ecosystems (Lachance et al. 2005). Consequently, continued loss and degradation of peatlands from agriculture, forestry, urbanization, and the harvest of peat moss may provide a significant threat to regional biological diversity. Additionally, potential changes in peatland vegetation composition and structure from anthropogenic climate change are expected to exert profound changes in peatland flora and fauna (Weltzin et al. 2003, Lachance et al. 2005).

Two fundamental emphases in recent avian ecology research have been the importance of patch area and habitat characteristics to both species richness and species composition (Swift et al. 1984, Cody 1985, Winter and Faaborg 1999, Riffell et al. 2001). General theories of avian habitat relationships have evolved into the development of species-specific regression models (e.g., Gutzwiller and Anderson 1987, Naugle et al. 1999, Riffell et al. 2001) and predictive habitat suitability models to guide avian conservation and management (e.g., Prosser and Brooks 1998). However, much of this research has been conducted in terrestrial landscapes, whereas information concerning habitat relationships of wetland birds remains relatively scarce (Weller 1999, Riffell et al. 2001).

Avian habitat relationships have been investigated for some wetland ecosystems, including wet meadows (Riffell et al. 2001), depressional forested wetlands (Riffell et al. 2006), inland riparian wetlands (Inman et al. 2002), and prairie potholes (Naugle et al. 1999). However, information concerning species assemblages and habitat associations is lacking or limited for many wetland types, including peatlands. Recent work has documented the area and habitat associations of bird communities within the boreal peatlands of Canada (Calmé and Desrochers 2000, Calmé et al. 2002, Lachance et al. 2005). In general, bird species richness within Canadian peatlands is positively correlated with habitat heterogeneity (Calmé and Desrochers 2000). Alarmingly, however, the species assemblages and habitat relationships of birds within peatlands of the Great Lakes Region of the United States have been poorly characterized. This is of particular concern because these peatlands serve as boreal refugia within the surrounding temperate landscapes, and may provide critical migratory, breeding, and foraging habitat for a wide variety of bird species (Cutright et al. 2006).

Few North American bird species exclusively depend on peatland habitats (Gauthier and Aubry 1995, Calmé et al. 2002, Cutright et al. 2006). The palm warbler (*Dendroica palmarum*) is considered most strongly and perhaps exclusively associated with peatlands, at least in temperate regions where upland coniferous forests are scarce (Wilson et al. 1998, Desrochers 2001, Lachance et al. 2005). This species is associated with muskegs or open bogs containing deep beds of sphagnum moss (*Sphagnum* spp.) and small copses of black spruce (*Picea mariana*) surrounded by open areas, a situation intermediate between open and closed canopy (Lachance et al. 2005, Cutright et al. 2006). Palm warblers typically nest on the ground but use trees within the copse for singing and surveillance (Welsh 1971). This species appears particularly sensitive to changes in vegetative structure of peatlands that increase forest cover at the expense of open patches (Lachance et al. 2005), but also to peatland area (Calmé and Desrochers 2000). Accordingly, palm warblers may be an important indicator of avian habitat conditions within peatlands (Calmé and Desrochers 2000, Lachance et al. 2005, Cutright et al. 2006).

Although less dependent on peatlands than palm warblers, common yellowthroats (*Geothylpis trichas*) and Nashville warblers (*Vermivora ruficapilla*) are frequent breeders within North American peatlands (Gauthier and Aubry 1995, Cutright et al. 2006). Common yellowthroats breed in a wide variety of moist, shrubby habitats (Robbins 1991), but within peatlands this species is similar to palm warblers in that it typically nests in black spruce copses localized in ecotones between forest edges and open areas

(Gauthier and Aubry 1995). However, the distribution of common yellowthroats does not appear to be influenced by peatland area (Calmé and Desrochers 2000). Breeding habitats of Nashville warblers range from upland conifer stands to densely vegetated bogs and shrub swamps, often with a significant conifer component (Collins et al. 1982, Cutright et al. 2006). A dense ground cover of bryophytes or grasses is strongly associated with Nashville warbler nest sites (Collins et al. 1982).

My objective was to determine if the presence and average relative abundance of three species within Wisconsin's peatlands could be explained by composition and structure of peatland habitat. Presumably, potential presence and average relative abundance of palm warblers, common yellowthroats, and Nashville warblers should serve as indicators of available range of avian habitat compositions and structures within peatland habitats. However, to date, the specific habitat relationships of these and other passerine bird species have not been studied much within peatlands of the Great Lakes region. I sampled breeding populations of palm warblers, common yellowthroats, and Nashville warblers, and a suite of macro- and microhabitat features, in 2006 and 2007 within a diverse assemblage of peatland wetlands distributed across Wisconsin. I also incorporated bird and habitat data previously collected at these and similar peatland sites in the state in 2004 and 2005. Without detailed knowledge about area and habitat relationships of birds using these wetlands, effective management and conservation of avian habitat is not possible in the Great Lakes region.

METHODS

Study area

My study was conducted at individual peatland wetlands (“sites”) scattered across Wisconsin that were selected by the Wisconsin Department of Natural Resources for a broader, multi-taxa project investigating potential effects of climate change on peatland natural communities. Study sites were selected to represent the geographic distribution of peatlands in Wisconsin and to account for differences in topography, climate, and vegetation characteristics between the two ecological provinces (Keys et al. 1995) within the state (Fig. 8). The Laurentian Mixed Forest Province covers the northern half of Wisconsin (Province 212), and the Eastern Broadleaf Forest Province (Province 222) covers southern Wisconsin (Fig. 8). The division between these two provinces is known as the “Tension Zone,” along which the northern coniferous-deciduous forest changes gradually into southern oak forests and savannas and the former prairie region. In Wisconsin, peatland natural communities include black spruce (*Picea mariana*) swamps, bog relicts, boreal rich fens, muskegs, open bogs, poor fens (including central poor fens), tamarack (*Larix laricina*) poor swamps, tamarack rich swamps, northern wet-mesic forests including white cedar (*Thuja occidentalis*) swamps, southern sedge meadows, and northern sedge meadows.

Selection of study sites was based on two levels of survey intensity. The WDNR used Natural Heritage Inventory (NHI) data for Wisconsin natural communities, state natural areas, and other sources to select 14 peatland complexes as intensive survey sites (Fig. 9). These sites were subjectively determined by the WDNR to have experienced minimal human disturbance and to have a high likelihood of future stability (i.e., protected from direct anthropogenic influences). The 14 sites also were selected to ensure broad geographic representation within each province and corresponding ecological sections in Wisconsin. Intensive sites were designated for repeated sampling during each year of the study in order to account for temporal variation in bird populations.

The WDNR used a stratified random sampling design to select additional individual peatlands, distributed statewide and within both ecological provinces, as potential extensive survey sites. New extensive sites were randomly selected to survey each year and were surveyed only once during the study. From 2004 to 2007, 74 extensive sites were completely surveyed (Fig. 10). The purpose of extensive sites was to provide broad spatial resolution across the peatland wetlands of Wisconsin. Intensive site peatlands ranged in size from 16-792 ha ($\bar{x}$ = 336 ha ± 67 SE), whereas the area of extensive site peatlands ranged from 16-607 ha ($\bar{x}$ = 126 ha ± 15).

Bird Sampling

Point counts (Ralph et al. 1995, Howe et al. 1997) were used to assess presence and relative abundance of breeding passerine birds (Robbins 1991) within both intensive and extensive peatland sites. Point-count stations were established along a transect running through the midsection of each peatland site. Because sites varied in size, I attempted to ensure that the number of points was proportional to peatland area (i.e., more points at larger sites). For peatlands ≥100-ha, the number of points was limited to nine to ensure that all points within a site could be surveyed during one visit (Bub and Werner 2004). Stations were located ≥250-m apart in forested peatlands and ≥300-m apart in open peatlands to ensure independence of detections between points (Ralph et al.

1995, Howe et al. 1997). Point-count stations were established ≥125-m from habitat edges (i.e., the mapped boundaries of each site) to minimize detection of birds associated with non-peatland habitat types (Howe et al. 1997).

Unlimited-radius point counts were conducted at each station for 10 minutes from 0400 to 0930 Central Daylight Time. Point count surveys were conducted from late May to mid-July between 2004 and 2007. This start date should have minimized detection of non-breeding migrant species (i.e., transients). Unlimited-radius counts were used because differences in vegetation among sites make judgment of exact distances difficult (Ralph et al. 1995). To minimize potential effects of seasonal variation in bird activity, intensive sites were surveyed in reverse order during the second visit. Because multiple surveyors assisted with point counts, observers were rotated among intensive sites to minimize observer bias. Each year a different set of ≤50 extensive sites, which were randomly selected by the WDNR, were surveyed once. Thus, point-count stations within extensive sites were only surveyed once during the course of the study (Bibby et al. 1992, Ralph et al. 1995). Surveys were not conducted during periods of rain, heavy fog, or high winds (i.e., Beaufort >3; Table 16) since these conditions are known to decrease detectability of birds. The wind code (Table 16), sky code (Table 17), and temperature (°C) were recorded at each point-count station prior to initiating a survey.

Species and sex (if known) of all birds heard or seen during counts were recorded. Counts were subdivided into 3 intervals (0-3 min, 3-5 min, 5-10 min) and the interval during which each bird was first detected was recorded. Birds that flew over the point during surveys (i.e., “flyovers”) or were detected before and after the 10-min period were recorded separately. Although exact distances to each bird could not be measured, the horizontal detection distances from the point center to each bird were mapped in classes. Within forested (closed-canopy) peatlands, bird distances were mapped at either 0-50 m or >50 m. Distances to birds in open habitats are easier to estimate (Ralph et al. 1995, Howe et al. 1997), so bird detections at these sites were mapped at either 0-50 m, 50-100 m, or >100 m.

Habitat Sampling

I sampled vegetation at and surrounding each point-count station following methods previously established by the WDNR for the multi-taxa peatland study (Table 18). Vegetation was surveyed at each point within intensive sites once per season in 2004, 2006, and 2007. Extensive sites were surveyed only once during the study. Therefore, vegetation at these sites was surveyed immediately after bird surveys. The point-centered quarter method (Cottam and Curtis 1956) was used to estimate tree species composition, size, and density (Krebs 1989) at each point-count station. At each point, the species, diameter at breast height (dbh; cm), height (measured with a clinometer; m), and distance (m) of the nearest ≥7.5-cm tree in each quarter was measured. Within open peatlands, an "N/A" was recorded for each quadrant in which no trees were encountered within 50 m of the point center.

Within a 10-m radius plot surrounding each point-count station, percent cover classes (≤1%, 2-5%, 6-25%, 26-50%, 51-75%, 76-95%, 96-100%) of 5 vegetation height strata were recorded: trees (>10 m), trees-high shrubs (2-10m), low shrubs and high herbs (0.5-2 m), low herbs (0-0.5 m), and moss (0 m). For tree and tree-high shrub strata, percent cover classes were recorded separately for total cover, conifer cover, and broadleaf cover. The number of snags was tallied within each plot. Ocular estimates of the structural position and relative abundance of tree, shrub, sub-shrub, and herbaceous plant species were obtained for each plot using structure and relative abundance codes (CNPS 1998). Structural codes included canopy dominant, canopy associate, subcanopy/sapling, seedling, shrub dominant, and shrub associate. To categorize relative abundance, a designation of "rare" was used for species with few individuals, "uncommon" was used for species that were infrequently encountered, "common" was used for species that were locally abundant or frequently encountered, and "abundant" was used for species that are dominant within their strata in the plot.

Additional Vegetation Sampling in 2007.—To further quantify vegetation characteristics within intensive and extensive sites, additional vegetation measurements were recorded at all point-count stations surveyed in 2007. Within the 10-m radius plot, tree species, tree height, and tree dbh were recorded for 3 additional randomly-selected trees in each quarter. The dbh of snags within the 10-m radius plot was also measured. Percent canopy closure in each plot was estimated with a spherical densiometer. Densiometer readings were taken in each cardinal direction and averaged for the plot. I measured ground cover at the center of the 10-m radius plot with a 1-m^2 Daubenmire frame (Daubenmire 1959) and recorded the percent cover of herbaceous vegetation, woody ground cover, and leaf litter. Sapling height was measured with a meter-stick or clinometer for the three tallest saplings and averaged for the plot. Canopy height was measured with a clinometer for the three tallest canopy trees and averaged (Moorman and Guynn 2001). Visual obscurity was measured using a 2.5 × 150-cm cover pole (Robel et al. 1970), marked in 10-cm sections. The pole was placed in the center of the plot and the total number of sections ≥75% obscured from each cardinal direction was recorded, measured at eye level. The mean of the four readings was used to estimate percent shrub obscurity for each plot. Using GIS, I determined the total area (ha) of each peatland site. I traced the edge of peatland sites from digital orthophotos and calculated the total area (ha) of the peatland.

Model Specification and Analysis

I used logistic regression to determine the probability of bird occurrence and linear regression to determine variation in bird abundance in relation to habitat characteristics measured at each peatland site. Prior to model specification, I examined correlations among habitat variables for each data set (e.g. intensive sites, all extensive sites, 2007 extensive sites), and the most easily measured variable (i.e., most likely to be measured during peatland inventories) of an intercorrelated pair (Spearman's $r^2 \geq 0.70$) was retained. After eliminating redundant explanatory variables, 11 variables were included in logistic regression models for intensive sites and all extensive sites, 19 variables were included in logistic regression models for 2007 extensive sites, 12 variables were included in linear regression models for intensive sites, 11 variables were included in linear regression models for all extensive sites, and 19 variables were included in linear regression models for 2007 extensive sites (Table 18). Differences in the number of variables included for datasets was due to differences in collinearity of habitat variables within each dataset. Area was included in all models to account for variation in peatland size. Dependent variables included bird presence (logistic regression), and average bird abundance per site (linear regression). Square-root transformations of point-count data were performed prior to analysis to approximate normality. Bird habitat relationships were modeling separately for intensive and extensive sites because of different sampling intensities (i.e., years, number of point-count surveys per year).

I specified a set of *a priori*, candidate models based on (1) available published information on the three bird species, and (2) my previous experience with these species (Burnham and Anderson 2002). I specified 15 models: a global model containing all 11, 12, or 19 variables, depending upon the dataset used, and subset models representing potential influences of habitat characteristics on bird presence, richness, and abundance (Tables 19-53). I did not consider all possible combinations of variables, because this approach typically inflates the number of models beyond the number that can be reliably analyzed (Burnham and Anderson 2002). Prior to model selection, I examined fit of the global model following recommendations of Burnham and Anderson (2002) that included examining residuals, measures of fit (Nagelkerke's rescaled), classification tables, and histograms of expected probabilities.

Model selection.—I used Akaike's Information Criterion (AIC; Hurvich and Tsai 1989, Burnham and Anderson 2002) for model selection. Because the number of peatland sites (n) was small relative to the number of variables (K) in most models (i.e., $n/K < 40$), I used AIC corrected for small sample size (AIC$_c$) for model selection (Hurvich and Tsai 1989, Burnham and Anderson 2002). I used the formulas presented in Burnham and Anderson (2002) to calculate AIC$_c$ for maximum likelihood (logistic regression):

$$AIC_c = -2\log(L(\hat{\theta})) + 2K\left(\frac{n}{n-K-1}\right)$$

and least-squares (linear regression):

$$AIC_c = n\log\left(\hat{\sigma}^2\right) + 2K\left(\frac{n}{n-K-1}\right)$$

where the penalty term, *2K,* is multiplied by the correction factor *n/(n-K-1).* I ranked all candidate models according to their AIC_c values and the best model (i.e., most parsimonious) was the model with the smallest AIC_c value (AIC_{cmin}; Burnham and Anderson 2002). I drew primary inference from models within 2 units of AIC_{cmin}, although models within 5 units may have limited empirical support (Burnham and Anderson 2002). I calculated Akaike weights (w_i) to determine the weight of evidence in favor of each model (Burnham and Anderson 2002). Parameter estimates (including SEs) and fit (e.g., Hosmer and Lemeshow's goodness-of-fit, Nagelkerke's rescaled R^2) for models with empirical support were reported. All categorical variables were transformed into dummy variables (Cohen and Cohen 1983) and coefficients were calculated relative to the most frequently occurring category for each variable. I used SAS statistical package for all analyses (PROC REG, PROC LOGISTIC; SAS Institute, Cary, North Carolina).

RESULTS

Common yellowthroats.

Logistic regression models

Intensive sites

The "tree density" model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of common yellowthroats (hereafter COYE) at intensive sites (Table 19). COYE presence was negatively associated with increasing basal area (Table 20). The "shrubs" was also selected and showed COYE occurrence positively associated with percent cover of shrubs and low shrubs to high herbs (Table 20). The remaining 13 models received marginal to no empirical support ($\Delta AIC_c \geq 5.57$, $w_i \leq 0.04$; Table 19).

All Extensive Sites 2004 – 2007

The “overstory, midstory, understory” model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of COYE at all extensive sites 2004 – 2007 (Table 21). COYE presence was negatively associated with percent cover of broadleaf trees, percent cover of conifer trees, percent cover of broadleaf shrubs, percent cover of moss, and snag density, but was positively associated with percent cover of shrubs, percent cover of low shrubs to high herbs, tree density, and peatland area (Table 22). None of the other 14 models received empirical support ($\Delta AIC_c \geq 5.28$, $w_i \leq 0.07$; Table 21).

2007 Extensive Sites

The “snags and understory” model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of COYE at extensive sites in 2007 (Table 23). COYE presence was negatively associated with snag density, sapling height, and herbaceous ground cover, but positively associated with visual obscurity (Table 24). The “shrubs” model was also selected and showed COYE occurrence negatively associated with percent cover of broadleaf shrubs, but positively associated with percent cover of shrubs and percent cover of low shrubs to high herbs (Table 24). Three additional models selected were “snags,” “trees,” and “peatland area” which showed COYE presence influenced by snag and tree habitat variables and peatland area (Tables 23 and 24). The remaining 10 models received marginal or no empirical support ($\Delta AIC_c \geq 6.28$, $w_i \leq 0.02$; Table 23).

Linear regression models

Intensive sites

The "global" model was selected as the best approximating model of 15 linear regression models explaining the site-level average relative abundance of COYE at intensive sites (Table 25). COYE average relative abundance was negatively associated with percent cover of conifer trees, percent cover of low shrubs to high herbs, percent cover of low herbs, basal area, herbaceous ground cover, woody ground cover, leaf litter , and peatland area, but positively associated with percent cover of shrubs, percent cover of moss, snag density, and percent canopy closure (Table 26). None of the other 14 models received empirical support ($\Delta AIC_c \geq 411.70$, $w_i = 0.00$; Table 25).

All Extensive Sites 2004 – 2007

The "overstory, understory, area" model was selected as the best approximating model of 15 linear regression models explaining the site-level average relative abundance of COYE at all extensive sites 2004 – 2007 (Table 27). COYE average relative abundance was negatively associated with percent cover of trees and snag density, but positively associated with percent cover of low shrubs to high herbs and peatland area (Table 28). The "trees, shrubs, area" was also selected and showed COYE average relative abundance negatively associated with percent cover of trees, but positively associated with percent cover of shrubs and percent cover of low shrubs to high herbs, and peatland area (Table 28). None of the other 13 models received empirical support ($\Delta AIC_c \geq 11.36$, $w_i = 0.00$; Table 27).

2007 Extensive Sites

The “ground cover, canopy, area” model was selected as the best approximating model of 15 linear regression models explaining the average relative abundance of COYE at extensive sites in 2007 (Table 29). COYE average relative abundance was negatively associated with canopy height, but positively associated with percent cover of low shrubs to high herbs and peatland area (Table 30). The “shrubs” model was also selected and showed COYE average relative abundance negatively associated with percent cover of shrubs, but positively associated with percent cover of broadleaf shrubs and percent cover of low shrubs to high herbs (Table 30). The remaining 10 models received marginal or no empirical support ($\Delta AIC_c \geq 5.35$, $w_i \leq 0.06$; Table 29).

***Nashville warblers*.**

Logistic regression models

Intensive sites

The “trees” model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of Nashville warblers (hereafter NAWA) (Table 31). NAWA presence was negatively associated with snag density, but positively associated with percent cover of conifer trees (Table 32). The “conifer trees” model was also selected and showed NAWA occurrence positively associated with percent cover of conifer trees (Table 32). Seven additional models were selected, including “percent canopy,” “snags,” “peatland area,” “tree density,” “trees, shrubs, moss” “ground cover,” and “visual obscurity” all of which showed NAWA presence influenced by habitat variables corresponding with the model name (Tables 31 and 32).

The remaining 6 models received marginal or no empirical support ($\Delta AIC_c \geq 5.09$, $w_i \leq 0.03$; Table 31).

All Extensive Sites 2004 – 2007

The "overstory, understory, snags" model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of NAWA at all extensive sites 2004 – 2007 (Table 33). NAWA presence was positively associated with percent cover of conifer trees, percent cover of low herbs, and snag density (Table 34). The "mixed vertical vegetation" model was also selected and showed NAWA occurrence positively associated with percent cover of conifer trees, percent cover of low herbs, and percent cover of moss (Table 34). Three additional models were selected, including "conifer trees," "trees, shrubs, moss," and "trees", and showed NAWA presence to be influenced by habitat variables corresponding with the model names (Tables 33 and 34). The remaining 10 models received no empirical support ($\Delta AIC_c \geq 13.05$, $w_i = 0.00$; Table 33).

2007 Extensive Sites

The "ground cover and snag dbh" model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of NAWA at extensive sites in 2007 (Table 35). NAWA presence was positively associated with percent cover of low herbs, snag diameter, and herbaceous ground cover (Table 36). None of the 14 remaining models received marginal to no empirical support ($\Delta AIC_c \geq 7.92$, $w_i \leq 0.02$; Table 35).

Linear regression models

Intensive sites

The “global” model was selected as the best approximating model of 15 linear regression models explaining the site-level average relative abundance of NAWA at intensive sites (Table 37). NAWA average relative abundance was negatively associated with percent cover of low herbs, basal area, woody ground cover, and leaf litter, but positively associated with percent cover of conifer trees, percent cover of shrubs, percent cover of low shrubs to high herbs, percent cover of moss, snag density, percent canopy closure, herbaceous ground cover, and peatland area (Table 38). None of the other 14 models received empirical support ($\Delta AIC_c \geq 427.84$, $w_i = 0.00$; Table 37).

All Extensive Sites 2004 – 2007

The “conifer trees and snags” model was selected as the best approximating model of 15 linear regression models explaining the site-level average relative abundance of NAWA at all extensive sites 2004 – 2007 (Table 39). NAWA average relative abundance was positively associated with percent cover of conifer trees and snag density (Table 40). The “trees” was also selected and showed NAWA average relative abundance positively associated with percent cover of trees, percent cover of broadleaf trees, percent cover of conifer trees, and snag density (Table 40). One additional model, “trees, shrubs, moss,” was selected and shwoed NAWA average relative abundance positively associated with percent cover of broadleaf trees, percent cover of conifer trees , percent cover of shrubs, and percent cover of moss (Table 40). The remaining 12 models received marginal or no empirical support ($\Delta AIC_c \geq 7.30$, $w_i \leq 0.02$; Table 39).

2007 Extensive Sites

The “ground cover and basal area” model was selected as the best approximating model of 15 linear regression models explaining the site-level average relative abundance of NAWA at extensive sites in 2007 (Table 41). NAWA average relative abundance was positively associated with percent cover of low herbs and basal area (Table 42). The “snags” model was also selected and showed NAWA average relative abundance positively associated with snag density and snag diameter (Table 42). The remaining 13 models received no empirical support ($\Delta AIC_c \geq 11.28$, $w_i = 0.00$; Table 41).

Palm warblers

Logistic regression models

Intensive sites

The “tree density” model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of palm warblers (hereafter PAWA) (Table 43). PAWA presence was positively associated with basal area (Table 44). The “canopy” also was selected and showed PAWA occurrence negatively associated with percent canopy closure (Table 44). Seven additional models were selected, including “conifer trees,” “peatland area,” “snags,” “shrubs,” “trees,” “Daubenmire ground cover,” and “trees, shrubs, moss” (Tables 43 and 44), and showed PAWA presence to be influenced by habitat variables corresponding with each model name. The remaining 6 models received marginal or no empirical support ($\Delta AIC_c \geq 5.87$, $w_i \leq 0.01$; Table 43).

All Extensive Sites 2004 – 2007

The “trees, understory, area” model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of PAWA at all extensive sites 2004 – 2007 (Table 45). PAWA presence was negatively associated with percent cover of trees and percent cover of low shrubs to high herbs, but positively associated with percent cover of moss, snag density, and peatland area (Table 46). The "trees, shrubs, area" was also selected and showed PAWA occurrence negatively associated with percent cover of trees, percent cover of shrubs, and percent cover of low shrubs to high herbs, but positively associated with peatland area (Table 46). The remaining 13 models received marginal or no empirical support ($\Delta \mathrm{AIC}_c \geq 5.04$, $w_i \leq 0.05$; Table 45).

2007 Extensive Sites

The "ground cover and area" model was selected as the best approximating model of 15 logistic regression models explaining the site-level occurrence of PAWA at extensive sites in 2007 (Table 47). PAWA presence was negatively associated with percent cover of low shrubs to high herbs, but positively associated with woody ground cover and peatland area (Table 48). The "Daubenmire ground cover" model was also selected and showed PAWA occurrence negatively associated with leaf litter, but positively associated with herbaceous ground cover and woody ground cover (Table 48). The "ground cover" model was also selected and showed PAWA occurrence negatively associated with percent cover of moss, leaf litter, and visual obscurity, but positively associated with herbaceous ground cover and woody ground cover (Table 48). The remaining 12 models received marginal to no empirical support ($\Delta \mathrm{AIC}_c \geq 5.65$, $w_i \leq 0.03$; Table 47).

Linear regression models

Intensive sites

The “global” model was selected as the best approximating model of 15 linear regression models explaining the site-level average relative abundance of PAWA at intensive sites (Table 49). PAWA average relative abundance was negatively associated with percent cover of low herbs, percent canopy closure, herbaceous ground cover, woody ground cover, and leaf litter, but positively associated with percent cover of conifer trees, percent cover of shrubs, percent cover of low shrubs to high herbs, percent cover of moss, snag density, basal area, and peatland area (Table 50). None of the other 14 models received empirical support ($\Delta AIC_c \geq 427.27$, $w_i = 0.00$; Table 49).

All Extensive Sites 2004 – 2007

The “shrubs, moss, area” model was selected as the best approximating model of 15 linear regression models explaining the site-level average relative abundance of PAWA at all extensive sites 2004 – 2007 (Table 51). PAWA average relative abundance was negatively associated with percent cover of shrubs, but positively associated with percent cover of moss, snag density, and peatland area (Table 52). The remaining 14 models received marginal or no empirical support ($\Delta AIC_c \geq 10.54$, $w_i \leq 0.01$; Table 51).

2007 Extensive Sites

The “woody ground cover” model was selected as the best approximating model of 15 linear regression models explaining the site-level average relative abundance of PAWA at extensive sites in 2007 (Table 53). PAWA average relative abundance was positively associated with woody ground cover (Table 54). The “Daubenmire ground cover” was also selected and showed PAWA average relative abundance negatively associated with herbaceous ground cover and leaf litter, but positively associated with woody ground cover (Table 54). One additional model was selected, “ground cover,” and showed PAWA average relative abundance negatively associated with percent cover of moss, herbaceous ground cover, leaf litter, and visual obscurity, but positively associated with woody ground cover (Tables 53 and 54). The remaining 12 models received marginal to no empirical support ($\Delta AIC_c \geq 7.54$, $w_i \leq 0.01$; Table 53).

DISCUSSION

The presence and average relative abundance of common yellowthroats, Nashville warblers, and palm warblers was primarily influenced by understory vegetation features, especially percent cover of shrubs. Combinations of vegetation layers with stratified heights seemed to be the most explanatory models of bird habitat relationships within peatlands. This is not surprising because this concept was previously described by MacArthur and MacArthur (1961). The vertical stratification of vegetation provides birds with a variety of opportunities for breeding, feeding and seeking shelter. Recent work has shown that many factors may influence the distribution and diversity of bird species: for example, the distribution of particular microhabitats like treefall openings in forests (e.g. Terborgh et al. 1990) or rocky outcrops in shrubsteppe habitats (e.g. Wiens and Rotenberry 1981), percent canopy cover (Wiens and Rotenberry 1981), tree species diversity (e.g. James and Wamer 1982), or the distribution of specific plant taxa (e.g. Rice et al. 1984). In peatlands, the landscape composition and vegetation structure varies depending upon what type of peatland is being discussed. The peatlands surveyed in this study ranged from open sedge meadows to black spruce-tamarack swamps. No single model can explain habitat relationships of all species or groups of species because all species have their own unique niche requirements and behaviors.

Common yellowthroats use a variety of habitats and this could be an explanation for why the “global” linear regression model was selected as the best-approximating model for that species. Snag density was negatively associated with common yellowthroat average relative abundance which is contradictory to what has been found in a previous study (Riffell et al. 2001). Snags are commonly used by cavity-nesting species and as perches for singing and calling. Since common yellowthroats make nests of grass and other plants near the ground (Guzy and Ritchison 1999) and not in cavities, it may make sense that they are not positively correlated with snag density or snag diameter. Habitat size (area) was found to be weakly positively correlated with the presence and abundance of this neotropical migrant in this study. Similar results were found by Johnson and Igl (2001) in four northern Great Plains states. Neotropical migrants have been found to be positively associated with patch size (Brenner and Berad 1998, Edwards and Otis 1999, Fauth et al. 2000). In this study common yellowthroats were only weakly negatively correlated with percent canopy closure compared to opposite findings by Rodewald and Brittingham (2004). This relationship finding from this study could be misleading because of the collection of data from both forested and open sites in which this species was commonly detected. In previous peatland studies, common yellowthroats were found to be positively associated with coniferous tree species, including tamarack and black spruce (Wilson et al. 1998), but in my study very few models contain coniferous tree variables and the ones that do contain them show a slight negative correlation. Common yellowthroats presence and average relative abundance, in most of the models, are found to be positively associated with shrub cover that is vertically stratified, which corresponds with previous research (Schulte and Niemi

1998). Ground cover variables measured with the Daubenmire (1959) frame are associated slightly negatively with abundance of this species; whereas percent cover of low herbaceous vegetation and shrubs have a positive correlation with abundance, as seen in previous research (Fletcher and Koford 2002).

Ground cover elements had a positive influence on Nashville warbler presence and abundance in this study and this is in agreement with the habitat associations documented in the literature (Cutright et al. 2006). Descriptions of the breeding habitats of Nashville warblers commonly include conifer or mixed deciduous-conifer forests (Cutright et al. 2006), and not surprisingly, models in this study showed positive associations with snag and conifer tree variables. Another study in Wisconsin found female Nashville warblers foraging in hardwood stands (Sodhi and Paszkowski 1995). Males of this species typically forage in the mid-story and canopy of trees (Collins et al. 1982, Sodhi and Paszkowski 1995), which could explain the inclusion of tree and shrub variables in many of the supported models from this study.

Peatland area was shown to positively influence palm warbler presence and average relative abundance in my results and this has been previously documented from other studies (Calmé and Desrochers 2000). My models of palm warbler presence and average relative abundance had percent cover of trees and leaf litter negatively influencing the species, but percent cover of coniferous trees positively influencing PAWA. The negative influence of trees is not unlikely because palm warblers are typically found in more open and shrubby peatlands compared to forested peatlands. The affinity for coniferous trees has been found before in a peatland study in Maine (Wilson et al. 1998). Palm warblers in this study show weak correlations with tree density variables which is not surprising because only a few trees are consistently used as song posts (Welsh 1971). Palm warblers typically nest on the ground (Knight 1904, Walkinshaw and Wolf 1957, Welsh 1971), but in my results there are no strong correlations between palm warblers and any of the ground cover variables, such as herbaceous, woody, and leaf litter debris. Numerous models contain such variables but are only weakly correlated positively or negatively with palm warbler presence and average relative abundance. Leaf litter negatively influencing palm warblers in some of my models is a little strange because ordinarily I would think that a large amount of insects and seeds could be found amongst the leaf litter and included in the diets of the species. However, palm warblers might be negatively influenced by leaf litter because it conceals the sphagnum moss underneath which this species typically use.

IMPLICATIONS FOR CONSERVATION

Results of this study are most relevant to conservation planning, which the WDNR will likely continue to implement for peatlands and other natural communities throughout Wisconsin. None of the 3 species focused on in this manuscript are currently on Wisconsin's Wildlife Action Plan's (WDNR 2005) list of species of greatest conservation concern, but that does not mean that at some later date they could be added to it. If any of these species are added to the list at some point then the results of this study should provide some insight as to which habitat components to give priority to in terms of management.

Nashville warblers and palm warblers in Wisconsin are currently at the edge of their distribution ranges. This could become an important aspect of their conservation in the Great Lakes region. These species may be more likely to exhibit changes in presence or abundance as a result of climate change because they are likely to be the first species to be faced with habitat changes such as temperature, precipitation, or even vegetation structure within their currently used locations. It is important to continue to monitor the populations of these species through statewide bird surveys and counts.

A noteworthy comment to make regarding the results found from this study is the potential limited applicability to other habitats besides peatlands. The ways in which the intensive and extensive sites were selected did not provide the opportunity to view the results of these models to results with the same bird species in non-peatland habitats. The models selected as the best-approximating models and all models that received empirical support should be used as a guide to gaining a better understanding of the relationships between various bird species and the microhabitat and landscape features which influence their presence and abundance.

The predicted result of climate change characteristics, such as increased carbon-dioxide, increased variance in temperature and precipitation, is increased amounts of shrub cover and decreased amounts of graminoids (Weltzin et al. 2003). To say that bird species that are strongly and positively influenced by grasslands or areas comprised of herbaceous vegetation may shift their distributions to find suitable habitat is possible (Huntley 1991, Huntley 1994). Other organisms, such as insects and amphibians, which birds consume, may also be impacted by climate change. Bird species that are able to adapt to a changing climate will likely survive. To know and predict how individual bird species will react or adapt to such changes is not possible. Responses of all organisms are expected to be complex and, therefore, difficult to predict but a first step is predicting the potential response due to direct effects. That is only possible by linking large-scale models of bird distribution as a function of climate (Root and Schneider 1993).

ACKNOWLEDGEMENTS

I thank my graduate advisor, Dr. Kevin Russell for his support and guidance throughout the course of this research. His editorship, mentorship, and friendship were greatly appreciated. I thank Loren Ayers and other employees of the Wisconsin Department of Natural Resources for their cooperation in organizing, implementing and concluding this work. I would also like to thank members of my graduate committee, Drs. Tim Ginnett, Michael Hansen, and Robert Holsman for their advice, feedback and encouragement. Furthermore, I would like to thank other faculty at the University of Wisconsin – Stevens Point in the College of Natural Resources.

LITERATURE CITED

Bibby, C. J., N. D. Burgess, and D. H. Hill. 1992. Bird census techniques. Academic Press, London.

Brenner, F. J. and R. Berad. 1998. Relationship between forest fragmentation and woodlot characteristics on breeding birds. Journal of the Pennsylvania Academy of Science 71:73-77.

Bub, B. and K. Werner. 2004. Bird survey protocol: peatlands bird survey – May 2004. Unpublished report. Wisconsin Department of Natural Resources, Madision, WI, USA.

Burnham, K. P. and D. R. Anderson. 2002. Model selection and inference: A practical information-theoretic approach. Second edition. Springer-Verlag, New York, New York, USA.

California Native Plant Society (CNPS). 1998. Releve protocol, CNPS Vegetation Committee. Retrieved May 20, 2002 from http://www.cnps.org/vegetation/protocol.htm.

Calme, S. and A. Desrochers. 2000. Biogeographic aspects of the distribution of bird species breeding in Quebec's peatlands. Journal of Biogeography 27:725-732.

Calme, S., A. Desrochers, and J.-P. L. Savard. 2002. Regional significance of peatlands for avifaunal diversity in southern Quebec. Biological Conservation 107:273-281.

Cody, M. L. (editor) 1985. Habitat Selection in Birds. Academic Press, Inc., California.

Cohen J., and P. Cohen. 1983. Applied multiple regression–correlation analysis for the behavioral sciences. Lawrence Erlbaum Associates, Hillsdale.

Collins, S. L., F. C. James, and P. G. Risser. 1982. Habitat relationships of wood warblers (Parulidae) in northern central Minnesota. Oikos 39:50-58.

Cottam, G. and J. T. Curtis. 1956. The use of distance measures in phytosociological sampling. Ecology 37:451-460.

Cutright, N. J., B. R. Harriman, and R. W. Howe (editors). 2006. Atlas of the breeding birds of Wisconsin. Wisconsin Society for Ornithology, Inc. Waukesha, WI.

Daubenmire, R. K. 1959. A canopy coverage method of vegetational analysis. Northeast Science 43:43-64.

Desrochers, A. 2001. Les oiseaux : diversité et répartition. *In* S. Payette and L.

Rochefort (editors). Écologie des tourbières du Québec-Labrador. Presses de l'Université Laval, Saint-Nicolas, Québec

Edwards, N. T. and D. L. Otis. 1999. Avian communities and habitat relationships in South Carolina Piedmont beaver ponds. American Midland Naturalist 141:158-171.

Fauth, P. T., E. J. Gustafson, and K. N. Rabenold. 2000. Using landscape metrics to model source habitat for Neotropical migrants in midwestern US. Landscape Ecology 15:621-631.

Fletcher, R. J. and R. R. Koford. 2002. Habitat and landscape associations of breeding birds in native and restored grasslands. Journal of Wildlife Management 66:1011-1022.

Gauthier, J. And Y. Aubry (editors). 1995. Atlas des oiseaux nicheurs du Québec méridional. Association québécoise de protection des oiseaux and Service canadien de la faune, Environnement Canada (région du Québec), Montréal, Québec.

Gutzwiller, K. J. and S. H. Anderson. 1987. Multi-scale asociations between cavity-nester birds and features of Wyoming streamside woodlands. Condor 89:534-548.

Guzy, M. J. and G. Ritchison. 1999. Common Yellowthroat (*Geothylpis trichas*). *In* A. Poole and F. Gill (editors), The Birds of North America, no. 448. The Birds of North America, Philadelphia, PA.

Hall, J. V., W. E. Frayer, and B. O. Wilen. 1994. Status of Alaska wetlands. U. S. Fish and Wildlife Service, Alaska Region, Anchorage, AK. 32 pp.

Howe, R. W., G. J. Niemi, S. J. Lewis, and D. A. Welsh. 1997. A standard method for monitoring songbird populations in the Great Lakes Region. Passenger Pigeon 59(3):183-194.

Huntley, B. 1991. How plants respond to climate change: migration rates, individualism and the consequences for plant communities. Annals of Botany 675: 15-22.

Huntley, B. 1994. Plant species' response to climate change: implications for the conservation of European birds. Ibis 137:S127-S138.

Hurvich, C. and C. L. Tsai. 1989. Regression and time series model selection in small samples. Biometrika 76:297-307.

Inman, R. L., H. H. Prince, and D. B. Hayes. 2002. Avian communities in forested riparian wetlands of southern Michigan, USA. Wetlands 22:647-660.

James, F. C. and N. O. Wamer. 1982. Relationships between temperate forest bird communities and vegetation structure. Ecology 63:159-171.

Johnson, D. H. and L. D. Igl. 2001. Area requirements of grassland birds: A regional perspective. Auk 118:24-34.

Keys, J. Jr., C. Carpenter, S. Hooks, F. Koenig, W. H. McNab, W. Russell, and M. L. Smith. 1995. Ecological units of the eastern United States: first approximation. USDA Forest Service Southern Region, Atlanta, GA.

Knight, O. W. 1904. Contributions to the life history of the Yellow Palm Warbler. Journal of the Maine Ornithological Society 6:36-41.

Krebs, C. J. 1989. Ecological Methodology. New York, Harper and Row.

Lachance, D., C. Lavoie, and A. Desrochers. 2005. The impact of peatland afforestation on plant and bird diversity in southeastern Quebec. Ecoscience 12:161-171.

MacArthur, R. H. and J. W. MacArthur. 1961. On bird species. Ecology 42:594-598.

Moore, P. D. 2002. The future of cool temperate bogs. Environmental Conservation 29:3-20.

Moorman, C. E. and D. C. Guynn, Jr. 2001. Effects of group selection opening size on breeding bird habitat use in a bottomland forest. Ecological Applications 11:1680-1691.

Naugle, D. E., K. F. Higgins, S. M. Nusser, and W. C. Johnson. 1999. Scale-dependent habitat use in three species of prairie wetland birds. Landscape Ecology 14:267-276.

Prosser, D. J. and R. P. Brooks. 1998. A verified habitat suitability index for the Louisiana Waterthrush. Journal of Field Ornithology 69:288-298.

Ralph, C. J., J. R. Sauer, and S. Droege (editors). 1995. Monitoring bird populations by point counts. General Technical Report PSW-GTR-149. Pacific Southwest Research Station, USDA Forest Service, Albany, CA.

Rice, J. R., B. W. Anderson, and R. D. Ohmart. 1984. Comparison of the importance of different habitat attributes to avian community organization. Journal of Wildlife Management 48:895-911.

Riffell, S. K., B. E. Keas, and T. M. Burton. 2001. Area and habitat relationships of birds in Great Lakes coastal wet meadows. Wetlands 21:492-507.

Riffell, S. K., T. M. Burton, and M. Murphy. 2006. Birds in depressional forested wetlands: Area and habitat requirements and model uncertainty. Wetlands 26:107-118.

Robbins, S. D., Jr. 1991. Wisconsin birdlife: Population and distribution past and present. University of Wisconsin Press, Madison, WI, USA.

Robel, R. J., J. N. Briggs, A. D. Dayton, and L. C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Rodewald, P. G. and M. C. Brittingham. 2004. Stopover habitats of landbirds during fall: Use of edge-dominated and early-successional forests. Auk 121:1040-1055.

Root, T. L. and S. H. Schneider. 1993. Can large-scale climatic models be linked with multi scale ecological studies? Conservation Biology 7:256-270.

Schulte, L. S. and G. J. Niemi. 1998. Bird communities of early-successional burned and logged forest. Journal of Wildlife Management 62:1418-1429.

Sodhi, N. S. and C. A. Paszkowski. 1995. Habitat use and foraging behavior of 4 Parulid warblers in a 2nd-growth forest. Journal of Field Ornithology 66:277-288.

Swift, B. L., J. S. Larson, and R. M. DeGraaf. 1984. Relationship of breeding bird density and diversity to habitat variables in forested wetlands. Wilson Bulletin 96: 48-59.

Terborgh, J., S. K. Robinson, T. A. Parker, C. A. Munn, and N. Pierpont. 1990. Structure and organization of an Amazonian forest bird community. Ecological Monographs 60:213-238.

Walkinshaw, L. H. and M. A. Wolf. 1957. Distribution of the Palm warbler and its status in Michigan. Wilson Bulletin 69:338-351.

Weller, M. W. 1999. Wetland Birds. Cambridge University Press, Cambridge, UK.

Welsh, D. A. 1971. Breeding and territoriality of the Palm Warbler in a Nova Scotia bog. Canadian Field Naturalist 85:31-37.

Weltzin, J. F., S. D. Bridgham, J. Pastor, J. Chen, and C. Harth. 2003. Potential effects of warming and drying on peatland plan community composition. Global Change Biology 9:141-151.

Wiens, J. A. and J. T. Rotenberry. 1981. Habitat associations and community structure of birds in shrubsteppe environments. Ecological Monographs 51:21-41.

Wilson, W. H., R. E. Zierzow, and A. R. Savage. 1998. Habitat selection by peatland birds in a central Maine bog: The effects of scale and year. Journal of Field Ornithology 69:540-548.

Winter, M. and J. Faaborg. 1999. Patterns of area sensitivity in grassland birds. Conservation Biology 13:1424-1436.

Wisconsin Department of Natural Resources (WDNR). 2005. Wisconsin’s Strategy for Wildlife Species of Greatest Conservation Need. Madison, WI.

Table 16. Beaufort Wind Scale codes used to describe wind conditions for bird surveys.

Beaufort Code	mph	km	Description	Surroundings
0	< 1	< 1	Calm	Smoke rises vertically
1	1-3	1-5	Light Air	Smoke drift shows wind direction
2	4-7	6-11	Light Breeze	Leaves rustle, wind felt on face
3	8-12	12-19	Gentle Breeze	Leaves, small twigs in constant motion
4	13-18	20-28	Moderate Breeze	Raises dust, leaves, small branches in motion
5	19-24	23-38	Fresh Breeze	Small trees in leaf sway
6	25-31	39-49	Strong Breeze	Larger branches in motion
7	32-38	50-61	Moderate Gale	Whole trees in motion
8	39-46	62-74	Fresh Gale	Walking impeded, broken branches
9	> 47	> 75	Strong Gale	

Table 17. List of sky codes used to describe weather conditions for bird surveys.

Sky	Description	Cloud Cover
0	Clear	0-15%
1	Partly cloudy	16-50%
2	Mostly cloudy	51-75%
3	Overcast	76-100%
4	Wind-driven sand, dust,	-
5	Fog or haze	-
6	Drizzle	-
7	Rain	-
8	Snow	-
9	Thunderstorm, w or w/out	-

Table 18. List of variables measured in vegetation surveys.

Variable	**Units**	**Abbreviation**	**Description**
Overstory canopy	%	PCAN	Canopy closure of overstory trees
Basal area	sq m/ha	BA	Basal area of plot
DBH	cm		Diameter Breast Height of tree in plot
Tree Height	m		Height of tree in plot
Snag abundance	#	SNAG	number of snags within 10-m radius
Snag diameter	Cm	SDBH	Diameter Breast Height of snags in plot
Absolute Percent Cover	%	PCTT	Absolute percent cover of strata: tree (total)
		PCTC	Absolute percent cover of strata: tree (conifer)
		PCTB	Absolute percent cover of strata: tree (broadleaf)
		PCST	Absolute percent cover of strata: shrubs (total)
		PCSC	Absolute percent cover of strata: shubs (conifer)
		PCSB	Absolute percent cover of strata: shrubs (broadleaf)
		PCHH	Absolute percent cover of strata: low shrubs to high herbs
		PCLH	Absolute percent cover of strata: low herbs
		MOSS	Absolute percent cover of strata: moss
Structural Position (of tree, shrub, sub-shrub, and herbaceous plants)		CD	Canopy dominant
		CA	Canopy associate
		SC/SA	Sub-canopy/Sapling
		SD	Seedling
		DS	Dominant shrub
		AS	Associate shrub
Abundance	1, 2, 3, 4		Rare (1), Uncommon (2), Common (3), Abundant (4)
Distance	m		Distance to nearest ≥7.5cm tree
Ground cover	%	HERB	Cover of herbaceous vegetation
		WOOD	Cover of woody ground cover
		LEAF	Cover of leaf litter
Sapling height	m	SAPH	Average height of 3 tallest saplings per plot
Canopy height	m	CANH	Height of overstory canopy
Vertical cover	%	OBSC	Index of understory vegetation structure
Peatland Area	ha	AREA	Total size of peatland area
Temperature	ºC		Air temperature
PCQ Density	trees/ac	PDEN	Average PCQ density per site
PCQ Dominance	BA/ac	PDOM	Average PCQ dominance per site

Table 19. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of common yellowthroats at intensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Tree density {BA}	2	5.09	0.00	0.68
Shrubs {PCST, PCHH}	3	8.41	3.31	0.13
Conifer trees {PCTC}	2	10.66	5.57	0.04
Canopy {PCAN}	2	10.73	5.64	0.04
Peatland area {AREA}	2	11.92	6.83	0.03
Snags {SNAG}	2	12.29	7.20	0.02
Visual obscurity {PCST, PCHH, PCLH}	4	12.45	7.35	0.02
Trees, shrub, moss {PCTC, PCST, MOSS}	4	12.45	7.36	0.02
Daubenmire ground cover {HERB, WOOD}	3	13.40	8.31	0.01
Trees {PCTC, SNAG}	3	13.87	8.78	0.01
Ground cover {MOSS, HERB, WOOD}	4	16.26	11.17	0.00
Mixed vertical vegetation {PCTC, PCLH, BA, MOSS}	5	17.50	12.41	0.00
Percent cover totals {PCST, PCHH, PCLH, MOSS}	5	17.50	12.41	0.00
Ground cover and low herbs {MOSS, HERB, WOOD , PCLH}	5	17.51	12.41	0.00
Global {PCTC, PCST, PCHH, PCLH, MOSS, SNAG, BA, PCAN, HERB, WOOD, AREA}	12	17.51	12.41	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 20. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of common yellowthroats at intensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^{2a}
Tree density			0.999
Constant	15.682	67.944	
Basal area	-0.089	0.562	
Shrubs			0.999
Constant	-10.470	38.480	
Percent cover shrubs (total)	0.046	1.397	
Percent cover low shrubs/high herbs	0.683	2.077	

a Max-rescaled R^2

Table 21. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of common yellowthroats at all extensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Overstory, midstory, understory {PCTB, PCTC, PCST, PCSB, PCHH, MOSS, SNAG, PDEN, AREA}	10	39.43	0.00	0.93
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, PDEN, AREA}	12	44.71	5.28	0.07
Shrubs {PCST, PCSB, PCHH}	4	50.36	10.93	0.00
Trees, shrubs, area {PCTT, PCST, PCHH, AREA}	5	53.88	14.46	0.00
Visual obscurity {PCST, PCHH, PCLH}	4	57.79	18.36	0.00
Peatland area {AREA}	2	58.44	19.02	0.00
Percent cover totals {PCTT, PCST, PCHH, PCLH, MOSS}	6	60.92	21.49	0.00
Trees, shrubs, moss {PCTB, PCTC, PCST, MOSS}	5	62.99	23.56	0.00
Snags {SNAG}	2	64.60	25.17	0.00
Trees {PCTT, PCTB, PCTC, SNAG}	5	66.14	26.71	0.00
Conifer trees {PCTC}	2	66.97	27.54	0.00
Moss {MOSS}	2	68.24	28.81	0.00
Mixed vertical vegetation {PCTC, PCLH, MOSS}	3	68.41	28.98	0.00
Tree density {PDEN}	2	69.68	30.25	0.00
Broadleaf trees and shrubs{PCTB, PCSB}	2	71.26	31.84	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 22. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of common yellowthroats at all extensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^{2a}
Overstory, midstory, understory			0.832
Constant	22.014	12.408	
Percent cover trees (broadleaf)	-0.317	0.174	
Percent cover trees (conifer)	-0.281	0.151	
Percent cover shrubs (total)	0.454	0.237	
Percent cover shrubs (broadleaf)	-0.288	0.134	
Percent cover low shrubs/high herbs	0.167	0.073	
Percent cover moss	-0.295	0.150	
Snags	-0.753	0.486	
Tree density (Point-center-quarter)	0.002	0.001	
Peatland area	0.085	0.046	

a Max-rescaled R^2

Table 23. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of common yellowthroats at extensive peatlands in Wisconsin in 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Snags and understory vegetation {SNAG, OBSC, SAPH, HERB}	5	31.14	0.00	0.42
Shrubs {PCST, PCSB, PCHH}	4	31.77	0.63	0.31
Snags {SNAG, SDBH}	3	34.00	2.87	0.10
Trees {PCTT, PCTB, PCTC, SNAG}	5	34.81	3.67	0.07
Peatland area {AREA}	2	35.63	4.50	0.04
Visual obscurity {PCST, PCHH, PCLH, OBSC}	5	37.42	6.28	0.02
Conifer trees {APCTC}	2	38.90	7.76	0.01
Trees, shrubs, moss {PCTB, PCTC, PCST, MOSS, SAPH}	6	39.00	7.87	0.01
Daubenmire ground cover {HERB, WOOD, LEAF}	4	40.02	8.89	0.00
Understory vegetation {MOSS, HERB, WOOD, LEAF, OBSC}	6	40.59	9.45	0.00
Canopy {CANH}	2	40.83	9.69	0.00
Tree density {BA, PDEN}	3	41.59	10.45	0.00
Percent cover totals {PCTT, PCST, PCHH, PCLH, MOSS}	6	42.30	11.16	0.00
Ground cover {MOSS, HERB, WOOD, LEAF, OBSC, PCLH}	7	43.30	12.16	0.00
Global {PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, SDBH, OBSC, BA, CANH, SAPH, HERB, WOOD, LEAF, PDEN, AREA}	20	69.00	37.86	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 24. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of common yellowthroats at extensive peatlands in Wisconsin in 2007.

Model	β	SE	R^{2a}
Snags and understory vegetation			0.552
Constant	5.050	3.394	
Snags	-0.300	0.209	
Visual obscurity	0.088	0.054	
Sapling height	-1.368	0.804	
Daubenmire ground cover (herbs)	-0.043	0.030	
Shrubs			0.464
Constant	-0.364	1.370	
Percent cover shrubs (total)	0.018	0.029	
Percent cover shrubs (broadleaf)	-0.055	0.027	
Percent cover low shrubs/high herbs	0.079	0.033	
Snags			0.324
Constant	4.130	1.445	
Snags	-0.441	0.174	
Snag diameter	-0.054	0.096	
Trees			0.448
Constant	5.933	2.166	
Percent cover trees (total)	-0.001	0.018	
Percent cover trees (broadleaf)	-0.029	0.023	
Percent cover trees (conifer)	-0.028	0.017	
Snags	-0.474	0.208	
Peatland area			0.194
Constant	0.425	0.835	
Peatland area	0.020	0.012	

a Max-rescaled R^2

Table 25. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of common yellowthroats at intensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Global {PCTC, PCST, PCHH, PCLH, MOSS, SNAG, BA, PCAN, HERB, WOOD, LEAF, AREA}	14	-417.40	0.00	1.00
Snags and basal area {SNAG, BA}	4	-5.70	411.70	0.00
Tree density {BA}	3	-3.99	413.41	0.00
Canopy and basal area{SNAG, BA, PCAN}	5	-2.50	414.90	0.00
Conifer trees {PCTC}	3	5.82	423.23	0.00
Snags {SNAG}	3	7.03	424.43	0.00
Trees {PCTC, SNAG}	4	7.13	424.53	0.00
Shrubs {PCST, PCHH}	4	7.22	424.62	0.00
Canopy {PCAN}	3	7.44	424.84	0.00
Mixed vertical vegetation {PCTC, PCLH, BA, MOSS}	6	8.08	425.48	0.00
Peatland area {AREA}	3	8.75	426.15	0.00
Visual obscurity {PCST, PCHH, PCLH}	5	11.85	429.25	0.00
Trees, shrubs, moss {PCTC, PCST, MOSS}	5	11.87	429.27	0.00
Daubenmire ground cover {HERB, WOOD, LEAF}	5	15.76	433.16	0.00
Percent cover totals {PCST, PCHH, PCLH, MOSS}	6	17.73	435.13	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 26. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on average species abundance of common yellowthroats at intensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^2
Global			0.848
Constant	6.843	9.098	
Percent cover trees (conifer)	-0.011	0.029	
Percent cover shrubs (total)	0.078	0.148	
Percent cover low shrubs/high herbs	-0.045	0.076	
Percent cover low herbs	-0.082	0.146	
Percent cover moss	0.028	0.075	
Snags	0.368	1.142	
Basal area	-0.036	0.040	
Percent canopy closure	0.034	0.058	
Daubenmire ground cover (herbs)	-0.006	0.048	
Daubenmire ground cover (woody vegetation)	-0.065	0.112	
Daubenmire ground cover (leaf litter)	-0.057	0.105	
Peatland area	-0.001	0.004	

Table 27. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of common yellowthroats at extensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Overstory, understory, area {PCTT, PCHH, SNAG, AREA}	6	15.62	0.00	0.91
Trees, shrubs, area {PCTT, PCST, PCHH, AREA}	6	20.22	4.60	0.09
Percent cover totals {PCTT, PCST, PCHH, PCLH, MOSS}	7	26.97	11.36	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, PDEN, AREA}	13	29.90	14.28	0.00
Visual obscurity {PCST, PCHH, PCLH}	5	32.21	16.59	0.00
Shrubs{PCST, PCSB, PCHH}	5	32.37	16.76	0.00
Trees {PCTT, PCTB, PCTC, SNAG}	6	46.01	30.39	0.00
Snags{SNAG}	3	48.05	32.43	0.00
Trees, shrubs, moss {PCTB, PCTC, PCST, MOSS}	6	52.88	37.26	0.00
Mixed vertical vegetation{PCTC, PCLH, MOSS}	5	54.06	38.44	0.00
Moss{MOSS}	3	55.57	39.96	0.00
Peatland area{AREA}	3	55.99	40.37	0.00
Ground cover{MOSS, PCLH}	4	56.40	40.78	0.00
Conifer trees{PCTC}	3	61.57	45.96	0.00
Broadleaf trees and shrubs{PCTB, PCSB}	4	64.59	48.98	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 28. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on average species abundance of common yellowthroats at extensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^2
Overstory, understory, area			0.529
Constant	1.400	0.378	
Percent cover trees (total)	-0.012	0.005	
Percent cover low shrubs/high herbs	0.022	0.004	
Snags	-0.083	0.039	
Area	0.003	0.001	
Trees, shrubs, area			0.499
Constant	0.811	0.318	
Percent cover trees (total)	-0.013	0.005	
Percent cover shrubs (total)	0.002	0.006	
Percent cover low shrubs/high herbs	0.027	0.004	
Peatland area	0.003	0.001	

Table 29. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of common yellowthroats at extensive peatlands in Wisconsin in 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Ground cover, canopy, area{PCHH, CANH, AREA}	5	18.03	0.00	0.83
Shrubs{PCST, PCSB, PCHH}	5	22.81	4.78	0.08
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	7	23.38	5.35	0.06
Visual obscurity{OBSC, PCST, PCHH, PCLH}	6	25.43	7.41	0.02
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	6	28.51	10.48	0.00
Snags{SNAG, SDBH}	4	28.80	10.77	0.00
Trees{PCTT, PCTB, PCTC, SNAG}	6	29.55	11.53	0.00
Tree density{BA, PDEN}	4	29.85	11.83	0.00
Peatland area{AREA}	3	39.58	21.55	0.00
Daubenmire ground cover{HERB, WOOD, LEAF}	5	40.08	22.05	0.00
Conifer trees{PCTC}	3	41.10	23.07	0.00
Ground cover{MOSS, HERB, WOOD, LEAF, OBSC}	7	42.56	24.53	0.00
Trees, shrubs, moss{PCTB, PCTC, PCST, MOSS, SAPH}	7	42.94	24.91	0.00
Understory vegetation{PCLH, MOSS, HERB, WOOD, LEAF, OBSC}	8	43.19	25.16	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, SDBH, OBSC, BA, CANH, SAPH, HERB, WOOD, LEAF, PDEN, AREA}	21	55.53	37.50	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 30. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on average species abundance of common yellowthroats at extensive peatlands in Wisconsin in 2007.

Model	β	SE	R^2
Ground cover, canopy, area			0.468
Constant	0.804	0.414	
Canopy height	-0.011	0.030	
Percent cover low shrubs/high herbs	0.028	0.005	
Peatland area	0.003	0.001	
Shrubs			0.414
Constant	1.146	0.450	
Percent cover shrubs (total)	-0.004	0.007	
Percent cover shrubs (broadleaf)	0.001	0.006	
Percent cover low shrubs/high herbs	0.028	0.006	

Table 31. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of Nashville warblers at intensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Trees{PCTC, SNAG}	3	8.42	0.00	0.33
Conifer trees{PCTC}	2	8.92	0.50	0.25
Percent canopy{PCAN}	2	11.41	2.99	0.07
Snags{SNAG}	2	11.58	3.16	0.07
Peatland area{AREA}	2	12.05	3.63	0.05
Tree density{BA}	2	12.12	3.71	0.05
Trees, shrubs, moss{PCTC, PCST, MOSS}	4	12.45	4.03	0.04
Ground cover{MOSS, HERB, WOOD}	4	12.46	4.04	0.04
Visual obscurity{PCST, PCHH, PCLH}	4	12.46	4.04	0.04
Shrubs{PCST, PCHH}	3	13.50	5.09	0.03
Daubenmire ground cover{HERB, WOOD}	3	15.60	7.18	0.01
Percent cover totals{PCST, PCHH, PCLH, MOSS}	5	17.50	9.09	0.00
Understory vegetation{MOSS, HERB, WOOD, PCLH}	5	17.52	9.10	0.00
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	5	17.52	9.10	0.00
Global{PCTC, PCST, PCHH, PCLH, MOSS, SNAG, BA, PCAN, HERB, WOOD, AREA}	12	336.00	327.59	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 32. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of Nashville warblers at intensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^{2a}
Trees			0.998
Constant	27.708	58.489	
Percent cover trees (conifer)	0.727	1.452	
Snags	-5.717	12.135	
Conifer trees			0.533
Constant	-0.448	3.802	
Percent cover trees (conifer)	1.141	3.493	
Percent canopy closure			0.152
Constant	4.641	3.118	
Percent canopy closure	-0.056	0.066	
Snags			0.124
Constant	4.039	2.347	
Snags	-0.312	0.368	
Peatland area			0.043
Constant	3.381	2.157	
Peatland area	-0.002	0.004	
Tree density			0.030
Constant	2.129	1.507	
Basal area	0.010	0.031	
Trees, shrubs, moss			0.999
Constant	-20.624	106.600	
Percent cover trees (conifer)	0.014	1.274	
Percent cover shrubs (total)	0.233	1.767	
Percent cover moss	0.435	1.586	

a Max-rescaled R^2

Table 32. (continued) Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of Nashville warblers at intensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^{2a}
Ground cover			0.999
Constant	-63.482	198.700	
Percent cover moss	0.572	1.251	
Daubenmire ground cover (herbs)	0.667	2.414	
Daubenmire ground cover (woody vegetation)	0.202	2.339	
Visual obscurity			0.999
Constant	115.100	231.900	
Percent cover shrubs (total)	-0.046	1.448	
Percent cover low shrubs/high herbs	-0.823	1.757	
Percent cover low herbs	-1.143	2.463	

a Max-rescaled R^2

Table 33. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of Nashville warblers at extensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Overstory, understory, snags{PCTC, PCLH, SNAG}	4	62.24	0.00	0.59
Mixed vertical vegetation{PCTC, PCLH, MOSS}	4	65.06	2.83	0.14
Conifer trees{PCTC}	2	65.12	2.88	0.14
Trees, shrubs, moss{PCTB, PCTC, PCST, MOSS}	5	66.81	4.57	0.06
Trees{PCTT, PCTB, PCTC, SNAG}	5	66.86	4.62	0.06
Visual obscurity{PCST, PCHH, PCLH}	4	75.29	13.05	0.00
Tree density{PDEN}	2	76.61	14.38	0.00
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	6	77.11	14.88	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, PDEN, AREA}	12	77.19	14.95	0.00
Trees, shrubs, area{PCTT, PCST, PCHH, AREA}	5	77.93	15.70	0.00
Shrubs{PCST, PCSB, PCHH}	4	78.34	16.11	0.00
Snags{SNAG}	2	79.71	17.47	0.00
Ground cover{MOSS, PCLH}	3	79.94	17.71	0.00
Moss{MOSS}	2	83.81	21.58	0.00
Broadleaf trees and shrubs{PCTB, PCSB}	3	84.48	22.24	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 34. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of Nashville warblers at extensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^{2a}
Overstory, understory, snags			0.451
Constant	-1.288	0.722	
Percent cover trees (conifer)	0.088	0.036	
Percent cover low herbs	0.026	0.014	
Snags	0.153	0.098	
Mixed vertical vegetation			0.409
Constant	-1.035	0.741	
Percent cover trees (conifer)	0.086	0.035	
Percent cover low herbs	0.024	0.014	
Percent cover moss	0.005	0.008	
Conifer trees			0.340
Constant	0.197	0.358	
Percent cover trees (conifer)	0.075	0.032	
Trees, shrubs, moss			0.417
Constant	-1.030	0.738	
Percent cover trees (broadleaf)	0.028	0.023	
Percent cover trees (conifer)	0.078	0.034	
Percent cover shrubs (total)	0.010	0.016	
Percent cover moss	0.012	0.008	
Trees			0.417
Constant	-0.411	0.464	
Percent cover trees (total)	-0.004	0.026	
Percent cover trees (broadleaf)	0.023	0.027	
Percent cover trees (conifer)	0.081	0.043	
Snags	0.146	0.097	

a Max-rescaled R^2

Table 35. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of Nashville warblers at extensive peatlands in Wisconsin in 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Ground cover and snag diameter{PCLH, SDBH, HERB}	4	21.08	0.00	0.97
Snags{SNAG, SDBH}	3	28.99	7.92	0.02
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	5	31.19	10.11	0.01
Tree density{BA, PDEN}	3	34.11	13.03	0.00
Conifer trees{PCTC}	2	34.15	13.07	0.00
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	6	34.59	13.51	0.00
Trees, shrubs, moss{PCTB, PCTC, PCST, MOSS, SAPH}	6	34.98	13.90	0.00
Canopy{CANH}	2	35.31	14.23	0.00
Shrubs{PCST, PCSB, PCHH}	4	36.62	15.54	0.00
Trees{PCTT, PCTB, PCTC, SNAG}	5	37.15	16.07	0.00
Understory vegetation{MOSS, HERB, WOOD, LEAF, OBSC, PCLH}	7	38.64	17.56	0.00
Visual obscurity{PCST, PCHH, PCLH, OBSC}	5	39.02	17.94	0.00
Ground cover{MOSS, HERB, WOOD, LEAF, OBSC}	6	41.82	20.74	0.00
Daubenmire ground cover{HERB, WOOD, LEAF}	4	43.56	22.48	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, SDBH, OBSC, BA, CANH, SAPH, HERB, WOOD, LEAF, PDEN, AREA}	20	69.00	47.92	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 36. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of Nashville warblers at extensive peatlands in Wisconsin in 2007.

Model	β	SE	R^{2a}
Ground cover and snag diameter			0.824
Constant	-8.544	3.863	
Percent cover low herbs	0.062	0.035	
Snag diameter	0.934	0.399	
Daubenmire ground cover (herbs)	0.062	0.037	

a Max-rescaled R^2

Table 37. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of Nashville warblers at intensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Global{PCTC, PCST, PCHH, PCLH, MOSS, SNAG, BA, PCAN, HERB, WOOD, LEAF, AREA}	14	-425.23	0.00	1.00
Conifer shrubs{PCSC}	3	2.61	427.84	0.00
Conifer trees{PCTC}	3	8.30	433.53	0.00
Tree density{BA}	3	10.59	435.82	0.00
Snags{SNAG}	3	11.57	436.79	0.00
Trees{PCTC, SNAG}	4	11.58	436.80	0.00
Canopy{PCAN}	3	11.90	437.13	0.00
Peatland area{AREA}	3	12.04	437.27	0.00
Trees, shrubs, moss{PCTC, PCST, MOSS}	5	14.68	439.90	0.00
Shrubs{PCST, PCHH}	4	14.99	440.22	0.00
Ground cover{MOSS, HERB, WOOD, LEAF}	6	18.15	443.38	0.00
Daubenmire ground cover{HERB, WOOD, LEAF}	5	19.30	444.52	0.00
Visual obscurity{PCST, PCHH, PCLH}	5	19.72	444.95	0.00
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	6	21.40	446.63	0.00
Percent cover totals{PCST, PCHH, PCLH, MOSS}	6	22.84	448.07	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 38. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on average species abundance of Nashville warblers at intensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^2
Global			0.928
Constant	-9.398	6.879	
Percent cover trees (conifer)	0.021	0.022	
Percent cover shrubs (total)	0.081	0.112	
Percent cover low shrubs/high herbs	0.020	0.058	
Percent cover low herbs	-0.083	0.110	
Percent cover moss	0.097	0.056	
Snags	0.987	0.864	
Basal area	-0.020	0.030	
Percent canopy closure	0.005	0.044	
Daubenmire ground cover (herbs)	0.023	0.036	
Daubenmire ground cover (woody vegetation)	-0.034	0.085	
Daubenmire ground cover (leaf litter)	-0.065	0.080	
Peatland area	0.004	0.003	

Table 39. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of Nashville warblers at extensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC$_c$).

Model[a]	K[b]	AIC$_c$[c]	ΔAIC$_c$[d]	w_i[e]
Conifer trees and snags{PCTC, SNAG}	4	25.11	0.00	0.68
Trees{PCTT, PCTB, PCTC, SNAG}	6	27.52	2.41	0.20
Trees, shrubs, moss{PCTB, PCTC, PCST, MOSS}	6	30.03	4.93	0.06
Visual obscurity{PCST, PCHH, PCLH}	5	32.40	7.30	0.02
Mixed vertical vegetation{PCTC, PCLH, MOSS}	5	33.22	8.11	0.01
Shrubs{PCST, PCSB, PCHH}	5	33.29	8.18	0.01
Conifer trees{PCTC}	3	34.05	8.94	0.01
Trees, shrubs, area{PCTT, PCST, PCHH, AREA}	6	34.93	9.82	0.01
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	7	35.39	10.28	0.00
Snags{SNAG}	3	37.85	12.74	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, PDEN, AREA}	13	38.21	13.10	0.00
Ground cover{MOSS, PCLH}	4	42.61	17.50	0.00
Tree density{PDEN}	3	45.08	19.97	0.00
Moss{MOSS}	3	45.50	20.39	0.00
Peatland area{AREA}	3	45.91	20.80	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC$_c$ of the current model versus the best-approximating model (AIC$_{cmin}$).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 40. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on average species abundance of Nashville warblers at extensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^2
Conifer trees and snags			0.278
Constant	0.952	0.214	
Percent cover trees (conifer)	0.014	0.004	
Snags	0.125	0.037	
Trees			0.300
Constant	0.853	0.227	
Percent cover trees (total)	0.007	0.005	
Percent cover trees (broadleaf)	0.002	0.007	
Percent cover trees (conifer)	0.012	0.004	
Snags	0.123	0.037	
Trees, shrubs, moss			0.275
Constant	0.536	0.324	
Percent cover trees (broadleaf)	0.007	0.007	
Percent cover trees (conifer)	0.013	0.004	
Percent cover shrubs (total)	0.012	0.006	
Percent cover moss	0.008	0.004	

Table 41. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of Nashville warblers at extensive peatlands in Wisconsin in 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Ground cover and basal area{PCLH, BA}	4	0.51	0.00	0.87
Snags{SNAG, SDBH}	4	4.50	3.99	0.12
Canopy{CANH}	3	11.79	11.28	0.00
Shrubs{PCST, PCSB, PCHH}	5	13.09	12.57	0.00
Visual obscurity{PCST, PCHH, PCLH, OBSC}	6	14.78	14.27	0.00
Conifer trees{PCTC}	3	15.19	14.68	0.00
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	6	16.87	16.36	0.00
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	7	17.02	16.51	0.00
Trees{PCTT, PCTB, PCTC, SNAG}	6	17.19	16.68	0.00
Trees, shrubs, moss{PCTB, PCTC, PCST, MOSS, SAPH}	7	17.26	16.75	0.00
Daubenmire ground cover{HERB, WOOD, LEAF}	5	20.37	19.86	0.00
Tree density{BA, PDEN}	4	22.05	21.54	0.00
Ground cover{MOSS, HERB, WOOD, LEAF, OBSC}	7	22.78	22.27	0.00
Peatland area{AREA}	3	24.22	23.71	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, SDBH, OBSC, BA, CANH, SAPH, HERB WOOD, LEAF, PDEN, AREA}	21	40.38	39.87	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 42. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on average species abundance of Nashville warblers at extensive peatlands in Wisconsin in 2007.

Model	β	SE	R^2
Ground cover and basal area			0.207
Constant	0.879	0.333	
Percent cover low herbs	0.014	0.006	
Basal area	0.007	0.003	
Snags			0.372
Constant	0.683	0.260	
Snags	0.104	0.051	
Snag diameter	0.112	0.025	

Table 43. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of palm warblers at intensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Tree density{BA}	2	22.43	0.00	0.25
Canopy{PCAN}	2	23.23	0.80	0.17
Conifer trees{PCTC}	2	23.46	1.03	0.15
Peatland area{AREA}	2	23.92	1.49	0.12
Snags{SNAG}	2	23.98	1.54	0.12
Shrubs{PCST, PCHH}	3	24.66	2.23	0.08
Trees{PCTC, SNAG}	3	26.48	4.04	0.03
Daubenmire ground cover{HERB, WOOD}	3	27.18	4.74	0.02
Trees, shrubs, moss{PCTC, PCST, MOSS}	4	27.29	4.85	0.02
Visual obscurity{PCST, PCHH, PCLH}	4	28.31	5.87	0.01
Ground cover{MOSS, HERB, WOOD}	4	28.90	6.47	0.01
Percent cover totals{PCST, PCHH, PCLH, MOSS}	5	31.83	9.40	0.00
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	5	32.47	10.03	0.00
Understory vegetation{MOSS, HERB, WOOD, PCLH}	5	33.08	10.65	0.00
Global{PCTC, PCST, PCHH, PCLH, MOSS, SNAG, BA, PCAN, HERB, WOOD, AREA}	12	336.01	313.57	0.00

---

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 44. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of palm warblers at intensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^{2a}
Tree density			0.160
Constant	-0.537	0.943	
Basal area	0.018	0.020	
Canopy			0.0910
Constant	1.162	1.082	
Percent canopy closure	-0.029	0.031	
Conifer trees			0.070
Constant	-0.281	0.854	
Percent cover of trees (conifer)	0.016	0.019	
Peatland area			0.027
Constant	0.701	0.954	
Peatland area	-0.001	0.002	
Snags			0.022
Constant	0.684	0.992	
Snags	-0.104	0.216	
Shrubs			0.248
Constant	1.965	1.615	
Percent cover shrubs (total)	-0.059	0.040	
Percent cover low shrubs/high herbs	0.012	0.029	
Trees			0.096
Constant	0.134	1.158	
Percent cover trees (conifer)	0.017	0.019	
Snags	-0.116	0.217	

a Max-rescaled R^2

Table 44. (continued) Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of palm warblers at intensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^{2a}
Daubenmire ground cover			0.033
Constant	0.157	2.300	
Daubenmire ground cover (herbs)	0.006	0.024	
Daubenmire ground cover (woody vegetation)	-0.012	0.033	
Trees, shrubs, moss			0.354
Constant	-0.158	2.636	
Percent cover trees (conifer)	0.008	0.021	
Percent cover shrubs (total)	-0.050	0.042	
Percent cover of moss	0.028	0.031	

a Max-rescaled R^2

Table 45. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of palm warblers at extensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Trees, understory, area{PCTT, PCHH, MOSS, SNAG, AREA}	6	41.58	0.00	0.68
Trees, shrubs, area{PCTT, PCST, PCHH, AREA}	5	43.56	1.98	0.25
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	6	46.62	5.04	0.05
Trees{PCTT, PCTB, PCTC, SNAG}	5	51.71	10.13	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, PDEN, AREA}	12	52.81	11.23	0.00
Shrubs{PCST, PCSB, PCHH}	4	52.95	11.36	0.00
Broadleaf trees and shrubs{PCTB, PCSB}	3	53.58	12.00	0.00
Tree density{PDEN}	2	55.45	13.87	0.00
Moss{MOSS}	2	56.11	14.53	0.00
Ground cover{MOSS, PCLH}	3	57.80	16.22	0.00
Snags{SNAG}	2	57.87	16.29	0.00
Visual obscurity{PCST, PCHH, PCLH}	4	58.94	17.36	0.00
Peatland area{AREA}	2	59.11	17.53	0.00
Mixed vertical vegetation{PCTC, PCLH, MOSS}	4	59.58	17.99	0.00
Trees, shrubs, moss{PCTB, PCTC, PCST, MOSS}	5	60.79	19.21	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 46. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of palm warblers at extensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^{2a}
Trees, understory, area			0.614
Constant	-2.799	1.801	
Percent cover trees (total)	-0.162	0.129	
Percent cover low shrubs/high herbs	-0.047	0.025	
Percent cover moss	0.031	0.020	
Snags	0.073	0.112	
Peatland area	0.009	0.004	
Trees, shrubs, area			0.540
Constant	0.807	1.196	
Percent cover trees (total)	-0.162	0.121	
Percent cover shrubs (total)	-0.021	0.024	
Percent cover low shrubs/high herbs	-0.054	0.022	
Peatland area	0.008	0.004	

a Max-rescaled R^2

Table 47. Logistic regression models explaining influence of microhabitat and landscape attributes on occurrence of palm warblers at extensive peatlands in Wisconsin in 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Ground cover and area{PCHH, WOOD, AREA}	4	22.44	0.00	0.57
Daubenmire ground cover{HERB, WOOD, LEAF}	4	23.64	1.21	0.31
Ground cover{MOSS, HERB, WOOD, LEAF, OBSC}	6	26.47	4.03	0.08
Understory vegetation{MOSS, HERB, WOOD, LEAF, OBSC, PCLH}	7	28.09	5.65	0.03
Shrubs{PCST, PCSB, PCHH}	4	32.31	9.88	0.00
Trees{PCTT, PCTB, PCTC, SNAG}	5	32.75	10.31	0.00
Peatland area{AREA}	2	33.63	11.19	0.00
Snags{SNAG}	2	34.19	11.75	0.00
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	6	34.65	12.21	0.00
Visual obscurity{PCST, PCHH, PCLH, OBSC}	5	34.79	12.36	0.00
Canopy{CANH}	2	35.46	13.03	0.00
Tree density{BA, PDEN}	3	36.56	14.12	0.00
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	5	36.65	14.22	0.00
Conifer trees{PCTC}	2	36.76	14.33	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, SDBH, OBSC, BA, CANH, SAPH, HERB,WOOD, LEAF, PDEN, AREA}	20	68.99	46.55	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 48. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of palm warblers at extensive peatlands in Wisconsin in 2007.

Model	β	SE	R^{2a}
Ground cover and area			0.660
Constant	-3.675	1.788	
Percent cover low shrubs/high herbs	-0.069	0.045	
Daubenmire ground cover (woody vegetation)	0.063	0.030	
Peatland area	0.007	0.004	
Daubenmire ground cover			0.625
Constant	-3.302	29.533	
Daubenmire ground cover (herbs)	0.016	0.150	
Daubenmire ground cover (woody vegetation)	0.080	0.135	
Daubenmire ground cover (leaf litter)	-0.557	4.727	
Ground cover			0.689
Constant	0.464	29.947	
Percent cover moss	-0.043	0.038	
Daubenmire ground cover (herbs)	0.001	0.184	
Daubenmire ground cover (woody vegetation)	0.112	0.152	
Daubenmire ground cover (leaf litter)	-0.588	4.246	
Visual obscurity	-0.036	0.065	

a Max-rescaled R^2

Table 49. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of palm warblers at intensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Global{PCTC, PCST, PCHH, PCLH, MOSS, SNAG, BA, PCAN, HERB, WOOD, LEAF, AREA}	14	-429.19	0.00	1.00
Broadleaf shrubs{PCSB}	3	-1.92	427.27	0.00
Canopy{PCAN}	3	1.03	430.22	0.00
Conifer trees{PCTC}	3	2.02	431.20	0.00
Tree density{BA}	3	2.04	431.23	0.00
Peatland area{AREA}	3	2.66	431.85	0.00
Snags{SNAG}	3	2.88	432.07	0.00
Shrubs{PCST, PCHH}	4	5.69	434.88	0.00
Trees{PCTC, SNAG}	4	5.90	435.09	0.00
Daubenmire ground cover{HERB, WOOD, LEAF}	5	6.90	436.08	0.00
Trees, shrubs, moss{PCTC, PCST, MOSS}	5	9.15	438.33	0.00
Visual obscurity{PCST, PCHH, PCLH}	5	10.71	439.90	0.00
Ground cover{MOSS, HERB, WOOD, LEAF}	6	12.72	441.90	0.00
Percent cover totals{PCST, PCHH, PCLH, MOSS}	6	15.84	445.03	0.00
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	6	16.06	445.25	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 50. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on occurrence of palm warblers at intensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^2
Global			0.897
Constant	-3.362	5.972	
Percent cover trees (conifer)	0.024	0.019	
Percent cover shrubs (total)	0.019	0.097	
Percent cover low shrubs/high herbs	0.030	0.050	
Percent cover low herbs	-0.013	0.096	
Percent cover moss	0.019	0.049	
Snags	0.410	0.750	
Basal area	0.007	0.026	
Percent canopy closure	-0.060	0.038	
Daubenmire ground cover (herbs)	-0.000	0.032	
Daubenmire ground cover (woody vegetation)	-0.019	0.074	
Daubenmire ground cover (leaf litter)	-0.030	0.069	
Peatland area	0.004	0.002	

Table 51. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of palm warblers at extensive peatlands in Wisconsin from 2004 to 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC_c).

Model[a]	K[b]	AIC_c[c]	ΔAIC_c[d]	w_i[e]
Shrubs, moss, area{PCST, MOSS, SNAG, AREA}	6	-68.20	0.00	0.99
Trees{PCTT, PCTB, PCTC, SNAG}	6	-57.66	10.54	0.01
Trees, shrubs, area{PCTT, PCST, PCHH, AREA}	6	-56.19	12.01	0.00
Snags{SNAG}	3	-56.11	12.10	0.00
Moss{MOSS}	3	-54.22	13.98	0.00
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	7	-54.01	14.19	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, PDEN, AREA}	13	-53.61	14.60	0.00
Ground cover{MOSS, PCLH}	4	-52.57	15.63	0.00
Mixed vertical vegetation{PCTC, PCLH, MOSS}	5	-51.42	16.78	0.00
Trees, shrubs, moss{PCTB, PCTC, PCST, MOSS}	6	-50.27	17.94	0.00
Peatland area{AREA}	3	-49.52	18.69	0.00
Conifer trees{PCTC}	3	-49.23	18.98	0.00
Visual obscurity{PCST, PCHH, PCLH}	5	-48.98	19.23	0.00
Broadleaf trees and shrubs{PCTB, PCSB}	4	-48.75	19.45	0.00
Shrubs{PCST, PCSB, PCHH}	5	-46.92	21.28	0.00

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC_c of the current model versus the best-approximating model (AIC_{cmin}).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 52. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on average species abundance of palm warblers at extensive peatlands in Wisconsin from 2004 to 2007.

Model	β	SE	R^2
Shrubs, moss, area			0.322
Constant	-0.177	0.161	
Percent cover shrubs (total)	-0.009	0.003	
Percent cover moss	0.004	0.002	
Snags	0.074	0.021	
Peatland area	0.002	0.001	

Table 53. Linear regression models explaining influence of microhabitat and landscape attributes on average species abundance of palm warblers at extensive peatlands in Wisconsin in 2007. Model rankings were based on Akaike's Information Criterion corrected for small sample size (AIC$_c$).

Model[a]	K[b]	AIC$_c$[c]	ΔAIC$_c$[d]	w_i[e]
Woody ground cover{WOOD}	3	-100.92	0.00	0.62
Daubenmire ground cover{HERB, WOOD, LEAF}	5	-9.49	1.43	0.31
Ground cover{MOSS, HERB, WOOD, LEAF, OBSC}	7	-96.14	4.78	0.06
Understory vegetation{MOSS, HERB, WOOD, LEAF, OBSC, PCLH}	8	-93.39	7.54	0.01
Peatland area{AREA}	3	-82.23	18.69	0.00
Canopy{CANH}	3	-80.11	20.81	0.00
Shrubs{PCST, PCSB, PCHH}	5	-79.40	21.53	0.00
Snags{SNAG, SDBH}	4	-79.28	21.64	0.00
Conifer trees{PCTC}	3	-78.85	22.07	0.00
Visual obscurity{PCST, PCHH, PCLH, OBSC}	6	-78.32	22.60	0.00
Percent cover totals{PCTT, PCST, PCHH, PCLH, MOSS}	7	-78.20	22.72	0.00
Tree density{BA, PDEN}	4	-77.69	23.23	0.00
Mixed vertical vegetation{PCTC, PCLH, BA, MOSS}	6	-77.37	23.55	0.00
Trees{PCTT, PCTB, PCTC, SNAG}	6	-76.46	24.46	0.00
Global{PCTT, PCTB, PCTC, PCST, PCSB, PCHH, PCLH, MOSS, SNAG, SDBH, OBSC, BA, CANH, SAPH, HERB, WOOD, LEAF, PDEN, AREA}	21	-49.72	51.20	0.00

---

a Abbreviations in parentheses correspond to model parameters in Table 3.

b Number of estimable parameters in approximating model.

c Akaike's Information Criterion corrected for small sample size.

d Difference in value between AIC$_c$ of the current model versus the best-approximating model (AIC$_{cmin}$).

e Akaike weight. Probability that the current model (w_i) is the best-approximating model among those considered.

Table 54. Parameter estimates (β) and standard errors (SE) from the best-approximating models explaining influence of habitat attributes on average species abundance of palm warblers at extensive peatlands in Wisconsin in 2007.

Model	β	SE	R^2
Woody ground cover			0.360
Constant	-0.127	0.070	
Daubenmire ground cover (woody vegetation)	0.010	0.002	
Daubenmire ground cover			0.403
Constant	0.517	0.442	
Daubenmire ground cover (herbs)	-0.005	0.004	
Daubenmire ground cover (woody vegetation)	0.006	0.003	
Daubenmire ground cover (leaf litter)	-0.008	0.004	
Ground cover			0.425
Constant	0.882	0.538	
Percent cover moss	-0.002	0.002	
Daubenmire ground cover (herbs)	-0.007	0.004	
Daubenmire ground cover (woody vegetation)	0.006	0.004	
Daubenmire ground cover (leaf litter)	-0.009	0.004	
Visual obscurity	-0.002	0.003	

Figure 8. The Laurentian Mixed Forest (212) and Eastern Broadleaf Forest (222) Ecological Provinces in Wisconsin.

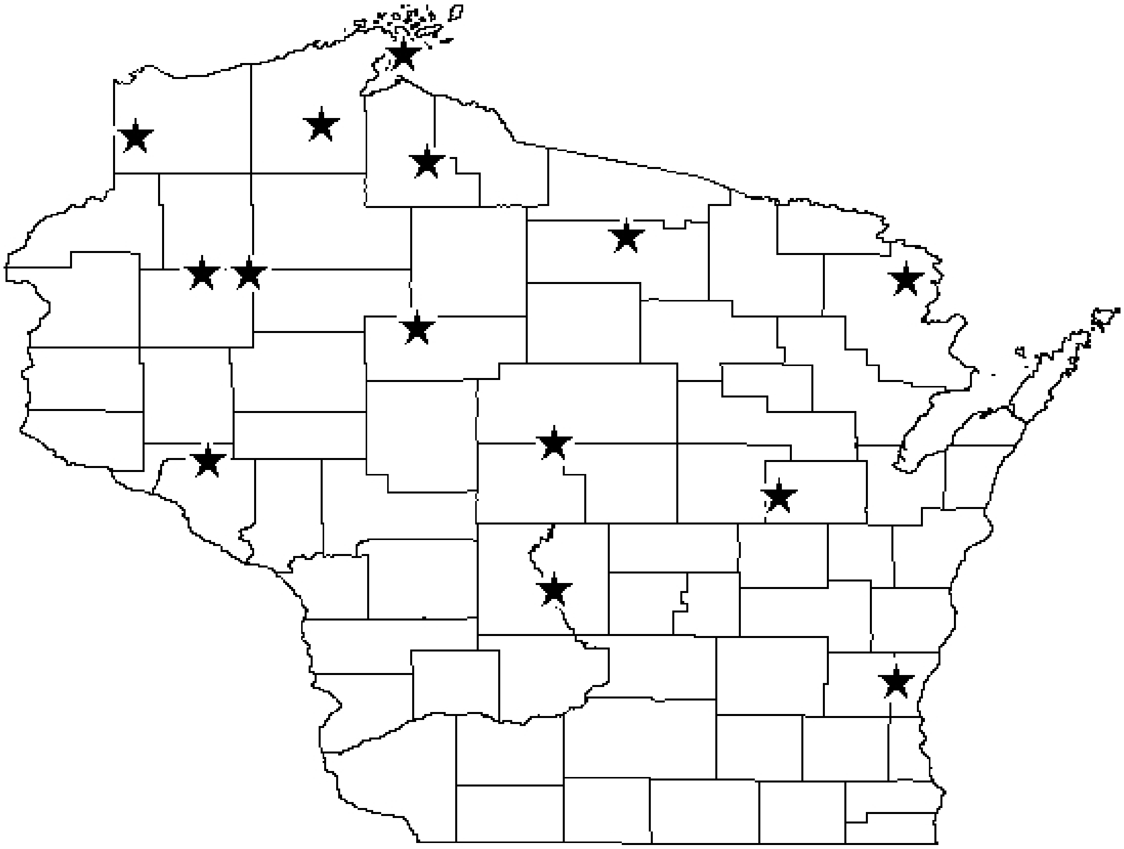


Figure 9. Locations of peatland intensive survey sites 2004 – 2007, Wisconsin.

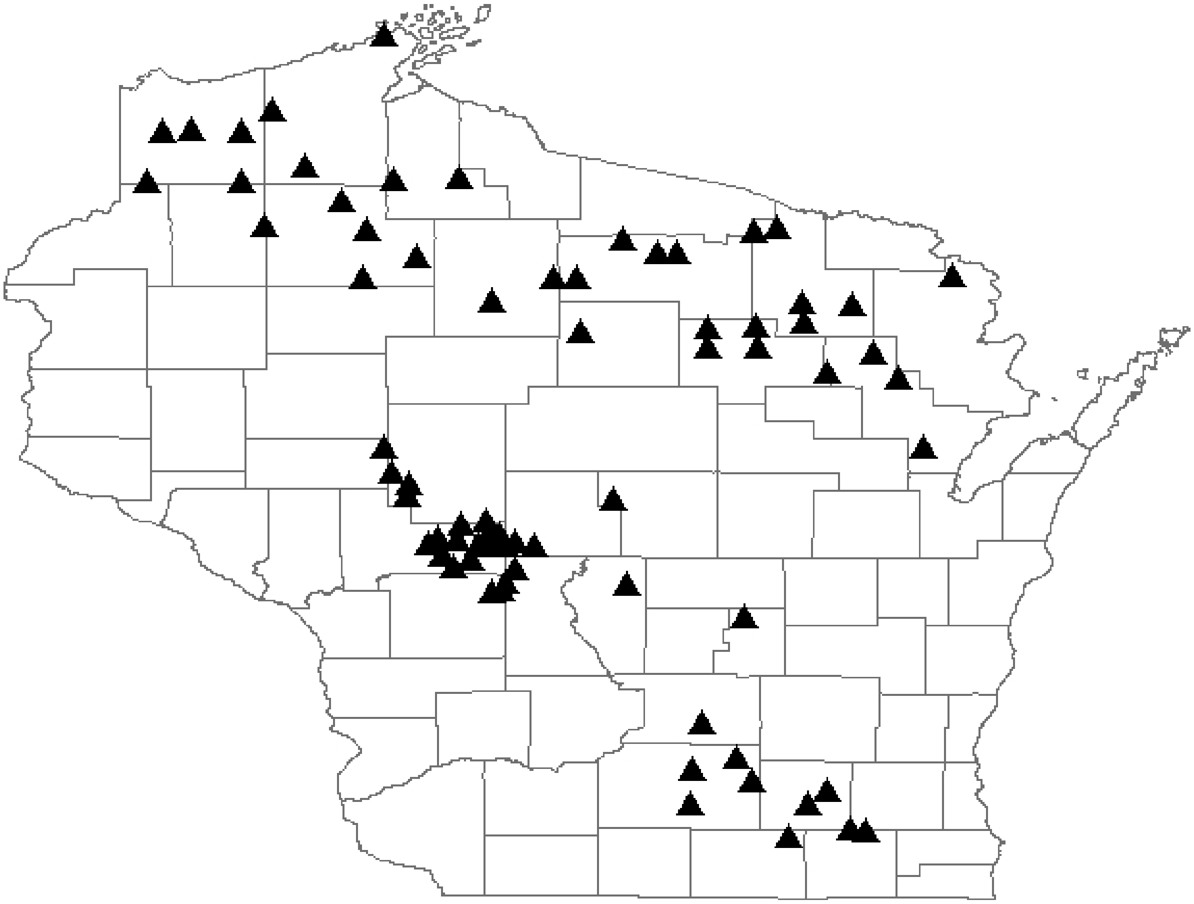


Figure 10. Locations of peatland extensive sites surveyed in 2004 – 2007, Wisconsin.

CONCLUSIONS

Habitat variables explained most variation in bird community structure within peatlands of Wisconsin. Variation in short-distance migrants was largely explained with CCA. A large amount of variation in peatland-associated bird relative abundance was explained. The forest bird dataset and neotropical migrant dataset had less variation explained by CCA. Intensive site dataset showed forest birds positively correlated with percent cover of all trees and basal area. Peatland-associated birds were negatively correlated with visual obscurity, sapling height, and percent cover of broadleaf trees. Neotropical migrants were negatively correlated with snag diameter, percent cover of broadleaf trees, and sapling height.

Results including all extensive sites were similar to those from 2007 alone (see below). Much of the variance of average relative abundance of all bird species at extensive sites was explained by CCA. Short-distance migrants produced the highest explanation of variation for this dataset, as it did in each of the previous runs of datasets. Peatland-associates also produced strong explanatory results (Table 5) and were positively correlated with moss ground cover, percent cover of broadleaf shrubs, and percent cover of broadleaf trees. Resident birds were negatively correlated with percent cover of all shrubs and tree density. The open-shrub birds were positively correlated with percent cover of low shrubs and high herbs.

Moderately strong results were produced when species currently at the edge of their distribution range were analyzed with the data collected at all extensive sites from 2004 to 2007. Blue-winged warblers were positively correlated with peatland area, whereas, mourning warblers were negatively influenced by the percent cover of conifer trees.

Intensive and extensive sites produced similar results when average relative species abundances were modeled. At intensive sites, many of the forest-associated bird species were positively correlated with conifer shrubs and snag diameter. Shrub variables were included in models for open-shrub peatland-associated bird species and resulted in a positive relationship between these variables and open-shrub peatland-associated birds. Models of species average relative abundances from all extensive sites included low shrubs, low herbs, and trees, especially conifers, as important microhabitat components. Visual obscurity and canopy closure influenced some forest-associated birds and forested peatland-associated birds. Many models of species presence contained shrub cover variables. Models for presence of forested peatland-associated birds at all extensive sites generally contained the same variables, but the direction of influence of the variable was different among individual species. Variables representing shrub and tree microhabitat characteristics were commonly included in the models created for 16 species currently at the edge of their distribution range.

Species presence and average relative abundance models ranked using Akaike's Information Criterion (AIC) selected the "overstory, midstory, understory" model as the best-approximating for common yellowthroats at all extensive sites. In 5 of 6 supported models using logistic and linear regression common yellowthroats were negatively associated with the number of snags at a site. Trees, snags, and snag diameter were common variables among selected models from all analyses for Nashville warblers. The best-approximating model for species presence at extensive sites in 2007 was "ground cover and snag diameter" in which this species exhibits a positive association with snag diameter and percent of cover of low herbs. The best model of species presence at intensive sites was "tree density" but it had low explanatory power. Another model receiving support using intensive sites, "trees, shrubs, moss" explained the most variation in the data compared to other supported models. Palm warblers were positively associated with peatland area, snags, and percent cover of moss, while being negatively associated with percent cover of all shrubs.

Review of average relative abundance models created for 42 bird species reveals some differences in variables included in individual species models between intensive and extensive sites. Related variables were sometimes included in individual species habitat models between intensive and extensive sites. Models produced for species at intensive sites generally had higher explanatory power than those produced for species at extensive sites. More variation was observed between intensive and extensive sites for the species presence models, although peatland area was included more often, than for the average relative abundance models. Percent cover of trees and shrubs were commonly included variables in selected presence and average relative abundance models for common yellowthroats at both intensive and extensive sites. The explanatory power was typically higher for selected models for common yellowthroats at intensive sites compared to models selected for extensive sites. Models containing all or mostly tree and shrub variables were selected using AIC for Nashville warblers at both intensive and extensive sites using linear and logistic regression. Similar results were exhibited for analysis of palm warblers at intensive and extensive sites, but ground cover models were selected and appeared to be most explanatory for the extensive sites surveyed in 2007.

In general, little variation was observed between intensive and extensive sites, but models for intensive sites often had stronger explanatory power. Repeated visits to intensive sites may be beneficial for long-term studies of presence and abundance of individual species in peatlands but a single visit to each extensive site was sufficient for purposes of creating habitat models to explain the relationships between birds and microhabitat components.

Appendix A. Complete list of species detected at sites in Wisconsin from 2004 to 2007.

Common Name	AOU Code	Scientific Name	Year			
			2004	2005	2006	2007
Acadian Flycatcher[†]	ACFL	*Empidonax virescens*	0	0	0	1
Alder Flycatcher[*‡]	ALFL	*Empidonax alnorum*	50	54	51	55
American Bittern[†]	AMBI	*Botaurus lentiginosus*	6	3	0	1
American Coot	AMCO	*Fulica americana*	0	1	0	1
American Crow[*]	AMCR	*Corvus brachyrhynchos*	76	105	89	108
American Goldfinch[*]	AMGO	*Carduelis tristis*	63	69	48	67
American Redstart	AMRE	*Setophaga ruticilla*	27	22	2	22
American Robin[*]	AMRO	*Turdus migratorius*	20	48	28	115
American Tree Sparrow	ATSP	*Spizella arborea*	0	0	0	1
American Woodcock[†]	AMWO	*Scolopax minor*	0	2	0	0
Bald Eagle[†]	BAEA	*Haliaeetus leucocephalus*	1	2	0	1
Baltimore Oriole	BAOR	*Icterus galbula*	5	7	0	1
Barn Swallow	BARS	*Hirundo rustica*	0	0	2	2
Black-and-White Warbler	BAWW	*Mniotilta varia*	11	12	11	33
Black-backed Woodpecker[†]	BBWO	*Picoides arcticus*	0	0	1	0
Black-billed Cuckoo[†]	BBCU	*Coccyzus erythropthalmus*	0	3	7	3
Blackburnian Warbler	BLBW	*Dendroica fusca*	0	2	0	1
Black-capped Chickadee[*]	BCCH	*Poecile atricapillus*	63	63	80	117
Blackpoll Warbler	BLPW	*Dendroica striata*	0	2	0	1
Black-throated Blue Warbler[†]	BTBW	*Dendroica caerulescens*	0	0	5	2
Black-throated Green Warbler[*‡]	BTNW	*Dendroica virens*	5	17	16	13

* Species detected at 5% or more of sampling stations; used in analysis.

‡ Species currently near the edge of their distribution range; used in analysis.

† Species of greatest conservation need, as listed on Wisconsin's Wildlife Action Plan.

Appendix A. (continued) Complete list of species detected at sites in Wisconsin from 2004 to 2007.

			Year			
Common Name	**AOU Code**	**Scientific Name**	**2004**	**2005**	**2006**	**2007**
Blue Jay[*]	BLJA	*Cyanocitta cristata*	100	99	80	151
Blue-gray Gnatcatcher[‡]	BGGN	*Polioptila caerulea*	3	6	5	1
Blue-headed Vireo[*‡]	BHVI	*Vireo solitarius*	20	20	15	3
Blue-winged Warbler[*‡†]	BWWA	*Vermicora pinus*	10	21	20	13
Bobolink[†]	BOBO	*Dolichonyx oryzivorus*	0	1	1	0
Boreal Chickadee[†]	BOCH	*Poecile hudsonica*	0	2	0	0
Broad-winged Hawk	BWHA	*Buteo platypterus*	0	4	0	0
Brown Creeper	BRCR	*Certhia americana*	3	2	2	1
Brown Thrasher[†]	BRTH	*Toxostoma rufum*	1	0	0	0
Brown-headed Cowbird[*]	BHCO	*Molothrus ater*	18	14	8	26
Canada Goose	CANG	*Branta canadensis*	5	2	1	13
Canada Warbler[†]	CAWA	*Wilsonia canadensis*	2	2	1	3
Cape May Warbler	CMWA	*Dendroica tigrina*	0	2	2	0
Cedar Waxwing[*]	CEDW	*Bombycilla cedrorum*	14	23	22	17
Cerulean Warbler[†]	CERW	*Dendroica cerulea*	0	3	0	0
Chestnut-sided Warbler	CSWA	*Dendroica pensylvanica*	4	6	8	10
Chimney Swift	CHSW	*Chaetura pelagica*	0	1	0	0
Chipping Sparrow[*]	CHSP	*Spizella passerina*	25	23	30	14
Clay-colored Sparrow	CCSP	*Spizella pallida*	0	0	0	1
Common Goldeneye	COGO	*Bucephala clangula*	0	1	0	0

* Species detected at 5% or more of sampling stations; used in analysis.

‡ Species currently near the edge of their distribution range; used in analysis.

† Species of greatest conservation need, as listed on Wisconsin's Wildlife Action Plan.

Appendix A. (continued) Complete list of species detected at sites in Wisconsin from 2004 to 2007.

			Year			
Common Name	**AOU Code**	**Scientific Name**	**2004**	**2005**	**2006**	**2007**
Common Grackle	COGR	*Quiscalus quiscula*	2	0	9	4
Common Loon	COLO	*Gavia immer*	7	9	9	13
Common Raven*	CORA	*Corvus corax*	18	12	8	12
Common Snipe	COSN	*Gallinago gallinago*	2	2	1	9
Common Yellowthroat*	COYE	*Geothlypis trichas*	210	203	227	319
Connecticut Warbler†	CONW	*Oporornis agilis*	0	1	0	5
Downy Woodpecker	DOWO	*Picoides pubescens*	3	11	7	24
Eastern Bluebird	EABL	*Sialia sialis*	0	1	0	2
Eastern Kingbird	EAKI	*Tyrannus tyrannus*	2	3	7	3
Eastern Phoebe	EAPH	*Sayornis phoebe*	1	1	2	0
Eastern Towhee*	EATO	*Pipilo erythrophtalmus*	4	35	12	7
Eastern Wood-Pewee*	EAWP	*Contopus virens*	18	23	16	13
Field Sparrow†	FISP	*Spizella pusilla*	0	0	0	6
Golden-crowned Kinglet*	GCKI	*Regulus satrapa*	14	23	28	20
Golden-winged warbler*†	GWWA	*Vermivora chrysoptera*	5	18	10	20
Grasshopper Sparrow†	GRSP	*Ammodramus savannarum*	2	2	0	0
Gray Catbird	GRCA	*Dumetella carolinensis*	6	16	17	14
Gray Jay	GRAJ	*Perisoreus canadensis*	0	1	0	7
Great-crested Flycatcher*	GCFL	*Myiarchus crinitus*	20	27	28	22
Hairy Woodpecker	HAWO	*Picoides villosus*	2	7	0	3
Hermit Thrush*‡	HETH	*Catharus guttatus*	63	79	46	80

* Species detected at 5% or more of sampling stations; used in analysis.
‡ Species currently near the edge of their distribution range; used in analysis.
† Species of greatest conservation need, as listed on Wisconsin's Wildlife Action Plan.

Appendix A. (continued) Complete list of species detected at sites in Wisconsin from 2004 to 2007.

Common Name	AOU Code	Scientific Name	Year			
			2004	2005	2006	2007
Hooded Warbler[†]	HOWA	*Wilsonia citrina*	0	1	0	2
House Wren	HOWR	*Troglodytes aedon*	26	4	9	18
Indigo Bunting	INBU	*Passerina cyanea*	7	10	2	9
Killdeer	KILL	*Charadrius vociferus*	0	1	0	1
Le Conte's Sparrow[‡†]	LCSP	*Ammodramus leconteii*	3	13	3	13
Least Flycatcher[†]	LEFL	*Empidonax minimus*	1	7	32	22
Lincoln's Sparrow[*‡]	LISP	*Melospiza lincolnii*	30	57	28	68
Magnolia Warbler	MAWA	*Dendroica magnolia*	0	2	2	4
Mallard	MALL	*Anas platyrhynchos*	1	2	0	6
Marsh Wren	MAWR	*Cistothorus palustris*	1	24	2	12
Mourning Dove[*]	MODO	*Zenaida macroura*	50	56	57	131
Mourning Warbler[‡]	MOWA	*Oporornis philadelphia*	1	2	5	3
N. Rough-winged Swallow	NRWS	*Stelgidopteryx serripennis*	1	0	2	0
Nashville Warbler[*‡]	NAWA	*Vermivora ruficapilla*	190	176	176	246
Northern Cardinal[*]	NOCA	*Cardinalis cardinalis*	21	8	6	38
Northern Harrier[†]	NOHA	*Circus cyaneus*	0	0	3	0
Northern Parula	NOPA	*Parula americana*	5	5	6	2
Northern Waterthrush	NOWA	*Seiurus noveboracensis*	18	14	8	7
Olive-sided Flycatcher[‡†]	OSFL	*Contopus cooperi*	4	2	6	4
Ovenbird[*]	OVEN	*Seiurus aurocapilla*	13	40	26	24
Palm Warbler[*‡]	PAWA	*Dendroica palmarum*	36	26	20	24

* Species detected at 5% or more of sampling stations; used in analysis.
‡ Species currently near the edge of their distribution range; used in analysis.
† Species of greatest conservation need, as listed on Wisconsin's Wildlife Action Plan.

Appendix A. (continued) Complete list of species detected at sites in Wisconsin from 2004 to 2007.

Common Name	AOU Code	Scientific Name	Year 2004	2005	2006	2007
Pied-billed Grebe	PBGR	*Podilymbus podiceps*	0	0	0	2
Pileated Woodpecker	PIWO	*Dryocopus pileatus*	0	5	1	3
Pine Warbler	PIWA	*Dendroica pinus*	1	3	8	3
Purple Finch	PUFI	*Carpodacus purpureus*	8	12	1	5
Red Crossbill[†]	RECR	*Loxia curvirostra*	1	1	0	0
Red-bellied Woodpecker[‡]	RBWO	*Melanerpes carolinus*	2	3	1	4
Red-breasted Nuthatch[*‡]	RBNU	*Sitta canadensis*	20	29	25	31
Red-eyed Vireo[*]	REVI	*Vireo olivaceus*	27	35	15	42
Red-headed Woodpecker[†]	RHWO	*Melanerpes erythrocephalus*	0	2	0	1
Red-necked Grebe[†]	RNGR	*Podiceps grisegena*	0	0	0	1
Red-shouldered Hawk[†]	RSHA	*Buteo lineatus*	1	1	1	0
Red-tailed Hawk	RTHA	*Buteo jamaicensis*	0	0	1	0
Red-winged Blackbird[*]	RWBL	*Agelaius phoeniceus*	83	122	89	128
Ring-necked Pheasant	RNPH	*Phasianus colchicus*	5	0	0	0
Rose-breasted Grosbeak[*]	RBGR	*Pheucticus ludovicianus*	40	36	40	25
Ruby-crowned Kinglet	RCKI	*Regulus calendula*	1	1	0	3
Ruby-throated Hummingbird	RTHU	*Archilochus colubris*	2	2	0	0
Ruffed Grouse	RUGR	*Bonasa umbellus*	10	0	1	11
Rusty Blackbird[†]	RUBL	*Euphagus carolinus*	0	1	0	4
Sandhill Crane[*]	SACR	*Grus canadensis*	30	27	22	41
Savannah Sparrow[*]	SAVS	*Passerculus sandwichensis*	21	22	35	36

* Species detected at 5% or more of sampling stations; used in analysis.
‡ Species currently near the edge of their distribution range; used in analysis.
† Species of greatest conservation need, as listed on Wisconsin's Wildlife Action Plan.

Appendix A. (continued) Complete list of species detected at sites in Wisconsin from 2004 to 2007.

Common Name	**AOU Code**	**Scientific Name**	**Year** **2004**	**2005**	**2006**	**2007**
Scarlet Tanager	SCTA	*Piranga olivacea*	11	10	2	3
Sedge Wren[*]	SEWR	*Cistothorus platensis*	63	74	70	64
Sharp-shinned Hawk	SSHA	*Accipiter striatus*	0	0	2	3
Slate-colored Junco	SCJU	*Junco hyemalis*	0	0	1	0
Song Sparrow[*]	SOSP	*Melospiza melodia*	115	132	99	69
Sora	SORA	*Porzana carolina*	0	1	0	2
Swainson's Thrush[‡]	SWTH	*Catharus ustulatus*	2	12	0	4
Swamp Sparrow[*]	SWSP	*Melospiza georgiana*	59	74	28	60
Tennessee Warbler	TEWA	*Vermivora peregrina*	0	0	0	1
Tree Swallow	TRES	*Tachycineta bicolor*	4	6	0	11
Veery[*‡†]	VEER	*Catharus fuscescens*	40	37	51	59
Warbling Vireo	WAVI	*Vireo gilvus*	1	0	2	3
White-breasted Nuthatch	WBNU	*Sitta carolinensis*	7	10	12	19
White-throated Sparrow[*‡]	WTSP	*Zonotrichia albicollis*	175	146	111	122
Wild Turkey	WITU	*Meleagris gallopavo*	0	3	1	4
Willow Flycatcher[†]	WIFL	*Empidonax traillii*	2	2	3	2
Wilson's Phalarope[†]	WIPH	*Phalaropus tricolor*	0	1	0	2
Winter Wren[*]	WIWR	*Troglodytes troglodytes*	13	33	15	4
Wood Thrush[†]	WOTH	*Hylocichla mustelina*	5	16	21	4
Yellow Warbler[*]	YWAR	*Dendroica petechia*	21	23	20	38
Yellow-bellied Flycatcher[*‡]	YBFL	*Empidonax flaviventris*	23	27	7	24

* Species detected at 5% or more of sampling stations; used in analysis.

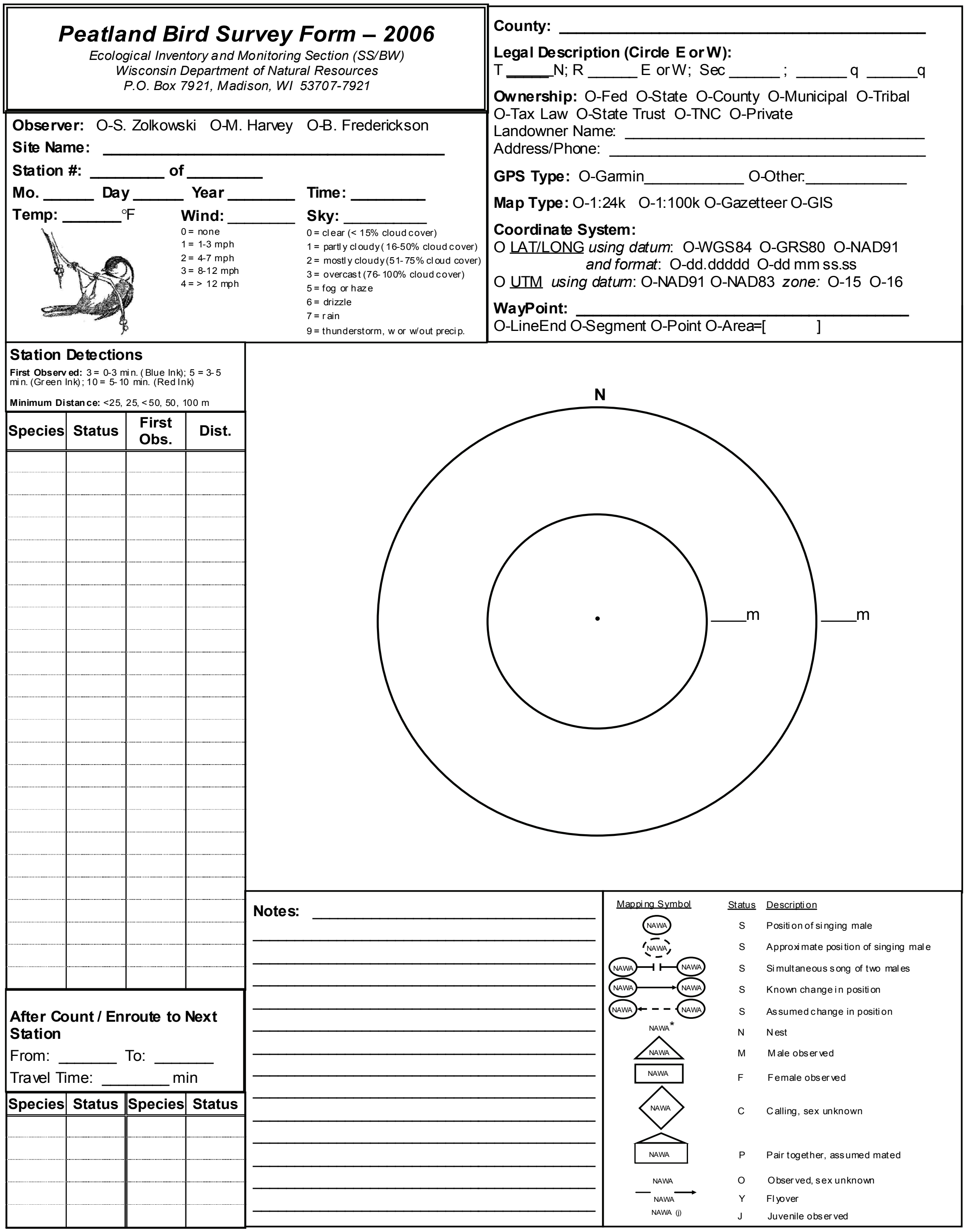
‡ Species currently near the edge of their distribution range; used in analysis.

† Species of greatest conservation need, as listed on Wisconsin’s Wildlife Action Plan.

Appendix A. (continued) Complete list of species detected at sites in Wisconsin from 2004 to 2007.

			Year			
Common Name	**AOU Code**	**Scientific Name**	**2004**	**2005**	**2006**	**2007**
Yellow-bellied Sapsucker	YBSA	*Sphyrapicus varius*	4	6	1	4
Yellow-billed Cuckoo[†]	YBCU	*Coccyzus americanus*	1	1	2	3
Yellow-rumped Warbler[*]	YRWA	*Dendroica coronata*	63	37	20	16
Yellow-shafted Flicker (Northern Flicker)[*]	YSFL	*Colaptes auratus*	14	28	18	18
Yellow-throated Vireo	YTVI	*Vireo flavifrons*	0	1	0	2
Yellow-throated Warbler[†]	YTWA	*Dendroica dominica*	0	0	0	3
GRAND TOTAL			2194	2550	2081	2899

Appendix B. Bird point count survey form.



Peatland Bird Survey Form – 2006

Ecological Inventory and Monitoring Section (SS/BW)
Wisconsin Department of Natural Resources
P.O. Box 7921, Madison, WI 53707-7921

Observer: O-S. Zolkowski O-M. Harvey O-B. Frederickson

Site Name: ______________________________

Station #: ________ **of** ________

Mo. ______ **Day** ______ **Year** ________ **Time:** ________

Temp: _______°F **Wind:** ________ **Sky:** __________

Wind:
0 = none
1 = 1-3 mph
2 = 4-7 mph
3 = 8-12 mph
4 = > 12 mph

Sky:
0 = clear (< 15% cloud cover)
1 = partly cloudy (16-50% cloud cover)
2 = mostly cloudy (51-75% cloud cover)
3 = overcast (76-100% cloud cover)
5 = fog or haze
6 = drizzle
7 = rain
9 = thunderstorm, w or w/out precip.

County: ______________________________

Legal Description (Circle E or W):
T _____N; R ______ E or W; Sec ______ ; ______ q ______q

Ownership: O-Fed O-State O-County O-Municipal O-Tribal O-Tax Law O-State Trust O-TNC O-Private
Landowner Name: ______________________________
Address/Phone: ______________________________

GPS Type: O-Garmin____________ O-Other:____________

Map Type: O-1:24k O-1:100k O-Gazetteer O-GIS

Coordinate System:
O LAT/LONG *using datum*: O-WGS84 O-GRS80 O-NAD91
and format: O-dd.ddddd O-dd mm ss.ss
O UTM *using datum*: O-NAD91 O-NAD83 *zone:* O-15 O-16

WayPoint: ______________________________
O-LineEnd O-Segment O-Point O-Area=[ ]

Station Detections

First Observed: 3 = 0-3 min. (Blue Ink); 5 = 3-5 min. (Green Ink); 10 = 5-10 min. (Red Ink)

Minimum Distance: <25, 25, <50, 50, 100 m

Species	Status	First Obs.	Dist.

N

____m ____m

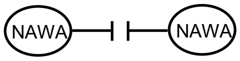
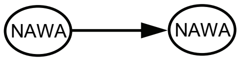
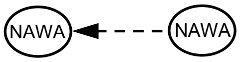
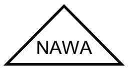
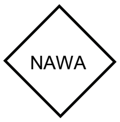
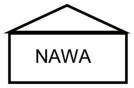
After Count / Enroute to Next Station
From: _______ To: _______
Travel Time: ________ min

Species	Status	Species	Status

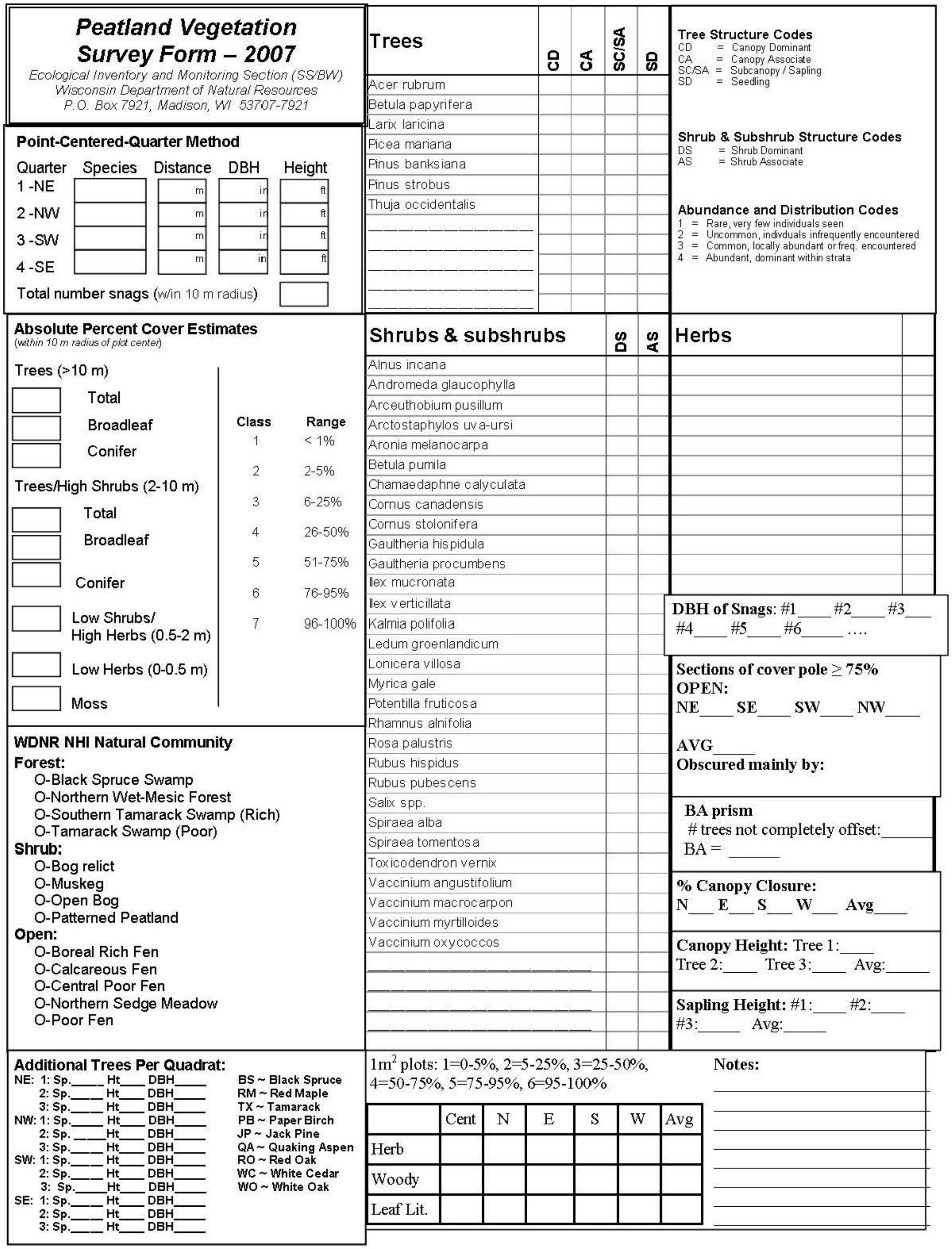
Notes: ______________________________

Mapping Symbol	Status	Description
NAWA	S	Position of singing male
NAWA	S	Approximate position of singing male
NAWA NAWA	S	Simultaneous song of two males
NAWA NAWA	S	Known change in position
NAWA NAWA	S	Assumed change in position
NAWA*	N	Nest
NAWA	M	Male observed
NAWA	F	Female observed
NAWA	C	Calling, sex unknown
NAWA	P	Pair together, assumed mated
NAWA	O	Observed, sex unknown
NAWA	Y	Flyover
NAWA (j)	J	Juvenile observed

Appendix C. Mapping symbols and status codes used for recording bird species, sex, activity, and location on point-count survey forms.

Status	Symbol	Description
S		Position of singing male
S		Approximate position of singing male
S		Simultaneous song of two males
S		Known change in position
S		Assumed change in position
N	NAWA *	Nest
M		Male observed
F		Female observed
C		Calling, sex unknown
P		Pair together, assumed mated
O	NAWA	Observed, sex unknown
Y	—— NAWA ——►	Flyover
J	NAWA (j)	Juvenile

Appendix D. Vegetation survey form.



Peatland Vegetation Survey Form – 2007

Ecological Inventory and Monitoring Section (SS/BW)
Wisconsin Department of Natural Resources
P.O. Box 7921, Madison, WI 53707-7921

Point-Centered-Quarter Method

Quarter	Species	Distance	DBH	Height
1 -NE		m	in	ft
2 -NW		m	in	ft
3 -SW		m	in	ft
4 -SE		m	in	ft

Total number snags (w/in 10 m radius) ☐

Absolute Percent Cover Estimates
(within 10 m radius of plot center)

Trees (>10 m)
☐ Total
☐ Broadleaf
☐ Conifer

Trees/High Shrubs (2-10 m)
☐ Total
☐ Broadleaf
☐ Conifer

☐ Low Shrubs/ High Herbs (0.5-2 m)

☐ Low Herbs (0-0.5 m)

☐ Moss

Class	Range
1	< 1%
2	2-5%
3	6-25%
4	26-50%
5	51-75%
6	76-95%
7	96-100%

WDNR NHI Natural Community
Forest:
O-Black Spruce Swamp
O-Northern Wet-Mesic Forest
O-Southern Tamarack Swamp (Rich)
O-Tamarack Swamp (Poor)
Shrub:
O-Bog relict
O-Muskeg
O-Open Bog
O-Patterned Peatland
Open:
O-Boreal Rich Fen
O-Calcareous Fen
O-Central Poor Fen
O-Northern Sedge Meadow
O-Poor Fen

Additional Trees Per Quadrat:
NE: 1: Sp.____ Ht___ DBH____
2: Sp.____ Ht___ DBH____
3: Sp.____ Ht___ DBH____
NW: 1: Sp.____ Ht___ DBH____
2: Sp. ____Ht___ DBH____
3: Sp.____ Ht___ DBH____
SW: 1: Sp.____ Ht___ DBH____
2: Sp.____ Ht___ DBH____
3: Sp.____Ht___ DBH____
SE: 1: Sp.____ Ht___ DBH____
2: Sp.____ Ht___ DBH____
3: Sp.____ Ht___ DBH____

BS ~ Black Spruce
RM ~ Red Maple
TX ~ Tamarack
PB ~ Paper Birch
JP ~ Jack Pine
QA ~ Quaking Aspen
RO ~ Red Oak
WC ~ White Cedar
WO ~ White Oak

Trees	CD	CA	SC/SA	SD
Acer rubrum				
Betula papyrifera				
Larix laricina				
Picea mariana				
Pinus banksiana				
Pinus strobus				
Thuja occidentalis				
________________				
________________				
________________				
________________				
________________				

Tree Structure Codes
CD = Canopy Dominant
CA = Canopy Associate
SC/SA = Subcanopy / Sapling
SD = Seedling

Shrub & Subshrub Structure Codes
DS = Shrub Dominant
AS = Shrub Associate

Abundance and Distribution Codes
1 = Rare, very few individuals seen
2 = Uncommon, indivduals infrequently encountered
3 = Common, locally abundant or freq. encountered
4 = Abundant, dominant within strata

Shrubs & subshrubs	DS	AS
Alnus incana		
Andromeda glaucophylla		
Arceuthobium pusillum		
Arctostaphylos uva-ursi		
Aronia melanocarpa		
Betula pumila		
Chamaedaphne calyculata		
Cornus canadensis		
Cornus stolonifera		
Gaultheria hispidula		
Gaultheria procumbens		
Ilex mucronata		
Ilex verticillata		
Kalmia polifolia		
Ledum groenlandicum		
Lonicera villosa		
Myrica gale		
Potentilla fruticosa		
Rhamnus alnifolia		
Rosa palustris		
Rubus hispidus		
Rubus pubescens		
Salix spp.		
Spiraea alba		
Spiraea tomentosa		
Toxicodendron vernix		
Vaccinium angustifolium		
Vaccinium macrocarpon		
Vaccinium myrtilloides		
Vaccinium oxycoccos		
____________________		
____________________		
____________________		
____________________		

Herbs	

DBH of Snags: #1____ #2____ #3___ #4____ #5____ #6_____ ….

Sections of cover pole ≥ 75% OPEN:
NE____ SE____ SW____ NW____

AVG_____
Obscured mainly by:

BA prism
# trees not completely offset:______
BA = ______

% Canopy Closure:
N___ E___ S___ W___ Avg____

Canopy Height: Tree 1:____
Tree 2:____ Tree 3:____ Avg:_____

Sapling Height: #1:____ #2:____
#3:_____ Avg:_____

1m^2 plots: 1=0-5%, 2=5-25%, 3=25-50%, 4=50-75%, 5=75-95%, 6=95-100%

	Cent	N	E	S	W	Avg
Herb						
Woody						
Leaf Lit.						

Notes:

Appendix E. Site descriptions and locations of study sites 2004 – 2007.

Intensive Sites

Bear Lake Sedge Meadow

State Natural Area (No. 323)
Location: Barron County. T36N-R12W, Sections 11, 12, 14. N 45.61134 W 991.80800. 167 acres.

Bear Lake Sedge Meadow occupies a large embayment on the southern shore of Bear Lake, a hard water drainage lake. The sedge meadow is quite open, with scattered islands of bog birch, alder, black spruce and tamarack close to the lake. Much of the meadow is dominated primarily by woolly fruit sedge intermixed with three-fruited sedge, marsh cinquefoil, cotton-grass, and blue-joint grass. The wetland has a distinctly bog-like character, with sphagnum moss, round-leaved sundew, pitcher plant, , rose pogonia, northern bog goldenrod, and the rare dragon's-mouth orchid (*Arethusa bulbosa*). Several species of bog shrubs including leather-leaf, bog-laurel, bog-rosemary, and Labrador-tea are scattered throughout. A small northern wet forest of tamarack and black spruce borders the lake and a fringe of alder-willow thicket lies along the remainder of the shoreline. Bear Lake Sedge Meadow is owned by Barron County and the Village of Haugen and was designated a State Natural Area in 1997.

Belden Swamp

State Natural Area (No. 317)
Location: Douglas County. T45N-R14W, Sections 18, 19, 30. T45N-R15W, Sections 13, 23, 24, 25, 26. N 46.36231 W 92.16742. 1,862 acres.

Belden Swamp is a huge wetland straddling the divide between two major watersheds. It forms the headwaters of the Spruce River, which flows south into the Mississippi River watershed; and the Black River, which flows north into the Lake Superior drainage basin. The wetland complex contains the largest remaining undisturbed open bog in Wisconsin, along with an extensive muskeg, northern wet forest and a zone of shrubby, emergent aquatic vegetation surrounding the wetland. The thinly timbered muskeg contains stunted black spruce and tamarack with ericaceous shrubs, and sedges over a carpet of Sphagnum moss. Other parts of the site are quite open with abundant wire-leaved sedges and a low growth of bog birch and ericads, including bog laurel and bog rosemary. A dense conifer swamp of black spruce and tamarack, recovering from long-ago logging, is found in the northeast corner of the site. Belden Swamp is owned by Douglas County and was designated a State Natural Area in 1997.

Bibon Swamp State Natural Area

State Natural Area (No. 275) Location: Bayfield County. T45N-R6W, Sections 1-18; T46N-R6W, Sections 29-35. N 46.42885 W 91.15604. 8,827 acres.

Bibon Swamp, the largest wetland in Bayfield County, occupies the basin of an extinct glacial lake drained by the White River, a hard, cold water trout stream. The community types of this 15-square mile lowland are unusually varied for such a topographically uniform basin. Portions are forested with a rich wet-mesic conifer swamp of medium-sized white cedar, although trunk coring revealed that at least parts of the stand are in excess of 150 years old. Bunchberry, twinflower, small bishop's-cap and a number of orchid species are representative of the groundlayer here. Bordering the cedar swamp is wet forest dominated by black ash, with a groundlayer of speckled alder, sensitive fern, wood nettle and poison ivy. North of the river conditions are very different, with a large complex of peatland communities including open bog, spruce-tamarack muskeg, and black spruce swamp. Deep sphagnum hummocks form a continuous ground cover upon which ericaceous shrubs grow including leather-leaf, bog laurel, and Labrador-tea. Vast shrub swamps composed of slender willow, red-osier dogwood, and speckled alder, blanket portions of the wetland. Other communities of lesser areal extent include northern sedge meadow composed of Carex species and blue-joint grass, and patches of riparian woodlands, dominated by American elm, green ash, and red maple, along the White River. The area supports a variety of rare plants and animals, including three state-threatened species: wood turtle, sheathed pondweed

(*Potamogeton vaginatus*), and sweet colt's-foot (*Petasites sagittatus*). Bibon Swamp is owned by the DNR and was designated a State Natural Area in 1992.

Big Bay Sand Spit And Bog

State Natural Area (No. 156)

Location: Within Big Bay State Park, Madeline Island, Ashland County. T50N-R3W, Section13. N 46.80505 W 90.70881. 402 acres.

Big Bay Sand Spit and Bog is located on an island in Lake Superior and features a long, curving baymouth bar behind which lies a lagoon, an extensive quaking sphagnum-sedge bog, and older sand ridges. The youngest bar is marked by four zones: 1) wet sand beach less than 20 feet wide; 2) dry beach stabilized by several species of beach grasses; 3) rear beach or heath zone sloping away from the beach sand, sparsely wooded with red and white pines in barrens-like openings covered with lichens, bearberry, low juniper, false heather, blueberry, and huckleberry; and 4) tall shrub zone bordering the lagoon edge of the sand spit. Total beach acreage is 34 acres. Vegetation west of the sand spit consists of submerged aquatics in the shallow water and bog shrubs on the many small islands as it grades into sphagnum-sedge bog. The floating bog contains one of the richest bog floras in the Lake Superior region. Just east of the old ridge is a conifer swamp of white cedar, black and white spruces, and tamarack. The old ridge is second-growth timber. Two state-threatened plant species are found on the site: linear-leaved sundew (*Drosera linearis*) and coast sedge (*Carex exilis*). An extensive "cordwalk" allows visitors to traverse the baymouth bar without disturbing the sensitive vegetation. Big Bay Sand Spit and Bog is owned by the DNR and was designated a State Natural Area in 1980.

Cedarburg Bog State Natural Area

State Natural Area (No. 2)

Location: Ozaukee County. T11N-R21E, Sections 20, 21, 28-33. N 43.38506 W 88.01781. 1600 acres.

Cedarburg Bog is the most intact large bog in southeastern Wisconsin and composed of a mosaic of vegetation types. Once part of a large glacial lake, the bog is a relict community - a southern example of the type more commonly found in northern Wisconsin. There are six lakes remaining within the bog, all with varying sizes and depths. The 245-acre Mud Lake is the largest, followed by the 34-acre Long Lake. Surrounding the lakes are areas of emergent aquatic vegetation while just outside this zone is a successional shrub-carr area. Most unusual is a string or "patterned" bog, unique here because it lies far south of its usual range in North America. It is composed of ridges of stunted cedar and tamarack that lie in an open flat sedge mat. The meadow vegetation consists of narrow-leaved sedges, pitcher plant, bogbean, water horsetail, arrow-grass, orchids, and the insectivorous sundew and bladderwort. A conifer-swamp hardwood forest is adjacent to the bog. There is a very diverse flora and fauna; many that are more common in northern boreal forests and that are at their southern range limit here. Cedarburg Bog is owned by the DNR and University of Wisconsin and was designated a State Natural Area in 1952.

Dry Lake

State Natural Area (No. 424)

Location: Within the Chequamegon-Nicolet National Forest, Ashland County. T43N-R2W, Sections 1, 2, 11, 12. N 46.22102 W 90.58079. 358 acres.

Dry Lake features intact, older second-growth upland hemlock-hardwoods surrounded by a fringe of hemlock and cedar forest. Locally (within Morse Township) as well as regionally, this forest type historically dominated the landscape and today is nearly gone in its original form. Also present is an extensive open wiregrass poor fen and tussock sedge meadow surrounding a spring-fed bog lake, northern wet forest, and a rocky-bottomed, shaded stream stretch that is a tributary to the Bad River. Although lightly managed about 20 years ago, the uplands are now approaching an old growth state and the forest supports other old growth attributes including snags, coarse woody debris, along with ephemeral ponds and intact gradient from upland to lowland. Sugar maple, yellow birch, and hemlock dominate the uplands with a sparse midstory and shrub layer. A few widely scattered super canopy white pine and white spruce are present. Canopy associates include balsam fir, red maple, white cedar, and ironwood. The ground flora is typical of ATO habitat type with wood fern, lady fern, and species of the lily family. A nice gradient exists from the uplands down to the open sedge meadow. Common understory plants include leather-leaf, tussock sedge, bladderwort, cat-tail, wild calla, crested shield fern, small cranberry, mountain holly, marsh bellflower, marsh cinquefoil. Rare species include Robbins spikerush (*Eleocharis robbinsii*) and dragon's-mouth orchid (*Arethusa bulbosa*). Surrounding Dry Lake are open wetlands that represent the best examples of poor fen and sedge meadow on the Valhalla/Marenisco Moraines Landtype on the Forest and provide excellent habitat for unique flora and fauna. Plants characteristic to poor fens, bogs and marshes are present including tamarack, sphagnum, leatherleaf, tussock sedge, willow, and cat-tails. The north side of the lake is characterized by tussock sedge and blue-joint grass meadow. The wetlands on the south side of the lake represent a unique poor fen community with boreal bog sedge, creeping sedge, white beak-rush, and cotton-grasses. The conifer swamp is patchy with alder and mixed northern white cedar, hemlock, and black ash. Ground flora includes dewberry, three-leaved goldthread, mountain wood sorrel, and ferns. Dry Lake is owned by the US Forest Service and was designated a State Natural Area in 2007.

Hortonville Bog State Natural Area

State Natural Area (No. 214)

Location: Outagamie County. T22N-R15E, Sections 3, 9, 10. N 44.39522 W 88.66013. 640 acres.

Hortonville Bog is one of the best bogs in southern Wisconsin and contains an open ericaceous bog with a very deep sphagnum layer. Dominants are leather-leaf and Labrador-tea. Although there is no open water, the bog is very spongy. Surrounding the bog is an advancing ring of tamarack and black spruce in all age and size classes. To the south is a wet-mesic forest dominated by tamarack and white cedar. Hortonville Bog is owned by the DNR and was designated a State Natural Area in 1987.

Kidrick Swamp State Natural Area

State Natural Area (No. 464)

Location: Within the Chequamegon-Nicolet National Forest. Taylor County. T33N-R2W, Sections 19, 20, 21, 26, 27, 28, 31, 32. N 45.31923 W 90.62629. 1,957 acres.

Kidrick Swamp is a large, hydrologically intact peatland complex of black spruce and tamarack bog and black spruce muskeg situated within a matrix of extensive upland hardwood forest. Numerous ericaceous understory shrubs are present including velvet-leaf blueberry, small cranberry, Labrador-tea, leather-leaf, creeping snowberry, and bog-laurel. Sedges include few-seeded (*Carex oligosperma*), boreal bog (*C. magellanica*), few-flowered (*C. pauciflora*), and three-seeded (*C. trisperma*). Tawny cotton-grass, tussock cotton-grass, and moccasin flower are also present. “Moated” areas along the swamp edges have cinnamon fern, false mayflower, and crested shield fern. On the nearly level, somewhat poorly drained ground moraine and surrounding upland islands are rich mesic hardwoods dominated by sugar maple, basswood, white ash, black ash, and red oak. A sparse, poorly developed shrubs layer is occupied primarily by alternate-leaved dogwood. White ash and maple seedlings are moderately dense. The stand is even-aged but large diameter white ash, black ash, and red oak are present in some numbers. The ground flora contains most of the rich site indicator species including wood anemone, dwarf ginseng, wild leek, bishop’s cap, wild geranium, blue cohosh, and bloodroot. Many neotropical migratory birds breed here including the yellow-bellied flycatcher and golden-winged warbler. Other species include wood duck, alder flycatcher, sedge wren, veery, hermit thrush, mourning warbler, Nashville warbler, ovenbird, rose-breasted grosbeak, and white-throated sparrow. Kidrick Swamp is owned by the US Forest Service and was designated a State Natural Area in 2007.

Lower Chippewa River State Natural Area

State Natural Area (No. 342)

Location: Buffalo, Dunn, and Pepin Counties. T24N-R12W, Sections 1, 2. T25N-R13W, Sections 7, 30, 31. T26N-R11W, Sections 1, 2, 5, 11. T26N-R13W, Sections 11, 14. N 44.58717 W 91.77347. 1,605 acres.

The Lower Chippewa River State Natural Area features the largest concentration of remaining prairies and savannas in the state. At the time of European settlement Wisconsin had over 7.7 million acres of native prairie but today only about 8,000 acres remain. This extensive project contains over 2,000 acres of prairie, which equals 25% of all known remaining prairie in the entire state. Lying along and interspersed within the river channels are islands of floodplain savanna and forest while the surrounding hillsides contain prairie and savanna. The largest contiguous floodplain forest in the Midwest is located just south of Durand within this natural area. Lower Chippewa River State Natural Area is owned by the DNR and was designated a State Natural Area in 2002.

Mead Conifer Bogs

State Natural Area (No. 373)

Location: Within George Mead Wildlife Area. Wood, Portage, and Marathon Counties. East Unit: T25N-R6E, Sections 5, 6, 7. T26N-R6E, Sections 31, 32. West Unit: T25N-R5E, Sections 2, 3, 10. N 44.68176 W 89.88260. 932 acres.

Mead Conifer Bogs are extensive areas containing northern wet forest dominated by black spruce and tamarack. Both species are reproducing well. The center of the tract is dominated by black spruce, which is gradually replaced by larger tamaracks at the perimeter. The groundcover is a firm carpet of sphagnum moss dominated by leather-leaf and cotton-grass. Poison sumac is abundant. Other species include bog birch, bog-rosemary, Labrador-tea, blueberry, bogbean, yellow blue-bead-lily, bogbean, pitcher plant, bunchberry, Canada mayflower, and royal, cinnamon, and interrupted fern. Alder-dogwood shrub-carr dominates on the eastern edge near the uplands. Mead Conifer Bogs is owned by the DNR and was designated a State Natural Area in 2002.

Miscauno Cedar Swamp State Natural Area

State Natural Area (No. 92)

Location: Within the Miscauno Wildlife Area, Marinette County. T36N-R20E, Sections 13, 14, 23, 24. N 45.58503 W 87.95910. 555 acres.

Miscauno Cedar Swamp features a northern wet-mesic forest in a steep-sided basin along the South Branch of Miscauno Creek. The timber varies from nearly pure stands of pole-sized white cedar to mixtures of white cedar, balsam fir, and black spruce with black ash and elm along the stream. Tamarack snags indicate a former forest of this species and which was undoubtedly logged in the past. The surrounding uplands are mainly an aspen-oak and pine cutover forest. The groundlayer is rich in smaller orchid species along with one-flowered pyrola, bunchberry, American starflower, yellow blue-bead-lily, gaywings, Canada mayflower, and several ferns. In the numerous headwater springs is a rich flora of mosses and lichens. Breeding bird surveys have shown that such uncommon birds such as ravens, hermit thrush, black and white warbler, pine warbler, scarlet tanager, and black-billed cuckoo are found during the nesting season. Although the lowlands have been logged they still retain natural conditions. The swamp was also the site of a 20-year research study looking at the effects of cedar thinning. Miscauno Cedar Swamp is owned by the DNR and was designated in 1971.

Pigeon Creek Swamp

Location: Barron County. T36N-R10W, Sections 12-13. N 45.61006 W 91.55421. 40 acres.

Pigeon Creek Swamp is wetland area in northeastern Barron County on the east side of Red Cedar Lake. Tamarack and black spruce are the primary tree species found within the swamp. Other vegetation commonly includes leatherleaf, Labrador-tea, Canada mayflower, blueberry, cotton grass, sedges, bog laurel, cranberry, spiraea, and alders.

Quincy Bluffs and Wetlands
State Natural Area (No. 272)
Location: Adams County. T16N-R5E, Sections 1-4, 10-15, 22, 23, 24, 26, 27. T16N-R6E, Sections 7, 18. T17N-R5E, Sections 25, 26, 27, 34, 35, 36. N 43.88652 W 89.88054. 5,102 acres.

Quincy Bluff and Wetlands is a large, landscape-scale natural area featuring a mosaic of communities including northern wet and wet-mesic forest, northern and southern sedge meadow, shrub-carr, pine barrens, and sand prairie. This unique area is located in the Central Sand Plain ecoregion of Wisconsin, the bed of extinct Glacial Lake Wisconsin and features a vast wetland complex with low sandy ridges, wetlands, and seepage ponds situated between sandstone mesas and buttes that rise 100-200 feet. Quincy Bluff, which rises 200 feet high and extends for approximately two miles, contains northern dry forest and open cliff communities. Lone Rock, an excellent example of a Driftless Area mesa, features one hundred-foot Cambrian sandstone cliffs. The uplands are forested with jack pine and Hill's oak with a shrub layer dominated by huckleberry, American hazelnut, and early low blueberry. Pennsylvania sedge is the dominant herb with wild lupine and spreading dogbane common constituents of the understory. Grasses and forbs characteristic of barrens and sandy prairies are found here including big blue-stem, June grass, needle grass, poverty grass, goat's-rue, prairie coreopsis, and rough blazing-star. Due to its large size and heterogeneous landscape, Quincy Bluff and Wetlands contains essential habitat for a great diversity of species. Quincy Bluff is owned by the DNR and The Nature Conservancy and was designated a State Natural Area in 1993.

Appendix E. (continued) Site descriptions and locations of study sites 2004 – 2007.

Swanson Lake

Location: Oneida Coutny. T39N-R8E, Section 34. T38N-R8E, Section 3.
N 45.81584 W 89.48817. 211 acres.

Swanson Lake is located in the Northern Highland American Legion State Forest in northeastern Oneida County. Tamarack and black spruce are the primary tree species found at this wetland. Other vegetation species include cranberry, sedges, cotton grass, Labrador-tea, bog laurel, blueberry, and dragon mouth orchid.

Extensive Sites

Site	Northing	Easting	Year Surveyed	Area (ha)
212-002	N45.17482	W88.28374	2004	31
212-007	N46.07679	W91.15181	2004	59
212-008	N46.17818	W91.66518	2004	23
212-014	N45.43151	W89.2674	2004	58
212-022	N45.55926	W88.78719	2007	81
212-024	N45.2952	W88.41117	2007	48
212-026	N45.32601	W89.27367	2007	455
212-032	N45.88797	W89.7028	2004	479
212-035	N45.45736	W88.77066	2004	28
212-056	N46.20325	W90.54407	2004	66
212-070	N45.81557	W89.42165	2004	68
212-074	N46.43474	W92.03815	2007	607
212-077	N45.68971	W90.06261	2004	181
212-098	N46.54401	W91.50272	2004	93
212-104	N45.69226	W88.01205	2004	34
212-106	N45.56235	W90.3794	2004	73
212-108	N45.81388	W89.52925	2004	62
212-109	N45.5508	W88.52034	2007	49
212-115	N45.67268	W89.91644	2007	81
212-124	N44.81767	W88.1556	2004	20
212-199	N45.20156	W88.65405	2004	40
212-207	N46.93202	W90.93406	2007	36
212-255	N45.94979	W91.53401	2007	22
212-259	N46.18696	W90.87171	2007	94
212-271	N45.94525	W88.90666	2007	125
212-272	N45.40606	W89.92134	2007	336

Appendix E. (continued) Site descriptions and locations of study sites 2004 – 2007.

Site	Northing	Easting	Year Surveyed	Area (ha)
212-279	N45.79151	W90.75843	2007	32
212-329	N45.43841	W89.02111	2006	127
212-339	N45.92223	W89.03461	2007	77
212-342	N46.44246	W91.91026	2007	21
212-366	N46.26667	W91.33808	2007	68
212-367	N45.32892	W89.0129	2007	36
212-376	N45.54664	W89.80996	2007	192
212-446	N46.44767	W91.63988	2007	83
212-490	N45.93691	W91.01766	2007	25
212-494	N45.68062	W91.03964	2007	29
212-507	N46.17139	W92.14533	2007	36
222-063	N44.30666	W90.39546	2007	287
222-075	N43.05803	W88.65031	2004	44
222-115	N43.40126	W89.29884	2006	45
222-135	N44.81013	W90.93664	2007	28
222-139	N44.30588	W90.30708	2006	79
222-155	N44.41786	W90.53519	2007	144
222-157	N44.3419	W90.55672	2006	324
222-307	N44.06527	W90.37686	2007	44
222-316	N44.30938	W90.16144	2007	182
222-342	N44.68305	W90.88623	2007	232
222-369	N44.57587	W90.80445	2007	68
222-374	N44.19248	W90.2532	2007	99
222-407	N44.44294	W90.4088	2007	77
222-419	N43.94568	W89.07277	2007	479
222-433	N44.32195	W90.66138	2007	30
222-436	N44.2063	W90.57627	2004	202
222-438	N43.22378	W89.11395	2006	416
222-439	N44.54563	W89.7485	2006	161
222-487	N44.26302	W90.63736	2007	151
222-505	N43.16193	W89.34201	2007	64
222-509	N44.3708	W90.33559	2007	16
222-510	N44.33245	W90.27649	2007	133
222-515	N44.10966	W89.67855	2006	138
222-519	N42.8418	W88.45621	2007	166
222-520	N42.8191	W88.83504	2007	75
222-525	N44.3378	W90.65231	2007	98
222-526	N44.32108	W90.69982	2007	63
222-527	N44.24353	W90.48632	2007	114
222-531	N44.0797	W90.32958	2007	106

Appendix E. (continued) Site descriptions and locations of study sites 2004 – 2007.

Site	**Northing**	**Easting**	**Year Surveyed**	**Area (ha)**
222-534	N44.12725	W90.30097	2007	137.598
222-537	N42.99358	W88.75666	2007	368.277
222-538	N44.24488	W90.48859	2007	140.4309
222-547	N44.39316	W90.38161	2007	231.0837
222-553	N42.85656	W88.53624	2007	27.1149
222-563	N42.98435	W89.35751	2007	127.4805
222-569	N44.32533	W90.44341	2007	109.6737
222-582	N43.09707	W89.03214	2007	108.0549