EFFECTS OF GROWING-SEASON PRESCRIBED FIRE ON EASTERN WILD TURKEY (*MELEAGRIS GALLOPAVO SILVESTRIS*) NEST SUCCESS AND POULT SURVIVAL IN SOUTHWESTERN GEORGIA

by

MARY MARGARET WILLIAMS

(Under the Direction of Robert J. Warren and Michael J. Chamberlain)

ABSTRACT

Growing-season prescribed fire effects on nest success, nest survival, poult survival, and nest and ground-roost site selection of eastern wild turkeys (*Meleagris gallopavo silvestris*) were investigated on 2 southwestern Georgia sites of predominantly pine and pine-hardwood forests—the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area. Of 52 nests 11.5% were lost to fire, and nest survival rates indicated those nests would have likely been successful otherwise. However, 75% of affected females renested, thus mitigating negative fire effects. Fire had a minimal impact (4%) on poult survival. Nests had less canopy cover and greater woody ground cover and minimum vegetation height, and ground-roosts were located farther from mature pine stands than random sites. Rotating, small-scale, growing-season fires should promote habitat improvement while offsetting nest losses. Maintaining open areas within and around Southeastern U.S. pine and pine-hardwood forests should enhance understory growth for nest and ground-roost cover.

INDEX WORDS: eastern wild turkey, *Meleagris gallopavo silvestris*, Mayfield daily nest survival, nest success, poult survival, nest site selection, ground-roost site selection, growing-season prescribed fire

EFFECTS OF GROWING-SEASON PRESCRIBED FIRE ON EASTERN WILD TURKEY (*MELEAGRIS GALLOPAVO SILVESTRIS*) NEST SUCCESS AND POULT SURVIVAL IN SOUTHWESTERN GEORGIA

by

MARY MARAGARET WILLIAMS

BS, University of Georgia, 2010

A Thesis Submitted to the Graduate Faculty of The University of Georgia in Partial Fulfillment of the Requirements for the Degree

MASTER OF SCIENCE

ATHENS, GEORGIA

2012

EFFECTS OF GROWING-SEASON PRESCRIBED FIRE ON EASTERN WILD TURKEY (*MELEAGRIS GALLOPAVO SILVESTRIS*) NEST SUCCESS AND POULT SURVIVAL IN SOUTHWESTERN GEORGIA

by

MARY MARGARET WILLIAMS

Major Professors:	Robert J. Warren
	Michael J. Chamberlain
Committee:	L. Mike Conner
	Steven B. Castleberry

Electronic Version Approved:

Maureen Grasso
Dean of the Graduate School
The University of Georgia
December 2012

DEDICATION

I would like to dedicate this thesis to my fiancé, Matt, and my parents, Robert and Traci. Thank you for all of your loving support and patience throughout the pursuit of my M.S. Degree—I could not have done this without you all.

ACKNOWLEDGEMENTS

First, I would like to thank my major advisors, Drs. Robert Warren and Michael Chamberlain, and thesis committee members, Drs. Mike Conner and Steven Castleberry, for all of their mentoring and support throughout the pursuit of my M.S. Degree.

I thank the Joseph W. Jones Ecological Research Center, the Georgia Department of Natural Resource's Wildlife Resource Division, the University of Georgia's Warnell School of Forestry and Natural Resources, and the Georgia Chapter of the National Wild Turkey Federation for providing financial support for this research. Data collection and turkey trapping could not have been done without the assistance and drive of the following "turkey crew" graduate students: Derek Colbert, Andy Little, Christina Perez, and Drew Ruttinger. Also assisting in data collection and turkey trapping were the following (in no particular order): Adam White, Nick Deuel, Will McGuire, Jess McGuire, Chaz Oliver, Melinda Nelson, Mike Cherry, John Denton, Jessica Rutledge, and Gail Morris. Thank you all for making this possible! I also thank the entire staff of the Jones Center for all of your support from turkey trapping, to putting out small fires, to ArcGIS assistance and finding obscure un-published information. Being a part of the Jones Center community has afforded me a unique opportunity to observe all aspects of natural resource management and conservation, and I will surely carry the basic tenets of stewardship throughout my career.

TABLE OF CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Prescribed burning can improve habitat for the eastern wild turkey (*Meleagris gallopavo silvestris*, hereafter, wild turkey) and other ground-foraging game birds (Palmer et al. 1996), and is an important management tool in the southeastern U.S. coastal plain (Stoddard 1963). Traditional prescribed fires are conducted during the winter (February-March); however, growing-season prescribed fires (April-May) are becoming increasingly popular for meeting ecological and forest management goals (Sisson and Speake 1994). Growing-season prescribed fires reduce hardwood encroachment, and enhance flowering and fruiting of native groundcover species without reducing survival and growth of pines within the longleaf pine (*Pinus palustris*) ecosystem (Streng et al. 1993). Growing-season prescribed fires have the potential to negatively impact wild turkey nest success, especially if burning occurs frequently, at large spatial scales, and/or during the peak of wild turkey nesting season (Sisson and Speak 1994, L.M. Conner, personal communication, 21 June 2010). It has even been recommended that fire be withheld from the landscape after 1 April because of potential damage to wild turkey nests (Stoddard 1935, 1946). Land managers and hunters interested in ground-nesting birds have expressed concern over use of growing-season fires, but little research has been conducted on the long-term population-level response of wild turkeys to growing-season fire (Robbins and Myers 1992). This concern towards growing-season fires has been accentuated by the decline in hunter harvest rates for wild turkeys observed during the past 5-10 years in several states across the Southeast, including Georgia (Kevin Lowrey, unpublished data), Alabama (Steve Barnett, unpublished data), and South Carolina (Charles Ruth, unpublished data).

Wild Turkey Life History

The wild turkey (*M. gallopavo*) is a non-migratory game bird indigenous to North America with a historical range that includes the lower 48 United States, southeastern Canada, and northern Mexico (Mock et al. 2002). The eastern wild turkey (*M. g. silvestris*) is found throughout the eastern half of the United States, including the Cumberland and Appalachian plateaus, Ozarks, and Gulf States (Eaton 1992). Wild turkeys are an important recreational resource within their range (Tapley et al. 2001). The species uses a wide range of habitats in the Southeast, including older aged forests (Porter 1992), large timberlands having little human disturbance (Shaw 1959), forest openings, farms, plantations (Shaffer and Gwynn 1967), and managed pine landscapes (Kennamer et al. 1980, Holbrook et al. 1985, Exum et al. 1987, Miller et al. 1995, Miller and Conner 2007).

The nesting season for wild turkeys spans from early April to mid-June (Eaton 1992). Females prefer to nest in regeneration areas that have an abundance of ground cover and a high density of woody vegetation, but they also readily use mature pine stands and mixed forest types (Speake et al. 1975, Seiss et al. 1990, Still and Bauman 1990, Badyaev 1995). Females also prefer nest sites in stands that have been burned within the previous 2 years (Still and Bauman 1990).

Initiation of egg-laying in radio-transmittered females is detected by restricted movements of females during the nesting season (Williams et al. 1974). Females will seldom be found near the nest during the egg-laying period (Williams et al. 1971, Williams, et al. 1974, Williams and Austin 1988) and females will avoid other females while laying eggs or searching for a nest site (Healy 1992). The clutch size for wild turkeys ranges from 4-17 eggs (Eaton 1992). In eastern wild turkeys, the mean incubation period length is 28.6 days, with a range of 27-31 days (Healy et al. 1975). Chronology of wild turkey initiation of incubation varies with year and latitude (Vangilder and Kurjezeski 1995). Peak incubation dates occurred 25 April to 1 May in Alabama (Everett et al. 1980), 24 April in Florida (Williams and Austin 1988), and 12 April to 2 May in Mississippi (Hurst 1988). Females may renest if a clutch is lost early enough in the nesting season (Glidden 1977, Lockwood and Sutcliffe 1985, Vander Haegen 1987, Harper and Exum 1999, Morgan and Schweitzer 2001) or after a clutch has hatched successfully (Harper and Exum 1999, Morgan and Schweitzer 2001). Females can store sperm in their oviducts up to 56 days, so copulation is not necessary for renesting (Marsden and Martin 1955).

The most-important period of poult survival is the first 2 weeks post-hatch, with previously observed survival rates ranging from 12-52% (Miller et al. 1998, Vander Haegen et al. 1988, Paisley et al. 1998). During this 2-week period, the flightless poults brood under the female on the ground at night. Survival rates then increase after the first 2 weeks post-hatch (Speake et al. 1985, Vangilder et al. 1987, Peoples et al. 1995, Hubbard et al. 1999). This increase has been attributed to the ability of poults to roost in trees at night with the female and fly into trees if threatened by predators. During the first week of roosting in trees, females will roost with the poults under their wings or close by in the same tree, and by week 8 the brood may occupy more than 1 tree, and poults of different broods may intermingle (Williams and Austin 1988). Weather, disease, malnourishment, lack of high-quality brooding habitat, and predation are all factors influencing preflight poult survival, with predation being the most important (Hurst et al. 1996, Palmer et al. 1993, Speake et al. 1985, Roberts and Porter 1998, Rolley et al, 1998).

Prescribed Fire and Wild Turkeys

The longleaf pine–wiregrass (*Aristida stricta*) ecosystem is one of the most endangered ecosystems in the United States (Outcalt and Sheffield 1996). Prior to European settlement, this ecosystem covered about 25 million ha of the southeastern United States; now less than 2% of this habitat remains. The suppression of fire, conversion of longleaf pine stands to agriculture and/or other pine species, timber harvest for the naval store industry, and soil disturbance by feral hogs (*Sus scrofa*) all have contributed to the decline of this important ecosystem (Myers 1990, Frost 1993, Stout and Marion 1993, Ware et al. 1993). Historically, this ecosystem was maintained by frequent natural burning (i.e., fire intervals between 1 and 10 years) (Chapman 1932; Harper 1962; Komarek 1974; Christensen 1981; Bridges and Orzell 1989; Platt et al. 1991). Currently, prescribed fire is the dominant management practice associated with this habitat type (Glitzenstein et al. 2003).

Prescribed fire is a common land-management tool used in the southeastern United States to manage vegetation, particularly for control of hardwood encroachment into pine ecosystems and maintaining native groundcovers and open vegetation communities (Waldrop et al. 1992, Cain et al. 1998). Prescribed fire also increases early-successional habitat and herbaceous vegetation, which increases availability of escape cover, nesting cover, and brood-rearing habitat for various ground-nesting birds (Dickson 1981, Hurst 1981, Landers 1981). Growing-season prescribed fires, in particular, are used to control invading hardwoods and understory shrubs (Lotti 1956). Traditionally, fire in the longleaf-wiregrass ecosystem occurred mostly during the growing-season from lightning-ignition (Komarek 1964, Pyne 1982, Robbins and Myers 1992). It has been shown that growing-season prescribed fires are a beneficial part of silvicultural techniques used in the longleaf-wiregrass ecosystem to improve the fruiting and flowering of native ground cover species, while avoiding reduction of growth and survival of pines (Streng et al. 1993). Growing-season prescribed fires produce results similar to natural lightning ignitions (Robbins and Myers 1992) and may improve turkey brood-rearing habitat by increasing insect abundance, adding variety to the seed bank, and enhancing plant growth (McGlincy 1985, Landers and Mueller 1986, Exum 1988, Provencher et al. 1998).

Most literature on the benefits of fire for wildlife focuses on the availability and quality of forage (Stransky and Harlow 1981, Robbins and Myers 1992, Main et al. 2000). Short-term studies (3-4 years) have indicated that growing-season fires can have a negative effect on wild turkey populations (Sisson and Speake 1994) and other game birds, such as northern bobwhite quail (*Colinus virginianus*) (Brennan et al. 1997, 1998; Carver et al. 1997). Stoddard (1935) suggested that growing-season fire be withheld from the landscape to avoid destroying wild turkey nests.

Frequency of prescribed fire has been shown to influence brood use of a specific habitat type. Separate studies conducted in Mississippi have shown broods use mixed pine-hardwood stands burned on a 2-3-year rotation (Jones et al. 2005), mature bottomland hardwoods in areas where upland pine stands were burned infrequently (Phalen et al. 1986, Jones et al. 2005), and mature pine stands burned 3 years prior to the brood use (Burk et al. 1990, Palmer 1990). Wild turkey broods use a variety of forest stand types and forest openings depending on the herbaceous ground cover within those stands (Jones et al. 2005). Wild turkey broods have been observed avoiding plots that have been subjected to growing-season fires, and nest loss from mowing and burning has been documented (Sisson and Speake 1994). Weather, disease, malnourishment, lack of high-quality brooding habitat and predation, are all factors influencing preflight poult survival, with predation being the most important (Hurst et al. 1996, Palmer et al. 1993, Speake et al. 1985, Roberts and Porter 1998, Rolley et al, 1998). The high predation risk in the first 2 weeks of life highlights the importance of ground-roost cover and ground escape cover in maintaining recruitment of wild turkey populations. No research has documented the direct impacts of growing-season prescribed fire on preflight wild turkey poult survival.

Some studies show that there are minimal nests lost to growing-season prescribed fire, especially when applied on a small-scale, and that wild turkey females will preferentially use sites burned during the growing-season. Moore (2006) showed only 9% (2) of 22-monitored females had nests destroyed by growing-season fires and 1 female renested in South Carolina; and a similar study in Mississippi had only 3% (2) of 64 nests destroyed by growing-season fire (Jones 2001). Despite this information more research is needed to understand the impacts of growing-season prescribed fire on wild turkey nest success. Females have also been documented to avoid nesting in areas ≥ 2 years since burn (Allen et al. 1996), and Sisson et al. (1990) documented 62% of all nests occurred in mature pine forests burned ≤ 2 years. Brood ground-roost site selection has been studied much less rigorously than nest site selection, and more research is needed to understand the impacts of growing-season prescribed fire on wild turkey ground-roost site selection.

In this thesis, I present information on growing-season prescribed fire impacts on wild turkey nest survival, nest success, poult survival, nest site selection and brood ground-roost site selection. The research was conducted on 2 similar study sites in southwestern Georgia—The Joseph W. Jones Ecological Research Center (Jones Center) and the Georgia Department of Natural Resources' Silver Lake Wildlife Management Area (Silver Lake WMA). Chapter 2 is a manuscript that describes wild turkey nest survival and nest success and evaluates evidence of effects of habitat and prescribed fire on nesting ecology; poult survival is also investigated. Chapter 3 describes wild turkey nest site selection and brood ground-roost selection at landscape and microhabitat levels. The final chapter provides guidelines for application of prescribed fire while maintaining nesting and brood-rearing habitat for wild turkeys. I also provide suggestions for future research directions.

References

Allen, A. W., Y. K. Bernal, and R. J. Moulton. 1996. Pine plantations and wildlife in the southeastern United States: an assessment of impacts and opportunities.

Information and Technology Report 3, U.S. Department of the Interior, Washington, D.C., USA.

Badyaev, A. V. 1995. Nesting habitat and nesting success of eastern wild turkeys in the Arkansas Ozark Highlands. The Condor 97:221-232.

Brennan, L. A., J. M. Lee, E. Staller, S. Wellendorf, and R. S. Fuller. 1997. Effects of seasonal fire applications on bobwhite brood habitat and hunting success. Quail IV: Fourth National Quail Symposium. Program Abstract. Tall Timbers Research Station, Tallahassee, Florida, USA.

Brennan, L. A., C. L. Hardy, L. W. Burger, and T. Sharpe. 1998. Assessing bobwhite population and habitat response to dormant and lightning prescribed fire in the North Carolina Sandhills: Preliminary report. North Carolina Wildlife Resources Commission, Raleigh, North Carolina, USA.

Bridges, E. L., and S. L. Orzell. 1989. Longleaf pine communities of the west gulf coastal plain. Natural Areas Journal 9:246-253.

Burk, J. D., D. R. Smith, G. A. Hurst, B. D. Leopold, and M. M. Melchiors. 1990. Wild turkey use of loblolly pine plantations for nesting and brood rearing. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 44:163-170.

Cain, M. D., T. B. Wigley, and D. J. Reed. 1998. Prescribed fire effects on structure in uneven-aged stands of loblolly and shortleaf pines. Wildlife Society Bulletin 26:209-218

Carver, A. V., L. W. Burger, and L. A. Brennan. 1997. Bobwhite brood ecology in relation to fallow field management techniques and prescribed fire regime. Quail

IV: Fourth National Quail Symposium. Program Abstract. Tall Timbers Research Station, Tallahassee, Florida, USA.

Chapman, H. H. 1932. Is the longleaf type a climax? Ecology 13:328-334.

Christensen, N. L. 1981. Fire regimes in southeastern ecosystems. Pages 112-136 *in* H. A. Mooney, T. M. Bonnicksen, N. L. Christensen, J. E. Lotan, and W. A. Reiners, editors. Proceedings of a Conference: fire regimes and ecosystem properties. (December 1978, Honolulu, Hawaii, USA). United States Department of Agriculture Forest Service, General Technical Report WO-26.

Dickson, J. G. 1981. Effects of forest burning on songbirds. Pages 67-72 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Eaton, S. W. 1992. Wild turkey (*Meleagris gallopavo*). A. Poole, editor. The Birds of North American Online. Ithaca: Cornell Lab of Ornithology.

Everett, D. D., D. W. Speake. and W. K. Maddox. 1980. Natality and mortality of a north Alabama wild turkey population. Proceedings of the National Wild Turkey Symposium 4:117-126.

Exum, J. H., J. A. McGlincy, D. W. Speake, J. L. Buckner, and F. M. Stanley. 1987. Ecology of the eastern wild turkey in an intensively managed pine forest in southern Alabama. Tall Timbers Research Station Bulletin 23, Tallahassee, Florida, USA.

Exum, J. H. 1988. Turkey management in southeastern pine woods. Proceedings of the Game Bird Seminar. Tall Timbers Research, Inc., Tallahassee, Florida, USA.

Frost, C. C. 1993. Four centuries of changing landscape patterns in the longleaf pine ecosystem. Pages 17-42 *in* S. M. Hermann, editor. The longleaf pine ecosystem: ecology, restoration, and management. Proceedings of the Annual Tall Timbers Fire Ecology Conference, No. 18. Tall Timbers Research Station, Tallahassee, Florida, USA.

Glidden, J. W. 1977. Net productivity of a wild turkey population in southwestern New York. Restoration Project W-81-R, Job 1-4. Federal Aid in Fish and Wildlife.

Glitzenstein, J. S., D. R. Streng, and D. D. Wade. 2003. Fire frequency effects on longleaf pine (*Pinus palustris* Miller) vegetation in South Carolina and northeast Florida, USA. Natural Areas Journal 23:22-37.

Harper, R. M. 1962. Historical notes on the relation of fires to forests. Proceedings of the Tall Timbers Fire Ecology Conference 1:11-29.

Harper, C. A., and J. H. Exum. 1999. Wild turkeys (Meleagris gallopavo) renest after successful hatch. Wilson Bulletin 111:426-427.

Healy, W. M. 1992. The wild turkey: biology and management. Pages 46-65 *in* J. G. Dickson, editor. Behavior. Stackpole Books, Harrisburg, Pennsylvania, USA.

Healy, W. M., R. O. Kimmel, and E. J. Goetz. 1975. Behavior of human-imprinted and hen-reared wild turkey poults. Proceedings of the National Wild Turkey Symposium 3:97-107

Holbrook, H. T., M. R. Vaughan, and P. T. Bromley. 1985. Wild turkey management on domesticated pine forests. Proceedings of the National Wild Turkey Symposium 5:253-258.

Hubbard. M. W., D. L. Garner, and E. E. Klaas. 1999. Wild turkey poult survival in south central Iowa. Proceedings of the National Wild Turkey Federation 8:167-171.

Hurst, G. A. 1981. Effects of prescribed burning on the eastern wild turkey. Pages 81-88 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Hurst, G. A. 1988. Population estimates for the wild turkey on Tallahala Wildlife Management Area. Mississippi Department of Wildlife Conservation, Federal Aid in Wildlife Restoration Annual Report, Project W-48, Study 21.

Hurst, G. A., L. W. Burger, and B. D. Leopold. 1996. Predation and galliforme recruitment: an old issue revisited. Proceedings of the North American Wildlife and Natural Resources Conference 61:62-76.

Jones, B. C. 2001. Wild turkey reproductive ecology on a fire-maintained national forest in Mississippi. Thesis, Mississippi State University, Starkville, Mississippi, USA.

Jones, B. C., J. E. Inglis, and G. A. Hurst. 2005. Wild turkey brood habitat use in relation to prescribed burning and red-cockaded woodpecker management. Proceedings of the National Wild Turkey Symposium 9:209-215.

Kennamer, J. E., J. R. Gwaltney, and K. R. Sims. 1980. Habitat preferences of eastern wild turkey on an area intensively managed for pine in Alabama. Proceedings of the National Wild Turkey Symposium 4:240-245.

Komarek, E. V., Sr. 1964. The natural history of lightning. Proceedings Tall Timbers Fired Ecology Conference 3:139-183.

Komarek, E. V., Sr. 1974. Effects of fire on temperate forests and related ecosystems: southeastern United States. Pages 251-278 *in* T. T. Kozlowski and C. E. Ahlgren, editors. Fire and ecosystems. Academic Press, New York, New York, USA.

Landers, J. L. 1981. The role of fire in bobwhite quail management. Pages 73-80 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Landers, J. L., and B. S. Mueller. 1986. Bobwhite quail management: a habitat approach. Tall Timbers Research Station Miscellaneous Publication 6, Tallahassee, Florida, USA.

Lockwood, D. R., and D. H. Sutcliffe. 1985. Distribution and reproduction of Merriam's Turkey in New Mexico. Proceedings of the National Wild Turkey Symposium 5:309-316.

Lotti, T. 1956. Eliminating understory hardwoods with summer prescribed fires in Coastal Plain loblolly pine stands. Journal of Forestry 54:191-192.

Main, M. B., M. J. Barry, K. Portier, B. J. Harper, and G. Allen. 2000. Effects of fire on soil nutrients, forage quality, and community composition on the Florida Panther NWR. Final Report to the United States Fish and Wildlife Service Florida Panther NWR. SWFREC-IMM-2000-03, Immokalee, Florida, USA.

Marsden, S. J., and J. H. Martin. 1955. Turkey management, Sixth edition, The Interstate. Dansville, Illinois, USA.

McGlincy, J. A. 1985. Wild turkeys and industrial forestry. Proceedings of the Tall Timbers Game Bird Seminar. Tall Timbers Research, Inc., Tallahassee, Florida, USA.

Miller, D. A., B. D. Leopold, and G. A. Hurst. 1998. Reproductive characteristics of a wild turkey population in central Mississippi. Journal of Wildlife Management 62:903-910.

Miller, D. A., and L. M. Conner. 2007. Habitat selection within seasonal use areas of female eastern wild turkeys in a managed pine landscape in Mississippi. Journal of Wildlife Management 71:744-751.

Miller, D. A., M. Weinstein, S. R. Priest, B. D. Leopold, and G. A. Hurst. 1995. Wild turkey reproductive parameters from two different forest ecosystems in central Mississippi. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 49:466-475.

Mock, K. E., T. C. Theimer, E. Rhodes, Jr., D. L. Greenberg, and P. Kleim. 2002. Genetic variation across the historical range of the wild turkey (Meleagris gallopavo). Molecular Ecology 11:643-756.

Moore, W. F. 2006. Survival, nesting success, and habitat selection of wild turkey populations in the upper coastal plain of south carolina. Thesis, Clemson University, Clemson, South Carolina, USA.

Morgan, J. J., and S. H. Schweitzer. 2001. Eastern wild turkey hatching two clutches during the same breeding season. Wilson Bulletin 113:335-337.

Myers, R. L. 1990. Scrub and high pine. Pages 150-193 *in* R. L. Myers and J. J. Ewel, editors. Ecosystems of Florida. University of Central Florida Press, Orlando, Florida, USA.

Outcalt, K. W., and R. M. Sheffield. 1996. The longleaf pine forest: trends and current conditions. United States Department of Agriculture, Forest Service Research Bulletin SRS-9.

Paisley, R. N., R. G. Wright, J. F. Kubisiak, and R. E. Rolley. 1998. Reproductive ecology of eastern wild turkeys in southwest Wisconsin. Journal of Wildlife Management 62:911-916

Palmer, W. E. 1990. Relationships of wild turkey hens and their habitat on Tallahala Wildlife Management Area. Thesis, Mississippi State University, Mississippi State, Starkville, Mississippi, USA.

Palmer, W. E., G. A. Hurst, J. E. Stys, D. R. Smith, and J. D. Burk. 1993. Survival rates of wild turkey hens in loblolly pine plantations in Mississippi. Journal of Wildlife Management 57:783-789.

Palmer, W. E., K. D. Godwin, G. A. Hurst, and D. A. Miller. 1996. Effects of prescribed burning on wild turkeys. Transactions of the North American Wildlife and Natural Resources Conference 61:228-236.

Peoples, J. C., D. C. Sisson, and D. C. Guynn, Jr. 1995. Mortality of wild turkey poults in coastal plain pine forests. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 49:448-453.

Phalen, P. S., G. A. Hurst, and W. J. Hamrick. 1986. Brood habitat use and preference by wild turkeys in central Mississippi. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 40:397-404.

Platt, W. J., J. S., Glitzenstein, and D. R. Streng. 1991. Evaluating pyrogenicity and its effects on vegetation in longleaf pine savannas. Proceedings Tall Timbers Fire Ecology Conference 17:143-162.

Porter, W. F. 1992. Habitat requirements. Pages 202-213 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole, Harrisburg, Pennsylvania, USA.

Provencher, L., N. M. Gobris. H. L. Rodgers, D. R. Gordon, and J. P. McAdoo. 1998. Scientific coordination and adaptive management and experimental restoration of longleaf pine community structure, function, and composition. Annual Report 3 (Dec 97-30 Mar 98). University of Florida, Gainesville, Florida, USA.

Pyne, S. J. 1982. Fire in America: a cultural history of wildland and rural fire. Princeton University Press, Princeton, New Jersey, USA.

Robbins, L. E., and R. L. Myers. 1992. Seasonal effects of prescribed burning in Florida: a review. Tall Timbers Research, Inc., Miscellaneous Publication No. 8. Tallahassee, Florida, USA.

Roberts, S. D., and W. F. Porter. 1998. Influence of temperature and precipitation on survival of wild turkey poults. Journal of Wildlife Management 62:1499-1505.

Rolley, R. E., J. F. Kubisiak, R. N. Paisley, and R. G. Wright. 1998. Wild turkey population dynamics in southwester Wisconsin. Journal of Wildlife Management 62:917-924.

Seiss, R. S., P. S. Phalen, and G. A. Hurst. 1990. Wild turkey habitat and success rates. Proceedings of the National Wild Turkey Symposium 6:18-24.

Shaffer, C. H., and J. W. Gwynn. 1967. Management of the eastern turkey in oak-pine forests of Virginia and the southeast. Pages 303-342 *in* O. H. Hewitt, editor. The wild turkey and its management. The Wildlife Society, Washington, D.C., USA.

Shaw, S. P. 1959. Timber sales and turkey management on eastern national forests. Proceedings of the National Wild Turkey Symposium 1:100-103.

Sisson, D. C., and D. W. Speake. 1994. Spring burning for wild turkey brood habitat: an evaluation. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 48:134-139.

Sisson, D. C., D. W. Speake, J. L. Landers, and J. L. Buckner. 1990. Effects of prescribed burning on wild turkey habitat preference and nest site selection in south Georgia. National Wild Turkey Symposium 6:44-50.

Speake, D. W., T. E. Lynch, W. J. Fleming, G. A. Wright, and W. J. Hamrick. 1975. Habitat use and seasonal movements of wild turkeys in the Southeast. Proceedings of the National Wild Turkey Symposium 3:122-130.

Speake, D. W., R. Metzler, and J. McGlincy. 1985. Mortality of wild turkey poults in northern Alabama. Journal of Wildlife Management 49:472-474.

Still, H. R., Jr., and D. P. Bauman, Jr. 1990. Wild turkey nesting ecology on the Francis Marion National Forest. Proceedings of the National Wild Turkey Symposium 6:12-18.

Stoddard, H. L. 1935. Use of controlled fire in southeastern upland game management. Journal of Forestry 33:346-351.

Stoddard, H. L. 1946. Relation of burning to timber and wildlife. Proceedings of the North American Wildlife Conference 1:399-403.

Stoddard, H. L. 1963. Maintenance and increase of the eastern wild turkey on private lands of the coastal plain of the deep southeast. Tall Timbers Research Station, Bulletin 3, Tallahassee, Florida, USA.

Stout, I. J., and W. R. Marion. 1993. Pine flatwoods and xeric pine forests of the southern coastal plain. Pages 373-446 *in* W. H. Martin, S. G. Boyce, and A. C. Echternacht, editors. Biodiversity of the southeastern United States lowland terrestrial communities. John Wiley, New York, New York, USA.

Stransky, J. J., and R. E. Harlow. 1981. Effects of fire on deer habitat in the southeast. Pages 135-142 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Streng, D. R., J. S. Glitzenstein, W. J. Platt. 1993. Evaluating effects of season of burn in longleaf pine forests: critical literature review and some results from an ongoing long-term study. Proceedings Tall Timbers Fire Ecology Conference 18:227-263.

Tapley, J. L., W. H. Heal, R. K. Abernathy, and J. E. Kennamer. 2001. Status of wild turkey hunting in North America. Proceedings of the National Wild Turkey Symposium 8:257-268.

Vander Haegen, W. M. 1987. Population dynamics and habitat preferences of wild turkeys in western Massachusetts, Thesis. University of Massachusetts, Amherst, USA.

Vander Haegen, W. M., W. E. Dodge, and M. W. Sayre. 1988. Factors affecting productivity in a northern wild turkey population. Journal of Wildlife Management 52:127-133.

Vangilder, L. D., E. W. Kurzejeski, V. L. Kimmel-Truitt, and J. B. Lewis. 1987. Reproductive parameters of wild turkey hens in North Missouri. Journal of Wildlife Management 51:535-540.

Vangilder, L. D., and E. W. Kurzejeski. 1995. Population ecology of the eastern wild turkey in northern Mississippi. Wildlife Monograph. No. 130.

Waldrop, T. A., D. L. White, and S. M. Jones. 1992. Fire regimes of pine-grassland communities in the southeastern United States. Forest Ecology and Management 47:195-210.

Ware, S., C. Frost, and P. D. Doerr. 1993. Southern mixed hardwood forest: the former longleaf pine forest. Pages 447-493 *in* W. H. Martin, S. G. Boyce, and A. C. Echternacht, editors. Biodiversity of the southeastern United States: lowland terrestrial communities. John Wiley, New York, New York, USA.

Williams, L. E., Jr., and D. H. Austin. 1988. Studies of the wild turkey in Florida. Florida Game and Freshwater Fish Commission, Technical Bulletin 10, Gainesville, USA.

Williams, L. E., Jr., D. H. Austin, T. E. Peoples. 1974. Movements of wild turkey hens in relation to their nests. Proceedings of the Southeastern Association of Game and Fish Commission 28:602-622.

Williams, L. E., Jr., D. H. Austin, T. E. Peoples, and R. W. Phillips. 1971. Laying data and nesting behavior of wild turkeys. Proceedings of the Southeastern Association of Game and Fish Commission 25:90-106.

CHAPTER 2

EFFECTS OF GROWING-SEASON PRESCRIBED FIRE ON NESTING ECOLOGY AND POULT SURVIVAL OF EASTERN WILD TURKEYS IN SOUTHWESTERN GEORGIA

Williams, M. M. To be submitted to the Journal of Wildlife Management.

Abstract

Land managers and hunters have expressed concern over the use of growing-season fire and its impact on eastern wild turkey (*Meleagris gallopavo silvestris*) nest survival, nest success, and poult survival; however, little research has been conducted on the effects of growing-season fires on the population-level responses. Although nest predation is commonly the greatest source of wild turkey nest failure, growing-season prescribed fire may also impact nest success. This research was conducted on 2 similar study sites in southwestern Georgia—the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area. Fifty-one wild turkey nests were monitored, but no important predictors of nest survival were found. Extrapolating a Mayfield daily survival estimate of 0.98 through a 29-day incubation period indicated that overall nest survival was 56%. Most (32.7%) nests were lost to predation, whereas growing-season prescribed fire contributed to the loss of 11.5% of nests. Mayfield nest survival rates indicated that 5 of the 6 nests affected by growing-season fire would have likely been successful in the absence of fire had they had the opportunity to complete incubation. However, the renest rate for females with initial nests lost to fire was 75%, which decreases the overall negative impacts of fire. Survival of 23 broods was found to be 35% during the first 2 weeks post-hatch; only 1 brood was lost to prescribed-fire, indicating that growing-season fire had a minimal impact on poult survival. Rotating, small-scale growing-season fires (< 20 ha) in the longleaf pine ecosystem should be used to enhance native plant species and herbaceous understory vegetation growth, which improves wild turkey foraging and nesting habitats. Applying these fires on a smaller-scale may offset wild turkey nest and poult loss.

Introduction

Prescribed fire is a common land-management tool used in the southeastern United States to manage vegetation, particularly to control hardwood encroachment into pine ecosystems and maintain native groundcover and open vegetative communities (Waldrop et al. 1992, Cain et al. 1998). Prescribed fire also increases early-successional habitat and herbaceous vegetation, which increases availability of escape cover, nesting cover, and brood-rearing habitat for various ground-nesting birds (Dickson 1981, Hurst 1981, Landers 1981). Growing-season prescribed fires, in particular, are used to control invading hardwoods and understory shrubs (Lotti 1956). Traditionally, fire in the longleaf (*Pinus palustris*) – wiregrass (*Aristida stricta*) ecosystem occurred mostly during the growing-season from lightning-ignition (Komarek 1964, Pyne 1982, Robbins and Myers 1992).

Land managers and hunters interested in ground-nesting birds have expressed significant concern over the use of growing-season fires by state and federal agencies, but little research has been conducted on the effects of growing-season fires on the population-level response of wild turkeys and other ground-nesting birds (Robbins and Myers 1992). Some wild turkey biologists have expressed concern that the potential effect of growing-season fires on turkey populations might be a factor in the decline in hunter harvest rates for wild turkeys observed during the past 5-10 years in several states across the Southeast, including Georgia (Kevin Lowrey, unpublished data), Alabama (Steve Barnett, unpublished data), and South Carolina (Charles Ruth, unpublished data).

Most literature on the benefits of fire for wildlife focuses on the availability and quality of forage (Stransky and Harlow 1981, Robbins and Myers 1992, Main et al.

2000). Growing-season prescribed fires produce vegetation responses similar to natural lightning ignitions (Robbins and Myers 1992) and may improve turkey brood-rearing habitat by increasing insect abundance and adding variety to seed banks and enhancing plant growth (McGlincy 1985, Landers and Mueller 1986, Exum 1988, Provencher et al. 1998). No research has assessed the long-term effects of growing-season fires on wild turkeys and other ground-nesting birds. Short-term studies (3-4 years) have indicated that growing-season fires can have a negative effect on wild turkeys populations (Sisson and Speake 1994) and other game birds, such as northern bobwhite quail (*Colinus virginianus*) (Brennan et al. 1997, 1998; Carver et al. 1997). Stoddard (1935) suggested that growing-season fire be withheld from the landscape to avoid destroying wild turkey nests.

Initial nesting rates, renesting rates, nesting success, and causes of nest failure are important factors influencing wild turkey populations (Vangilder 1992, Roberts and Porter 1996). Knowledge of how prescribed fire affects these reproductive parameters can help land managers improve wild turkey populations by enhancing habitat conditions that minimize nest predation risk and maximize nesting success. . There has been little research published on the effects of growing-season prescribed fires on wild turkey reproduction in the longleaf pine ecosystem (Sisson et al. 1990, Moore 2006). Some studies have reported minimal nest loss to growing-season prescribed fire, especially when fire was applied on a small-scale, and that wild turkey females will preferentially use sites burned during the growing-season. Moore (2006) showed only 9% (2) of 22-monitored females in South Carolina had nests destroyed by growing-season fires and 1 female renested. In a similar study in Mississippi only 3% (2) of 64 nests were destroyed by growing-season fire (Jones et al. 2005). Clearly, more research is needed to understand the impacts of growing-season prescribed fire on wild turkey nest success. The Georgia Department of Natural Resources Wildlife Resource Division and the National Wild Turkey Federation's Southeastern Wild Turkey Committee have also listed investigation into growing-season fire effects on wild turkey reproduction as an important research objective because of potential connections to recent population declines in Georgia (Kevin Lowrey, unpublished data; Southeast Wild Turkey Technical Committee 2010).

Wild turkey broods have been documented avoiding small plots subjected to growing-season fires, there has also been documented nest loss from mowing and burning (Sisson and Speake 1994). However, wild turkeys have been observed foraging in burned areas immediately after a growing-season prescribed fire (Komarek 1969); this use may be result of a significant increase in insect abundance and native legumes following the burn (Komarek 1969). No research has documented the impacts of growing-season prescribed fire on preflight wild turkey poult survival. However, weather, disease, malnourishment, lack of high-quality brooding habitat and predation, have all been cited as important factors for preflight poult survival, with predation being the most important (Hurst et al. 1996, Palmer et al. 1993, Speake et al. 1985, Roberts et al. 1998, Rolley et al, 1998). Greater predation risk during the first 2 weeks of life also highlights the importance of ground-roost cover for brood forage and escape cover.

My objectives were to investigate the effects of growing-season prescribed fire on wild turkey nest success and poult survival, and to determine impacts of microhabitat, landscape characteristics, time-since-burn and growing-season prescribed fire on daily nest survival.

Methods

Study Sites

My research was conducted on 2 similar study sites in southwestern Georgia—the Joseph W. Jones Ecological Research Center at Ichauway (Jones Center) and the Department of Natural Resources' Silver Lake Wildlife Management Area (Silver Lake WMA; Figure 2-1).

The Jones Center portion of my research was focused on Ichauway, a 12,000 ha outdoor research laboratory located in Baker County, Georgia, USA, and former northern bobwhite quail hunting plantation and surrounding properties (total study area 15,299 ha). The Ichawaynochaway Creek bisects the property and the Flint River borders the property to the east. The site includes a variety of forest types, including longleaf pine, loblolly pine (*Pinus taeda*), slash pine (*P. elliottii*), mixed pine and hardwood forests, oak barrens, lowland hardwood hammocks, and cypress-gum (*Taxodium ascendens-Nyssa biflora*) limesink ponds (Boring 2001). Twenty-nine percent of the area is mature pine, 21% mature pine-hardwood, 5% shrub/scrub, 3% forested and herbaceous wetlands, 9% hardwood, 18% agriculture/food plot, 11% evergreen pine plantation, 2% barren land/urban, and 2% open water. Prescribed fire is the primary tool for conserving native ground cover and controlling hardwood encroachment, with approximately 50% of the site being burned each year (Atkinson et al. 1996). Upland sites in particular are burned on an approximate 2-year burn rotation. Prescribed fire is applied throughout the year on the property; however, most burns are initiated from March – August. Prescribed fire creates a matrix of burned and unburned habitats, and allows areas burned in the winter sufficient re-growth to provide suitable nesting and foraging habitat for wild turkeys the following spring. Turkey hunting was not permitted on the Jones Center prior to or during my research.

Wiregrass, a fire-dependent species that requires growing-season fires to flower, dominates approximately 25% of the understory at the Jones Center. Since 1994, over 3,925 ha of the site has undergone significant hardwood removal, with the majority occurring since 2001 (Brandon Rutledge, personal communication). The scattered individual hardwoods and hardwood patches that exist throughout the site provided an important mast source for wildlife, including wild turkeys. Furthermore, historical management for northern bobwhite quail on the site has created a diverse habitat mosaic of small weedy openings and food plots interspersed within the forested ecosystem. Despite the intense burn regime at the Jones Center, including growing-season fires, wild turkey populations increased during the decade prior to my research (L.M. Conner, unpublished data), suggesting that wild turkey populations could be maintained while using growing-season prescribed fires.

The Silver Lake Wildlife Management Area (WMA) portion of my research was focused on the WMA, a 3,900 ha property owned by the Georgia Department of Natural Resources and located in Decatur County, Georgia, USA, and surrounding properties (total study area 7,731 ha). The Flint River borders the property to the east, Spring Creek to the west, and Lake Seminole to the south. Silver Lake WMA consists of a variety of forest types, including longleaf pine, loblolly pine (*Pinus taeda*), slash pine (*P. elliottii*), mixed pine and hardwood forests, hardwood forests, lowland hardwood hammocks, as well as many depressional wetlands, ponds, and the 150-ha Silver Lake (Silver Lake WMA 50-Year Plan 2009, Georgia DNR 2009). Twenty-six percent of the area is mature pine, 12% mature pine-hardwood, 1% shrub/scrub, 0% forested and herbaceous wetlands, 1% hardwood, 9% agriculture/food plot, 19% evergreen pine plantation, 1% barren land/urban, and 31% open water. Agricultural fields occur along the northern border of the property and no agricultural fields or food plots occur within the property. Like the Jones Center, the primary natural vegetation management tool used on Silver Lake WMA is prescribed fire, on an approximately 2-year burn rotation. Prior to becoming a WMA, most prescribed fires were conducted during the dormant-season, with few occurring during the growing-season. However, under new management the property is burned more frequently during the growing-season, and the scale of burns were reduced to promote landscape diversity by creating a larger array of stands with varying burn histories. To create a diverse fire-maintained upland plant community that provides quality wildlife habitat for game and non-game species, management is focused on restoration of native groundcover, reduction of undesirable hardwoods, such as water oak (*Quercus nigra*), and establishment of desirable fire-tolerant upland hardwoods, such as post oak (*Quercus stellata*) and southern red oak (*Quercus falcata*), in certain upland sites. Additional management for species, such as the northern bobwhite quail, has also created a diverse habitat mosaic of small openings within the forested stands. The property provides hunting and other opportunities for the general public.

Potential wild turkey nest and brood predators in the 2 study areas included coyotes (*Canis latrans*), bobcats (*Lynx rufus*), Virginia opossums (*Didelphis virginiana*), northern raccoons (*Procyon lotor*), red fox (*Vulpes vulpes*), gray fox (*Urocyon cinereoargenteus*), and several species of snakes.

Capture and Radio Telemetry

Female wild turkeys were captured with rocket nets at bait sites of cracked corn distributed throughout the 2 study sites during the winter (December – March) of 2010-2011, summer (June-August) of 2011, and winter of 2011-2012. Bait sites were checked twice daily, and capture attempts were made after consistent use of sites by females. Once captured, turkeys were removed from the net, classified as adults or juveniles (Williams and Austin 1988), and placed into cardboard boxes designed specifically to accommodate wild turkeys (76.2 × 35.6 × 61-cm). All captured females were fitted with serially numbered, butt-end (left leg) and riveted (right leg) aluminum leg bands (National Band and Tag Co., Newport, KY). A mortality-sensing VHF radio-transmitter, weighing approximately 60-g, (Sirtrack, Havelock North, New Zealand; and Telenax, Playa del Carmen, México) was attached backpack-style to all captured females. All birds were released at the capture site immediately after processing. Capture and handling followed protocols approved by The University of Georgia Institutional Animal Care and Use Committee, Permit number A2010 7-120.

Radio-tagged females were located by triangulation from roads (Cochran and Lord 1963) using a hand-held, 3-element Yagi antenna and Wildlife Materials TRX 2000S receiver (Wildlife Materials, Murphysboro, Illinois). Locations were calculated by triangulation and recorded in the field using a mobile phone fitted with Location Of A Signal-SD (LOAS-SD) software (Ecological Software Solutions, LLC) and a Bluetooth-GPS unit.

Females were located 3 times per week from August to early March, and ≥1 time per day during the nesting season to ensure all nesting activity was detected. A female was assumed to have initiated incubation when she was found in the same location for 2 consecutive days. Once a female was determined to be incubating, the nest was approached to within 25-m and compass bearings were recorded toward the nest to facilitate locating the nest after hatch or nest loss. Several nests were also located opportunistically by the Jones Center and Silver Lake WMA staff, and were used to increase our sample size for our nest success analysis.

After termination of incubation and female movement away from the nesting area, the nest was located and its location was recorded. Radio-telemetry and backdating of nests were used to determine nest initiation dates. Clutch size, brood size, and nest fate were also recorded. If a nest could not be located, the estimated nest location was used as the nest site. Clutch size was determined from counts of unhatched eggs and egg caps. Initial brood size was defined as the number of hatched eggs in each nest. Nests were categorized as successful (if ≥1 egg hatched) or unsuccessful (if no eggs hatched). Nests were considered depredated if eggs were found destroyed, trampled, or carried away from the nest site. Nests were considered abandoned if the nest site seemed undisturbed and an intact clutch of eggs was found.

Poult survival was measured using flush counts, incidental sightings, and female brood behavior (e.g., pre-flight ground-roosting activity by female). The first flush count was conducted as early as 3 days post-hatch and was continued weekly until the brood was lost or became indistinguishable in size from the female. Poult survival was defined as one or more of the hatched poults alive and with the female.

To investigate effects of growing-season prescribed fire on nest success or poult survival, hourly focal telemetry runs were conducted for all females beginning 1 hour before and ending 1 hour after growing-season prescribed fires.

Habitat Analyses

Microhabitat variables associated with the nests and random sites were measured to determine if habitat influenced nest survival. Variables included understory vegetation height, percent canopy cover, and percent ground cover. Understory vegetation height at nests and random sites were taken using a Robel pole (Robel et al. 1970). The robel pole was placed at the center of the site and minimum, average, and maximum understory vegetation height readings were taken from the 4 cardinal directions at a distance of 15 m from the center, while facing the pole at approximately 1-m in height. All 4 readings for each of the 3 vegetation height measurements were then averaged. A spherical densiometer was used to estimate canopy cover at nest and random sites (Lemmon 1956). Five readings were taken and then averaged using the densiometer—1 reading at the center of the site and 4 at 15-m away from the center in each cardinal direction. A 1-m^2 Daubenmire frame was used to measure ground cover type percentages at nest and random sites (Daubenmire 1959). Five readings were taken and then averaged using the Daubenmire frame—1 reading at the center of the site and 4 at 15-m away from the center in each cardinal direction. Ground cover was partitioned into 7 cover types, including bare ground, debris, fern, forb, grass, vine, and woody.

To investigate nest survival at the landscape level, point data at nest and random site locations were intersected with land cover and time-since-burn data in ArcGIS 9.3 (ESRI 2008). Nine habitat types were created within ArcGIS 9.3 (ESRI 2008): mature pine, mature pine-hardwood, shrub/scrub, forested/herbaceous wetlands, mature hardwood, agriculture field/food plot, evergreen pine plantation, barren land/urban, and open water. Land cover polygons for nest sites located outside property boundaries were manually digitized in ArcGIS 9.3 (ESRI 2008) from 2010 digital orthophoto quarter quadrangles (NAIP 2010). Detailed burn history data from January 2009—to present was compiled for each study site in ArcGIS 9.3 (ESRI 2008). Years-since-burn for nest sites was determined, and point distances (m) were calculated in meters to the nearest road, open water, edge between forest habitats and openings, and all 9 habitat types in ArcGIS 9.3 (ESRI 2008).

Data Analyses

Nest survival and nest success for the 2011 and 2012 nesting seasons were calculated independently and pooled for both study sites and both study years. Initial nesting rates were calculated as the percentage of females alive on April 5 of the 2011 and March 27 of the 2012 nesting seasons known to initiate incubation within a particular year. These dates were used because they were the earliest incubation initiation dates recorded for both study sites and both study years. Renesting rates were calculated as the percentage of females that renested following the failure of their first nest or early brood loss. Naïve nest success and renest success were calculated as the proportion of nests and renests that successfully hatched ≥1 egg.

To include relevant microhabitat and landscape-level variables within daily nest survival models, univariate statistics (*t*-tests, for unequal variances) were used to first identify significant ($P < 0.1$) variables (Johnson 1981; Rexstad et al. 1988, 1990; Taylor 1990; Table 2-1). The number of variables included in the model construction was further reduced by eliminating highly correlated ($|r| > 0.7$) variables (Brennan et al. 1986).

Logistic exposure (Shaffer 2004) of nest sites was used to develop models to predict whether daily nest survival was associated with nest site microhabitat and landscape-level variables, study site variables, and temporal variables (e.g., year) using the GLM procedure (R Core Team, Vienna, Austria). Sixteen models were developed, using variables from univariate and correlation filters, to describe daily nest survival. I then used the second-order Akaike's Information Criteria (AIC_c) to determine the weight of evidence in support of the models (Akaike 1973, Burnham and Anderson 2002; Table 2-2). The model with the lowest AIC_c was considered to be the best model, and all models with $AIC_c < 4.0$ units from the best model as the best set of approximating models. The Akaike weight (w_i) for each model was calculated as an estimate of the probability of the model being the most predictive of the developed models (Table 2-2). Model-averaging was used to calculate parameter estimates and unconditional standard errors (Burnham and Anderson 2002) of the top-performing models within 4 AIC_c based on their adjusted w_i (Table 2-3). Model-averaged parameter weights and their variable weights and 95% confidence intervals were calculated. Only those parameter estimates with 95% confidence intervals that excluded zero were considered important predictors (Miller and Conner 2007; Table 2-4).

Mayfield (1975) estimates of daily nest survival and 95% confidence intervals (Johnson 1979) were calculated for all nests. The daily nest survival estimate was used to calculate overall nest success. Nest survival as a function of growing-season prescribed fire could not be analyzed using logistic exposure, because if a nest site was burned then the associated microhabitat vegetation data were unavailable. Therefore, to investigate if nest success was independent from growing-season fire, a Fisher's exact test in a 2x2 contingency table (R Core Team, Vienna, Austria) was used. These results assumed that nests destroyed by fire would have otherwise survived. Therefore, the number of nests destroyed by fire using the Mayfield (1975) daily nest survival estimate was adjusted. To estimate the probability of nest success had it not been burned, the daily nest survival estimate was raised to the power of the remaining incubation days for all unsuccessful nests exposed to fire (Baicich and Harrison 1997, Twedt et al. 2001).

Naïve poult loss estimates for the 2011 and 2012 nesting seasons were calculated independently and pooled for both study sites and both study years. The 14 day poult survival estimate was calculated using the Kaplan-Meier approach, with the brood as the experimental unit, and survival defined as 1 or more poults alive and with the female (Kaplan and Meier 1958). Poult survival rates were then compared between sites using a chi-square test (Sauer and Williams 1989) and the SURVDIFF procedure ($P < 0.05$; R Core Team, Vienna, Austria).

Results

Sixty-two nests were located; 57 were associated with radio-tagged females and 5 were found opportunistically. The peak in onset of incubation for initial nests was from early April to early March for 2011, but there was a wider range of initiation onset during the 2012 season (Table 2-5). There were 2 instances of triple nesting—1 Jones Center female initiated her third nest on 1 July 2011 and 1 Silver Lake WMA female initiated her third nest on 10 July 2012. Average length of incubation for successful nests was 29 days (n = 25, range 26 – 31 days). Nine nests determined to be abandoned by the female due to observer interference were used for naïve nest success estimates, but were censored from nest survival analyses. The nest fate of one nest found opportunistically was undetermined. Of the remaining 52 nests, 25 (48.1%) were successful, 17 (32.7%) were depredated, 6 (11.5%) were lost to growing-season prescribed fire, 2 (3.8%) failed because the incubating female was depredated, and 2 (3.8%) were abandoned. When calculating the naïve nesting rate estimates, I included observer-caused abandoned nests (n = 9), excluded opportunistic nests (n = 5), categorized multiple nesting attempts after nest failure as renests, and categorized nests after early brood loss as renests. Initial nesting rates ranged from 50-75% and averaged 71% across both study sites and study years (Table 2-6). Pooled nesting rates were approximately 14% greater during 2012 than 2011, and nesting rates were approximately 20-25% greater on the Jones Center than Silver Lake WMA (Table 2-6). Pooled initial nest success rates were approximately 43% greater during the 2011 than 2012 nesting season (Table 2-6). Renest rates were 42-100% greater on the Jones Center than Silver Lake WMA (Table 2-6). These nests were all categorized as renesting attempts for naïve nesting rate estimates (Table 2-6). There were also 2 instances of successfully hatching 2 broods in one nesting season, 1 in 2011 and 1 in 2012.

The logistic exposure analysis suggested that the model containing site and landscape variables was best (w_i = 0.218; Table 2-2), but it was only slightly better than a model containing only landscape variables (w_i = 0.198) and another model that only had distance to mature pine as a predictor (w_i = 0.117). Model-averaged parameter estimates based on the top-performing models (Table 2-3) suggested that no variables were useful for predicting daily nest survival, as all parameter estimates included zero in their associated 95% confidence intervals (Table 2-4).

I calculated the percent area burned during the 2011 and 2012 nesting seasons from the date of the first nest initiated (27 March) to the final nesting attempt ending (30 July) for the 2011 and 2012 nesting seasons combined. For the Jones Center, 17% of the property was burned during this period, with an average burn size of 21.5 ha and the largest burn size was 195 ha. For Silver Lake WMA, 7% of the property was burned during this period, with an average burn size of 11.7 ha and the largest burn size of 38 ha. The average burn size during this period for both sites and years combined was 16.6 ha. The probability of nest survival for a 29-day incubation period in the absence of growing-season fire was 56% (Table 2-7). Nest success was dependent on growing-season fire ($\chi^2 = 5.51$, df = 1, $P = 0.019$). Across both study sites and years, 7 nests were exposed to growing-season fire, 6 of which failed and 1 hatched. Most growing-season prescribed fires that impacted nests occurred in late April, with 2 occurring in early May, and the average date of burn was 27 April for all years and sites pooled. The adjusted Mayfield nest survival estimate for nests destroyed by fire suggested that approximately 5 of those 6 nests would have been successful otherwise. This estimate, raised to the power of the remaining incubation days for 4 of the 6 unsuccessful nests lost to fire, suggested that 82% of those nests would have successfully completed incubation in the absence of fire. Four of the 6 females (75%) that were interrupted by fire during the incubation period renested.

Twenty-three broods were monitored across both study sites and nesting seasons. Poult survival was 35% from 1-14 days and 17% from 15-30 days. Seventeen percent of broods survived to 30 days and only 2 of those broods became indistinguishable in size from adult females (Table 2-8). An average of 8.4 poults hatched for every successful nest. I was unable to determine cause-specific mortality for most broods; however, 5 of 23 brood females were lost with their poults to depredation, with 80% of those brood females being depredated before 14 days post-hatch. One brood was lost to a growing-season prescribed fire that occurred immediately after hatching. The highest loss of broods occurred during days 1-14 at 65% for both years and sites pooled (Table 2-8). Poult survival from days 1-14 did not differ between study sites (χ^2 = 2.3, df = 1, P = 0.129).

Discussion

Nest survival clearly has a critical influence on wild turkey populations (Roberts and Porter 1998), and nest success has been cited as a major influence on annual population abundance in mixed agricultural and forested environments (Roberts et al. 1995, Roberts and Porter 1996). In the absence of growing-season prescribed fire our estimate of nest success (56%) was greater relative to similar wild turkey studies (34.8%, Smith-Blair 1993; 47.8%, Holbrook et al. 1987), suggesting low evidence of population declines in our 2 southwestern Georgia populations.

Nesting rates and success varied greatly between the 2 nesting seasons, which has been reported in other wild turkey reproduction studies (Vangilder 1992, Thogmartin and Johnson 1999). There was a potential I did not detect some nests initiated by radio-tagged females, since females do not begin incubation until the entire clutch has been laid (Eaton 1992). Reproductive parameters for studies conducted on eastern wild turkeys were summarized for comparison purposes to this study (Table 2-9). The initial nesting rate for this study (71%) was comparable to other studies, which ranged from 33% (Wilson et al. 2005) to 97.6% (Paisley et al. 1998). Nest success, with (41%) or without growing-season fire (56%) included, for this study was greater than most studies, except for Vander Haegen et al. (1988) in Massachusetts, which was 68%. The renest rate for this study (62%) was greater than other studies [range 26.7% (Byrne 2011) to 59.6% (Paisley et al. 1998)]. The renest success (40%) for this study was also greater than other studies, except for Vander Haegen et al. (1988) in Massachusetts, which was 50%. For both nesting seasons all nest success and nesting rates were greater on the Jones Center compared to Silver Lake WMA.

Similar to other studies (Miller and Leopold 1992), predation was the greatest source of nest failure. The primary predators on both study sites were mesopredators, which have also been documented as nest predators in other wild turkey nesting studies (Speake 1980, Vangilder et al. 1988). The next greatest source of nest loss was due to growing-season fire, but in the absence of growing-season fire 1 of the 6 nests destroyed by fire would have been expected to fail due to other sources. This is slightly higher than other studies that had 5% and 9% of nests destroyed by growing-season fires in South Carolina (Carlisle 2003 and Moore 2006, respectively), and another that had only 3% destroyed by fires in Mississippi (Jones 2001). The greater percentage of nests burned during this study is likely because a greater percentage of the sites were burned relative to other studies. For example, < 1% of the Moore (2006) study area in South Carolina was burned during the growing-season, and an average of 13% of these 2 study sites was burned during the nesting season. Notably, 75% of females renested after their initial nests were destroyed by fire and one nest was burned and yet hatched successfully 5 days post-burn. The successful hatching of nests exposed to fire was also observed in a South Carolina study (Carlisle 2003). Growing-season prescribed fires are an important factor in maintaining optimal understory conditions of increased early-successional habitat and herbaceous vegetation for wild turkey nesting and ground-roosting cover, and should not be excluded from the landscape. However, I speculate that large-scale growing-season fire (> 20 ha) may be detrimental to nesting, and should be applied judiciously until further studied.

The low poult survival in the first 2 weeks was consistent with previous studies (Glidden and Austin 1975, Lehman et al. 2001, Spears et al. 2007). Poult loss after 14 days post-hatch decreased significantly, since after 2 weeks broods could fly and roost in trees (Barwick et al. 1971). Survival within the first 30 days (17%) was greater compared to other studies in coastal plain pine forests (9%, Peoples et al. 1995; 13%, Exum et al. 1987; 10%, Sisson et al. 1991). Poult loss was largely due to predation, with 22% of brood females lost as well; however, 1 brood was lost to a growing-season prescribed fire just after hatch. This is the first documented brood loss attributed to growing-season prescribed fire, and is likely unimportant from a management perspective.

Although not significantly different, the Jones Center had greater nesting rates and nest success and lower poult survival than Silver Lake WMA. I hypothesize these differences may be from site-specific differences in predator communities, habitat types, and management.

The greater nesting rates and nest success on the Jones Center relative to Silver Lake WMA may be from year-round agricultural field and food plot availability, supplemental feeding for northern bobwhite quail management, and lower abundances of nest predators. It has been reported that wild turkey females will not attempt to nest if they are in poor nutritional condition (Pattee 1977, Porter et al. 1983), and studies also have shown that habitat quality for wild turkeys is greater in areas with more openings, agricultural fields and pastures (Wigley et al. 1986, Godwin et al. 1994). The Jones Center annually removes and average of 218 mesopredators from approximately 4,856-ha of the property for northern bobwhite quail management. The majority of predators removed are northern raccoons (*Procyon lotor*) and Virginia opossums (*Didelphis virginiana*) (L. Mike Conner, personal communication), which are considered major wild turkey nest predators (Speake 1980, Miller and Leopold 1992, Williams and Austin 1988).

The greater poult survival on Silver Lake WMA relative to the Jones Center may be indicative of a different predator community or abundances than that of the Jones Center. Silver Lake WMA has a lower percentage of agricultural fields and food plots and a greater percentage of open water compared to the Jones Center. Although the Jones Center has a greater percentage of hardwoods relative to Silver Lake WMA, there is a greater spatial dispersion between hardwood habitats on the Jones Center due to the extensive hardwood removal. The raccoon is the primary nest predator of wild turkeys throughout their range (Speake 1980, Miller and Leopold 1992, Williams and Austin 1988). Conversely, the Jones Center likely has a predator community more commonly associated with agricultural edges and early successional forest communities, such as bobcats (*Lynx rufus*) and coyotes (*Canis latrans)*, than Silver Lake WMA (Conner et al. 1992, Cochrane 2003, Doughty 2004). These predators are also more commonly associated with depredation of wild turkey poults (Peoples et al. 1995). Therefore, Silver Lake WMA likely has a predator community more associated with bottomland hardwood systems, such as northern raccoons (*Procyon lotor*), which are more likely to occur in habitats, such as bottomland hardwoods, that have a greater hardwood refugia and water component (Atkenson and Hulse 1953, Sanderson 1987, Leberg and Kennedy 1988, Gehrt and Fritzell 1998).

Negative effects of growing-season prescribed fires on wild turkey nest success and poult survival should be considered before their use, as the long-term effects on wild turkey populations are still somewhat uncertain. However, studies have shown that growing-season fires may improve turkey brood-rearing habitat by increasing insect abundance, adding variety to the seed bank, and enhancing plant growth (McGlincy 1985, Landers and Mueller 1986, Exum 1988, Provencher et al. 1998). Therefore, as long as growing-season fires are used in a rotating, small-scale (< 20 ha) application the effects on wild turkey populations will be minimal and the benefits to the entire ecosystem will be great. Mesopredator removal, at least during the wild turkey nesting season, should be considered as a potential management tool as it has been concluded that wild turkey nest success can improve after intensive predator control (Miller and Leopold 1992). Invasive hardwood removal in the longleaf pine ecosystem should also be considered to further reduce nest predator refugia (Atkenson and Hulse 1953, Sanderson 1987, Leberg and Kennedy 1988, Gehrt and Fritzell 1998).

References

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267-281 *in* B. N. Petrov and F. Csaki, editors. Proceedings of the

Second International Symposium on Information Theory. Akademiai Kiado, Budapest, Hungary.

Atkenson, T. Z., and D. C. Hulse. 1953. Trapping versus night hunting for controlling raccoons and opossums within sanctuaries. Journal of Wildlife Management 17:159–162.

Atkinson, J., J. Brock, and R. Smith. 1996. Operational longleaf pine management at Ichauway. The longleaf alliance annual meeting, Mobile, Alabama, USA.

Baicich, P. J., and C. J. O. Harrison. 1997. A guide to the nests, eggs, and nestlings of North American birds. Second edition. Academic Press, San Diego, California, USA.

Barwick, L. H., D. H. Austin, and L. E. Williams. 1971. Roosting of young turkey broods during summer in Florida. Proceedings of the Southeastern Association of Fish and Willdife Agencies 24:231-243.

Boring, L. R. 2001. The Joseph W. Jones Research Center: Co-directed applied and basic research in the private sector. Pages 233-258 *in* G. W. Barrett and T. L. Barret, editors. Holistic science: the evolution of the Georgia Institute of Ecology (1940-2000). Taylor and Francis, New York, New York.

Brennan, L. A., W. M. Block, R. J. Gutierrez. 1986. The use of multivariate statistics for developing habitat suitability index models. Pages 177-182 *in* J. Verner, M. L. Morrison, and C. J. Ralph, editors. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. University of Wisconsin Press, Madison, USA.

Brennan, L. A., C. L. Hardy, L. W. Burger, and T. Sharpe. 1998. Assessing bobwhite population and habitat response to dormant and lightning prescribed fire in the

North Carolina Sandhills: Preliminary report. North Carolina Wildlife Resources Commission, Raleigh, North Carolina, USA.

Brennan, L. A., J. M. Lee, E. Staller, S. Wellendorf, and R. S. Fuller. 1997. Effects of seasonal fire applications on bobwhite brood habitat and hunting success. Quail IV: Fourth National Quail Symposium.

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

Byrne, M. E. 2011. Influences of landscape characteristics on the nesting of female wild turkeys and behavior of raccoons. Dissertation, Louisiana State University, Baton Rouge, Louisiana, USA.

Cain, M. D., T. B. Wigley, and D. J. Reed. 1998. Prescribed fire effects on structure in uneven-aged stands of loblolly and shortleaf pines. Wildlife Society Bulletin 26:209-218.

Carlisle, W. D. 2003. The relationships between weather, mast production, and the breeding ecology of eastern wild turkeys in South Carolina. Thesis, Clemson University, Clemson, South Carolina, USA.

Carver, A. V., L. W. Burger, and L. A. Brennan. 1997. Bobwhite brood ecology in relation to fallow field management techniques and prescribed fire regime. Quail IV: Fourth National Quail Symposium.

Cochrane, J. C. 2003. Ecology of bobcats in a longleaf pine forest in southwestern Georgia. Thesis, University of Georgia, Athens, Georgia, USA.

Conner, L. M., B. D. Leopold, and K. J. Sullivan. 1992. Bobcat home range, density, and habitat use in east-central Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 46:147-158.

Daubenmire, R. F. 1959. A canopy coverage method of vegetational analysis. Northwest Science 33:43-64.

Dickson, J. G. 1981. Effects of forest burning on songbirds. Pages 67-72 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Doughty, J. 2004. Bobcat (Lynx rufus) ecology in a longleaf pine ecosystem in southwestern Georgia. Thesis, University of Georgia, Athens, Georgia, USA.

Eaton, S. W. 1992. Wild turkey (*Meleagris gallopavo*). A. Poole, editor. The Birds of North American Online. Ithaca: Cornell Lab of Ornithology.

Environmental Systems Resource Institute (ESRI). 2008. ArcMap 9.3. ESRI, Redlands, California, USA.

Exum, J. H. 1988. Turkey management in southeastern pine woods. Proceedings of the Game Bird Seminar. Tall Timbers Research, Inc., Tallahassee, Florida, USA.

Exum, J. H., J. A. McGlincy, D. W. Speake, J. L. Buckner, and F. M. Stanley. 1987. Ecology of the eastern wild turkey in an intensively managed pine forest in southern Alabama. Tall Timbers Research Station Bulletin 23. Tallahassee, Florida, USA.

Gehrt, S. D., and E. K. Fritzell. 1998. Resource distribution, female home range dispersion, and male spatial interactions: group structure in a solitary carnivore. Animal Behavior 55:1211–1227.

Georgia Department of Natural Resources (DNR). 2009. Silver Lake Wildlife Management Area 50-Year Habitat Plan. Georgia Department of Natural Resources Internal Report.

Glidden, J. W., and D. E. Austin. 1975. Natality and mortality of wild turkey poults in southwestern New York. Proceedings of the National Wild Turkey Symposium 3:48-54.

Godwin, K. D., G .A. Hurst, and B. D. Leopold. 1994. Movements of wild turkey gobblers in central Mississippi. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 48:117-122.

Hurst, G. A. 1981. Effects of prescribed burning on the eastern wild turkey. Pages 81-88 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Hurst, G. A., L. W. Burger, and B. D. Leopold. 1996. Predation and galliforme recruitment: an old issue revisited. Proceedings of the North American Wildlife and Natural Resources Conference 61:62-76.

Holbrook, H. T., M. R. Vaughan, and P. T. Bromley. 1987. Wild turkey habitat preference and recruitment in intensively managed piedmont forests. Journal of Wildlife Management 51:182-187.

Johnson, D. H. 1979. Estimating nest success: the Mayfield method and an alternative. Auk 96:651-661.

Johnson, D. H. 1981. The use and misuse of statistics in wildlife habitat studies. Pages 11-19 *in* D. E. Capen, editor. The use of multivariate statistics in studies of wildlife habitat. U.S. Forest Service General Technical Report RM-87, Fort Collins, Colorado, USA.

Jones, B. C. 2001. Wild turkey reproductive ecology on a fire-maintained national forest in Mississippi. Thesis, Mississippi State University, Starkville, Mississippi, USA.

Jones, B. C., J. E. Inglis, and G. A. Hurst. 2005. Wild turkey brood habitat use in relation to prescribed burning and red-cockaded woodpecker management. Proceedings of the National Wild Turkey Symposium 9:209-215.

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation from incomplete observations. Journal of American Statistics Association 53:457-481.

Komarek, E. V., Sr. 1964. The natural history of lightning. Proceedings Tall Timbers Fired Ecology Conference 3:139-183.

Komarek, E. V., Sr. 1969. Fire and animal behavior. Tall timbers Fire Ecology Conference 71:436-438.

Landers, J. L. 1981. The role of fire in bobwhite quail management. Pages 73-80 *in* G.W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Landers, J. L., and B. S. Mueller. 1986. Bobwhite quail management: a habitat approach. Tall Timbers Research Station Miscellaneous Publication 6, Tallahassee, Florida, USA.

Leberg, P. L., and M. L. Kennedy. 1988. Demography and habitat relationships of raccoons in western Tennessee. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 42:272–282.

Lehman, C. L., L. D. Flake, A. P. Leif, and R. D. Shields. 2001. Comparative survival and reproduction of sympatric eastern and Rio Grande wild turkey females in northeastern South Dakota. Proceedings of the National Wild Turkey Symposium 8:123-135.

Lemmon, P. E. 1956. A spherical densiometer for estimating forest overstory density. Forest Science 2:314-320.

Lotti, T. 1956. Eliminating understory hardwoods with summer prescribed fires in Coastal Plain loblolly pine stands. Journal of Forestry 54:191-192.

Main, M. B., M. J. Barry, K. Portier, B. J. Harper, and G. Allen. 2000. Effects of fire on soil nutrients, forage quality, and community composition on the Florida Panther NWR. Final Report to the United States Fish and Wildlife Service Florida Panther NWR. SWFREC-IMM-2000-03, Immokalee, Florida, USA.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

McGlincy, J. A. 1985. Wild turkeys and industrial forestry. Proceedings of the Tall Timbers Game Bird Seminar. Tall Timbers Research, Inc., Tallahassee, Florida, USA.

Miller, D. A., and L. M. Conner. 2007. Habitat selection within seasonal use areas of female eastern wild turkeys in a managed pine landscape in Mississippi. Journal of Wildlife Management 71:744-751.

Miller, J. E., and B. D. Leopold. 1992. Population influences: predators. Pages 119-128 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Miller, D. A., B. D. Leopold, and G. A. Hurst. 1998. Reproductive characteristics of a wild turkey population in central Mississippi. Journal of Wildlife Management 62:903-910.

Moore, W. F. 2006. Survival, nesting success, and habitat selection of wild turkey populations in the upper coastal plain of South Carolina. Thesis, Clemson University, Clemson, South Carolina, USA.

National Agriculture Imagery Program (NAIP). 2010. United States Department of Agriculture Farm Service Agency. Washington, D.C., USA.

Nguyen, L. P., J. Hamr, and G. H. Parker. 2003. Survival and reproduction of wild turkey hens in central Ontario. Wilson Bulletin 115:131-139.

Norman, G. W., J. C. Pack, C. I. Taylor, D. E. Steffen, and K. H. Pollock. 2001. Reproduction of eastern wild turkeys in Virginia and West Virginia. Journal of Wildlife Management 65:1-9.

Paisley, R. N., R. G. Wright, J. F. Kubisiak, and R. E. Rolley. 1998. Reproductive ecology of eastern wild turkeys in southwest Wisconsin. Journal of Wildlife Management 62:911-916

Palmer, W. E., G. A. Hurst, J. E. Stys, D. R. Smith, and J. D. Burk. 1993. Survival rates of wild turkey hens in loblolly pine plantations in Mississippi. Journal of Wildlife Management 57:783-789.

Pattee, O. H. 1977. Effects of nutrition on wild turkey reproduction in south Texas. Dissertation, Texas A&M University, College Station, Texas, USA.

Peoples, J. C., D. C. Sisson, and D. C. Guynn, Jr. 1995. Mortality of wild turkey poults in coastal plain pine forests. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 49:448-453.

Porter, W. F., G. C. Nelson, and K. Mattson. 1983. Effects of winter conditions on reproduction in northern wild turkey populations. Journal of Wildlife Management 47:281-290.

Provencher, L., N .M. Gobris. H. L. Rodgers, D. R. Gordon, and J. P. McAdoo. 1998. Scientific coordination and adaptive management and experimental restoration of longleaf pine community structure, function, and composition. Annual Report 3 (Dec 97-30 Mar 98). University of Florida, Gainesville, Florida, USA.

Pyne, S. J. 1982. Fire in America: a cultural history of wildland and rural fire. Princeton University Press, Princeton, New Jersey, USA.

R Core Team. 2012. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Rexstad, E. A., D. D. Miller, C. H. Flather, E. M. Anderson, J. W. Hupp, and D. R. Anderson. 1988. Questionable multivariate statistical inference in wildlife habitat and community studies. Journal of Wildlife Management 52:794-798.

Rexstad, E. A., D. D. Miller, C. H. Flather, E. M. Anderson, J. W. Hupp, and D. R. Anderson. 1990. Questionable multivariate statistical inference in wildlife habitat and community studies: a reply. Journal of Wildlife Management 54:189-193.

Robbins, L. E., and R. L. Myers. 1992. Seasonal effects of prescribed burning in Florida: a review. Tall Timbers Research, Inc., Miscellaneous Publication No. 8. Tallahassee, Florida, USA.

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

Roberts, S. D., J. M. Coffey, and W. F. Porter. 1995. Survival and reproduction of wild turkeys in New York. Journal of Wildlife Management 59:437-447.

Roberts, S. D., and W. F. Porter. 1996. Importance of demographic parameters to annual changes in wild turkey abundance. Proceedings of the National Wild Turkey Symposium 7:15-20.

Roberts, S. D., and W. F. Porter. 1998. Influence of temperature and precipitation on survival of wild turkey poults. Journal of Wildlife Management 62:1499-1505.

Rolley, R. E., J. F. Kubisiak, R. N. Paisley, and R. G. Wright. 1998. Wild turkey population dynamics in southwester Wisconsin. Journal of Wildlife Management 62:917-924.

Sanderson, G. C. 1987. Raccoon. Pages 486-499 *in* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Ontario.

Sauer, J. R., and B. K. Williams. 1989. Generalize procedures for testing hypotheses about survival and recovery rates. Journal of Wildlife Management 53:137-142.

Shaffer, T. L. 2004. A unified approach to analyzing nest success. The Auk 121:526-540.

Sisson, D. C., and D. W. Speake. 1994. Spring burning for wild turkey brood habitat: an evaluation. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 48:134-139.

Sisson, D. C., D. W. Speake, and J. L. Landers. 1991. Wild turkey brood habitat use in fire-type pine forests. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 45:49-57.

Sisson, D. C., D. W. Speake, J. L. Landers, and J. L. Buckner. 1990. Effects of prescribed burning on wild turkey habitat preference and nest site selection in south Georgia. National Wild Turkey Symposium 6:44-50.

Smith-Blair, A. E. 1993. Rio Grande wild turkey hen habitat and edge use, survival, and reproduction characteristics in the Texas Rolling Plains. Thesis, Texas Tech University, Lubbock, Texas, USA.

Southeast Wild Turkey Technical Committee. 2010. 36th technical committee meeting. Browns Summit, North Carolina, USA.

Speake, D. W. 1980. Predation on wild turkeys in Alabama. Proceedings of the National Wild Turkey Symposium 4:86-101.

Speake, D. W., R. Metzler, and J. McGlincy. 1985. Mortality of wild turkey poults in northern Alabama. Journal of Wildlife Management 49:472-474.

Spears, B. L, M. C. Wallace, W. B. Ballard, R. S. Phillips, D. P. Holdstock, J. H. Brunjes, R. Applegate, M. S. Miller, and P. S. Gipson. 2007. Habitat use and survival of preflight wild turkey broods. Journal of Wildlife Management 71:69-81.

Stoddard, H. L. 1935. Use of controlled fire in southeastern upland game management. Journal of Forestry 33:346-351.

Stransky, J. J., and R. E. Harlow. 1981. Effects of fire on deer habitat in the southeast. Pages 135-142 *in* G.W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Taylor, J. 1990. Questionable multivariate statistical inference in wildlife habitat and community studies: a comment. Journal of Wildlife Management 54:186-189.

Thogmartin, W. E., and J. E. Johnson. 1999. Reproduction in a declining population of wild turkeys in Arkansas. Journal of Wildlife Management 63:1281-1290.

Twedt, D. J., R. R. Wilson, J. L. Henne-Kerr, and R. B. Hamilton. 2001. Nest survival of forest birds in the Mississippi alluvial valley. Journal of Wildlife Management 65:450-460.

Vander Haegen, W. M., W. E. Dodge, and M. W. Sayre. 1988. Factors affecting productivity in a northern wild turkey population. Journal of Wildlife Management 52:12-133.

Vangilder, L. D. 1992. Population dynamics. Pages 144-164 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Vangilder, L. D., and E. W. Kurzejeski. 1995. Population ecology of the eastern wild turkey in northern Missouri. Wildlife Monographs 130.

Waldrop, T. A., D. L. White, and S. M. Jones. 1992. Fire regimes of pine-grassland communities in the southeastern United States. Forest Ecology and Management 47:195-210.

Wigley, T. B., J. M. Sweeney, M. E. Garner, and M. A. Melchiors. 1986. Wild turkey home ranges in Ouachita Mountains. Journal of Wildlife Management 50:540-544.

Williams, L. E., Jr., and D. H. Austin. 1988. Studies of the wild turkey in Florida. Florida Game and Freshwater Fish Commission, Technical Bulletin 10, Gainesville, USA.

Wilson, W. B., M. J. Chamberlain, and F. G. Kimmel. 2005. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 59:126-134.

Table 2-1. Results from *t*-tests for unequal variances identifying all significant ($P < 0.1$) microhabitat and landscape-level variables to be included in daily nest survival models of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Variable	Survived Mean (N=30)	SD	Failed Mean (N=21)	SD	P
%Bare Ground	8.70	10.06	7.56	9.04	0.67
%Debris	23.39	20.12	22.22	12.42	0.80
%Fern	3.37	7.66	4.33	5.67	0.61
%Forb	13.57	12.14	13.03	11.26	0.87
%Grass	18.56	14.42	16.36	9.32	0.51
%Vine	9.97	12.10	11.26	16.09	0.76
%Woody	22.43	15.99	25.24	12.56	0.49
%Canopy Closure (%CC)	48.76	31.92	63.30	23.96	0.07[a]
Average Visual Cover (VOavg)	11.00	3.30	11.24	2.28	0.76
Maximum Visual Cover (VOmax)	14.34	2.02	14.69	1.93	0.53
Minimum Visual Cover (VOmin)	8.64	3.21	8.43	2.93	0.81
Distance to Mature Pine (Dist1)	133.87	288.12	41.08	67.99	0.10[a]
Distance to Mature Pine-Hardwood (Dist2)	266.60	387.52	479.43	538.15	0.13
Distance to Shrub/Scrub (Dist3)	171.19	141.75	160.85	112.87	0.77
Distance to Wetland (Dist4)	1436.09	1798.63	2432.25	2634.11	0.14
Distance to Mature Hardwood (Dist5)	293.16	288.74	540.91	437.63	0.03[a]
Distance to Agriculture/Food Plot (Dist6)	433.15	621.61	1116.83	997.64	0.01[a]
Distance to Pine Plantation (Dist7)	197.13	267.47	106.69	149.55	0.13
Distance to Barren Land/Urban (Dist8)	603.40	453.19	1077.36	664.17	0.01[a]
Distance to Open Water (Dist9)	681.14	628.00	367.51	172.59	0.01[a]
Distance to Edge (DistEdge)	91.54	87.72	115.04	111.35	0.42
Distance to Roads (DistRoads)	54.79	52.44	56.90	59.06	0.90
Time-Since-Burn	1.50	0.86	1.19	0.75	0.18

[a] Indicates significant $P < 0.1$.

Table 2-2. Models, number of variables (*K*), distance from the lost second-order Akaike's Information Criterion (ΔAIC*c*), and model weights (w_i) for models explaining the effects of microhabitat variables (% canopy closure), landscape-level variables (distance to mature pine [1], hardwood [5], agriculture/food plot [6], open water [9]), and site and year on daily nest survival of 51 eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Model	*K*	ΔAIC*c*	w_i
Site + Landscape (Dist1, Dist5, Dist6, Dist9)	6	0.00	0.22
Landscape	5	0.20	0.20
Dist1	2	1.24	0.12
Dist6	2	1.86	0.09
Dist9	2	2.07	0.08
Dist5	2	2.12	0.08
%CC + Landscape	6	2.41	0.07
Year + Landscape	6	2.66	0.06
Site	2	4.01	0.03
Site + Year + %CC + Landscape	8	4.93	0.02
Site + %CC	3	5.36	0.01
%CC	2	5.76	0.01
Null	1	5.88	0.01
Site + Year	3	6.23	0.01
Year	2	7.97	0.00
Year + %CC	3	7.98	0.00

Table 2-3. Top-performing models, number of variables (*K*), distance from the second-order Akaike's Information Criterion ($\Delta AICc$), and adjusted model weights (w_i) explaining the effects of microhabitat variables (% canopy closure), landscape-level variables (distance to mature pine [1], hardwood [5], agriculture/food plot [6], open water [9]), and site and year on daily nest survival of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Model	*K*	$\Delta AICc$	Adjusted w_i
Site + Landscape (Dist1, Dist5, Dist6, Dist9)	6	0.00	0.24
Landscape	5	0.20	0.22
Dist1	2	1.24	0.13
Dist6	2	1.86	0.10
Dist9	2	2.07	0.09
Dist5	2	2.12	0.08
%CC + Landscape	6	2.41	0.07
Year + Landscape	6	2.66	0.06

Table 2-4. Model-averaged parameter estimates explaining the effects of microhabitat variables (% canopy closure), landscape-level variables (distance to mature pine [1], hardwood [5], agriculture/food plot [6], open water [9]), and site and year on daily nest survival, their standard errors, and 95% confidence intervals used to predict daily nest survival of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Effect	Model-Averaged Parameter Estimate	SE	Variable Weight	Lower 95% CI	Upper 95% CI
Dist1	-0.003	0.003	0.733	-0.008	0.002
Dist5	0.001	0.001	0.686	-0.001	0.002
Dist6	0.000	0.000	0.698	0.000	0.001
Dist9	-0.001	0.001	0.689	-0.002	0.000
%CC	0.000	0.001	0.073	-0.001	0.002
Site	-0.421	0.411	0.244	-1.227	0.384
Year	0.001	0.036	0.064	-0.070	0.073

[a] Indicates 95% CI does not contain zero.

Table 2-5. Mean and date ranges of the onset of incubation of initial nesting attempts of eastern wild turkeys at the Joseph W. Jones Ecological Research Center (JC) and Silver Lake Wildlife Management Area (SL), southwestern Georgia, USA, 2011-2012.

Year	Site	*N*	Mean Date	Range
2011	JC	6	13-Apr	5 April – 26 April
	SL	5	22-Apr	5 April – 9 May
2012	JC	14	19-Apr	27 March – 12 June
	SL	16	21-Apr	1 April – 2 June

Table 2-6. Reproductive parameters of eastern wild turkey nesting at the Joseph W. Jones Ecological Research Center (JC) and Silver Lake Wildlife Management Area (SL), southwestern Georgia, USA, 2011-2012. Numbers in parentheses correspond to the number of nesting attempts or successful nesting attempts of all females monitored from the start of the nesting season.

Year	Site	*N*	Initial Nesting Rate % (*N*)	Initial Nest Success % (*N*)	Renest Rate % (*N*)	Renest Success % (*N*)
2011	JC	8	75 (6)	83 (5)	100 (3)[b,c]	33 (1)[b,c]
	SL	10	50 (5)	60 (3)	0	N/A
Pooled		18	61 (11)	73 (8)	100 (3)[b,c]	33 (1)[b,c]
2012	JC	19	74 (14)	36 (5)[a]	80 (8)[a]	57 (4)[a]
	SL	25	64 (16)	25 (4)[a]	38 (5)[a,b,c]	20 (1)[a,b,c]
Pooled		44	75 (33)	30 (9)[a]	50 (13)[a,b,c]	42 (5)[a,b,c]
Pooled Sites and Years		62	71 (44)	41 (17)[a]	62 (16)[a,b,c]	40 (6)[a,b,c]

[a] Indicates observer-abandoned nests.
[b] Indicates triple nest.
[c] Indicates double-clutch.

Table 2-7. Mayfield nest success estimates (S), daily nest survival (DNS), and associated 95% confidence intervals for a 29-day incubation period of eastern wild turkeys at the Joseph W. Jones Ecological Research Center (JC) and Silver Lake Wildlife Management Area (SL), southwestern Georgia, USA, 2011-2012.

Year	Site	Nest Days	Failed Nests	Lower 95% CI	DNS	Upper 95% CI	S
2011	JC	166	3	0.96	0.98	1.00	0.59
	SL	100	2	0.95	0.98	1.01	0.56
2012	JC	449	5	0.98	0.99	1.00	0.72
	SL	336	11	0.95	0.97	0.99	0.38
Pooled Sites and Years		1051	21	0.97	0.98	0.99	0.56

Table 2-8. Poult survival of eastern wild turkey broods at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012. Numbers in parentheses correspond to the number of broods survived during that time period.

Year	Site	*N*	Day 1-14 (%survived)	Day 15-30 (%survived)
2011	JC	6	17 (1)	0
	SL	3	67 (2)	33 (1)
Pooled		9	33 (3)	11 (1)
2012	JC	9	22 (2)	11 (1)
	SL	5	60 (3)	40 (2)
Pooled		14	36 (5)	21 (3)
Pooled Sites and Years		23	35 (8)	17 (4)

Table 2-9. Reproductive parameters of adult female eastern wild turkeys in North America relative to the current study conducted at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Citation	Study Location	Adult Females (*N*)	Initial Nesting Rate (%)[a]	Initial Nest Success (%)[b]	Renest Rate (%)[c]	Renest Success (%)[d]
Vangilder and Kurzejeski 1995	Missouri	178	-	34.8	38.8	28.9
Vander Haegen et al. 1988	Massachusetts	19	-	68.0	57.1	50.0
Palmer et al. 1993	Mississippi	143	72.7	30.8	34.8	26.1
Miller et al. 1998	Mississippi	213	72.3	27.9	34.8	25.3
Paisley et al. 1998	Wisconsin	164	97.6	16.0	59.6	22.7
Norman et al. 2001	West Virginia and Virginia	533	79.9	-	-	-
Thogmartin and Johnson 1999	Arkansas	118	65.3	18.2	34.9	4.5
Nguyen et al. 2003	Ontario, Canada	22	68.2	46.7	-	-
Wilson et al. 2005	Louisiana	24	33.0	38.0	-	-
Byrne 2011	Louisiana	50	60.0	39.3	26.7	20.0
Current Study	Georgia	62	71.0	41.0	62.0	40.0

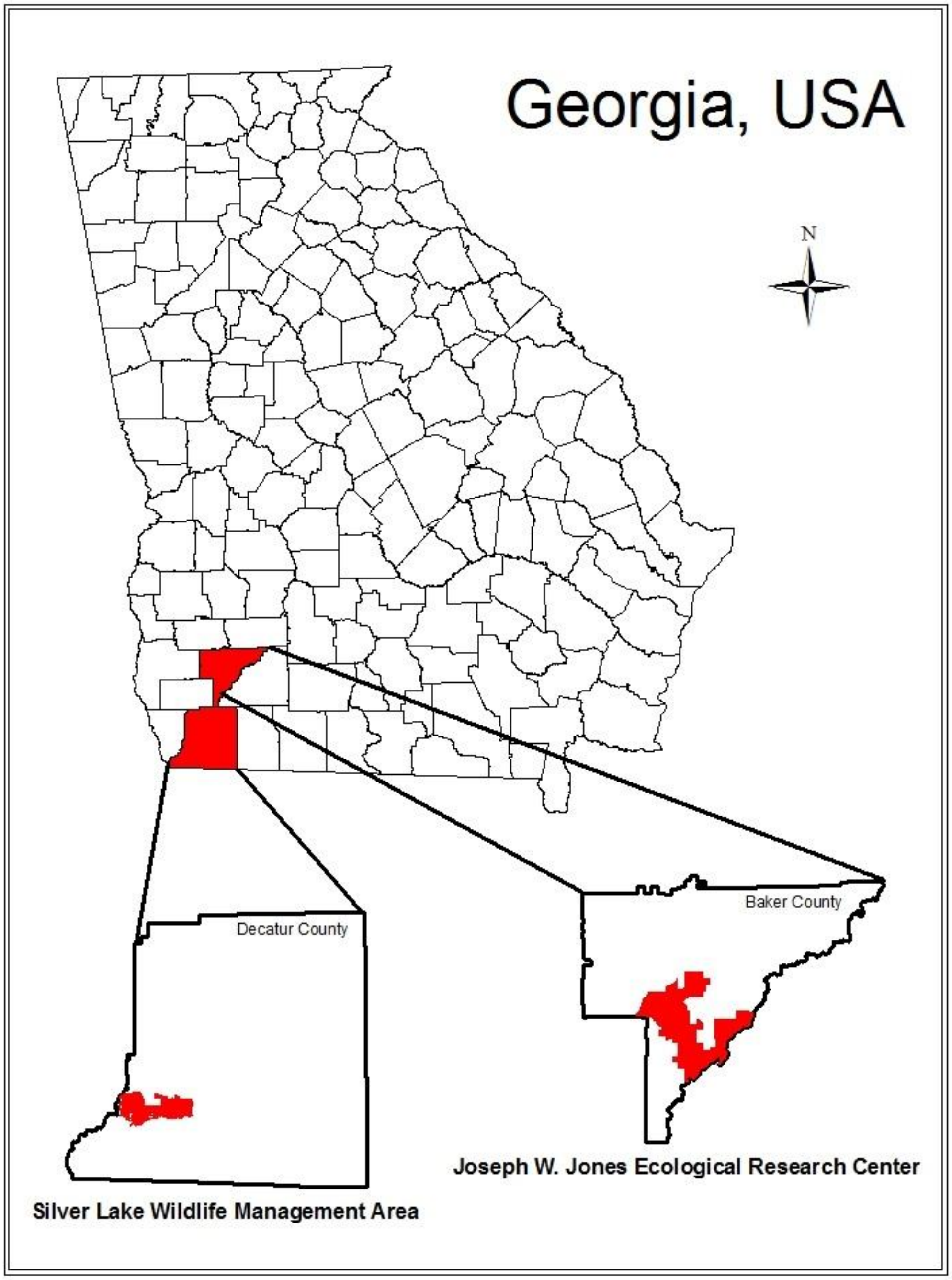
[a] Initial nesting rate is the percentage of adult females entering the nesting season that initiated incubation.

[b] Initial nest success is the proportion of nests that successfully hatched ≥1 egg.

[c] Renest rate is the percentage of adult females that renested following failure of their first nest or early brood loss.

[d] Renest success is the proportion of renests that successfully hatched ≥1 egg.

Figure 2-1. The Joseph W. Jones Ecological Research Center at Ichauway and the Georgia Department of Natural Resources' Silver Lake Wildlife Management Area in southwestern Georgia, USA.



CHAPTER 3

NEST SITE AND GROUND-ROOST SITE SELECTION OF EASTERN WILD TURKEYS IN SOUTHWESTERN GEORGIA

Williams, M. M. To be submitted to the Journal of Wildlife Management.

Abstract

Prescribed fires, including growing-season fires, are an important land management tool in the Southeast used to control hardwood encroachment into pine ecosystems and maintain native groundcover and open vegetation communities. Burning during all seasons, including the growing-season, increases opportunities of creating a mosaic of 2-3-year burn patches across the landscape. If used properly, growing-season fires can also benefit eastern wild turkey (*Meleagris gallopavo silvestris*) populations by improving nesting and ground-roosting habitats. My objective was to determine micro and landscape-level habitat associated with nest and ground-roost site selection of female wild turkeys on 2 similar study sites in southwestern Georgia—the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area. Habitat data associated with 52 nests and 31 preflight ground-roosts were collected during the 2011 and 2012 nesting seasons. Nests were characterized by less canopy cover, greater woody ground cover, and greater minimum vegetation height relative to random sites. Ground-roosts were further from mature pine stands relative to random sites. Nesting females selected open canopy areas and ground-roosting females selected areas outside of mature pine stands. Management on properties in the Southeastern coastal plain, which have high densities of mature pine stands, should focus on maintaining a mosaic of open canopy areas to promote understory herbaceous growth for nesting cover and areas such as food plots and agricultural fields around forested stands for ground-roosting cover and poult feeding. Herbaceous growth and woody stem densities will also increase through a rotating application of small-scale growing-season prescribed fires (< 20 ha).

Introduction

Prescribed fire is commonly used in the Southeast to control hardwood encroachment and maintain native groundcover within pine ecosystems (Waldrop et al. 1992, Cain et al. 1998). Prescribed fire promotes herbaceous vegetation, which is used for cover and nesting and brood-rearing habitat for various ground-nesting birds (Dickson 1981, Hurst 1981, Landers 1981). Growing-season prescribed fires are often advocated to control invading hardwoods and understory shrubs (Lotti 1956) and promote native vegetation. Traditionally, fire in the longleaf (*Pinus palustris*) – wiregrass (*Aristida stricta*) system was ignited by lightning during the growing-season (Komarek 1964, Pyne 1982, Robbins and Myers 1992).

Land managers and hunters interested in ground-nesting birds have expressed significant concern over the use of growing-season fires by state and federal agencies, but little research has examined effects of growing-season fires on nest and brood ecology of wild turkeys (Robbins and Myers 1992). Some wild turkey biologists have expressed concern that the potential effect of growing-season fires on turkey populations might be a factor in the decline in hunter harvest rates for wild turkeys observed during the past 5-10 years in several states across the Southeast, including Georgia (Kevin Lowrey, unpublished data), Alabama (Steve Barnett, unpublished data), and South Carolina (Charles Ruth, unpublished data).

Most research on the effects of fire on wildlife focuses on forage availability and quality (Stransky and Harlow 1981, Robbins and Myers 1992, Main et al. 2000). Growing-season fires produce results similar to natural lightning ignitions (Robbins and Myers 1992) and may improve turkey brood-rearing habitat by increasing insect abundance, adding variety to seed banks, and enhancing plant growth (McGlincy 1985, Landers and Mueller 1986, Exum 1988, Provencher et al. 1998). Short-term studies have indicated that growing-season fires can have a negative effect on wild turkeys populations (Sisson and Speake 1994) and other game birds, such as northern bobwhite quail (*Colinus virginianus*) (Brennan et al. 1997, 1998; Carver et al. 1997). Stoddard (1935) suggested withholding growing-season fire to avoid destroying wild turkey nests.

Wild turkey females will use a variety of habitats (Hurst and Dickson 1992); for instance, they will nest in areas that have an abundance of ground cover and a high density of woody vegetation, and they will also use mature pine stands and mixed forest types (Speake et al. 1975, Seiss et al. 1990, Still and Bauman 1990, Badyaev 1995). Females have been observed nesting in stands that have been burned within the previous 2 years (Still and Bauman 1990), and have been observed avoiding nesting in areas greater than 2 years since burn (Allen et al. 1996). Sisson et al. (1990) documented 62% of all nests occurred in mature pine forests burned within 2 years or less and broods were observe using areas. Despite this information more research is needed to understand the effects of growing-season fire on wild turkey nest site selection.

Wild turkey broods use a variety of forest stand types and forest openings—showing preference for areas with moderate herbaceous ground cover (Jones et al. 2005). Studies have shown broods will select for more open areas, such as pastures or forest openings, for their increased abundance in invertebrates for poult feeding (Hillestad and Speake 1970, Hurst and Stringer 1975, Martin and McGinnes 1975, Sisson et al. 1991). These areas may also provide cover from predators as a result of their higher herbaceous ground cover (Sisson et al. 1991, Harper et al. 2001). Frequency of prescribed fire has also been shown to influence brood use of a specific habitat type. Separate studies conducted in Mississippi have shown broods using mixed pine-hardwood stands burned on a 2-3-year rotation (Jones et al. 2005), mature bottomland hardwoods in areas where upland pine stands were burned infrequently (Phalen et al. 1986, Jones et al. 2005), and mature pine stands burned 3 years earlier (Burk et al. 1990, Palmer 1990). Ground-roost site selection by broods has been studied much less rigorously than nest site selection, so more research is needed to understand the effects of growing-season prescribed fire on wild turkey ground-roost site selection. My objectives were to investigate wild turkey nest and ground-roost site selection at micro and landscape-level scales and determine effects of time-since-burn and growing-season fire on selection.

Methods

Study Sites

This research was conducted on 2 similar study sites in southwestern Georgia—The Joseph W. Jones Ecological Research Center at Ichauway (Jones Center) and the Silver Lake Wildlife Management Area (Silver Lake WMA; Figure 3-1).

The Jones Center portion of my research was focused on Ichauway, a 12,000 ha outdoor research laboratory located in Baker County, Georgia, USA, and former northern bobwhite quail hunting plantation and surrounding properties (total study area 15,299 ha). The Ichawaynochaway Creek bisects the property and the Flint River borders the property to the east. The site includes a variety of forest types, including longleaf pine, loblolly pine (*Pinus taeda*), slash pine (*P. elliottii*), mixed pine and hardwood forests, oak barrens, lowland hardwood hammocks, and cypress-gum (*Taxodium ascendens-Nyssa biflora*) limesink ponds (Boring 2001). Twenty-nine percent of the area is mature pine, 21% mature pine-hardwood, 5% shrub/scrub, 3% forested and herbaceous wetlands, 9% hardwood, 18% agriculture/food plot, 11% evergreen pine plantation, 2% barren land/urban, and 2% open water. Prescribed fire is the primary tool for conserving native ground cover and controlling hardwood encroachment, with approximately 50% of the site being burned each year (Atkinson et al. 1996). Upland sites in particular are burned on an approximate 2-year burn rotation. Prescribed fire is applied throughout the year on the property; however, most burns are initiated from March – August. Prescribed fire creates a matrix of burned and unburned habitats, and allows areas burned in the winter sufficient re-growth to provide suitable nesting and foraging habitat for wild turkeys the following spring. Turkey hunting was not permitted on the Jones Center prior to or during my research.

Wiregrass, a fire-dependent species that requires growing-season fires to flower, dominates approximately 25% of the understory at the Jones Center. Since 1994, over 3,925 ha of the site has undergone significant hardwood removal, with the majority occurring since 2001 (Brandon Rutledge, personal communication). The scattered individual hardwoods and hardwood patches that exist throughout the site provided an important mast source for wildlife, including wild turkeys. Furthermore, historical management for northern bobwhite quail on the site has created a diverse habitat mosaic of small weedy openings and food plots interspersed within the forested ecosystem. Despite the intense burn regime at the Jones Center, including growing-season fires, wild turkey populations increased during the decade prior to my research (L.M. Conner, unpublished data), suggesting that wild turkey populations could be maintained while using growing-season prescribed fires.

The Silver Lake Wildlife Management Area (WMA) portion of my research was focused on the WMA, a 3,900 ha property owned by the Georgia Department of Natural Resources and located in Decatur County, Georgia, USA, and surrounding properties (total study area 7,731 ha). The Flint River borders the property to the east, Spring Creek to the west, and Lake Seminole to the south. Silver Lake WMA consists of a variety of forest types, including longleaf pine, loblolly pine (*Pinus taeda*), slash pine (*P. elliottii*), mixed pine and hardwood forests, hardwood forests, lowland hardwood hammocks, as well as many depressional wetlands, ponds, and the 150-ha Silver Lake (Silver Lake WMA 50-Year Plan 2009, Georgia DNR 2009). Twenty-six percent of the area is mature pine, 12% mature pine-hardwood, 1% shrub/scrub, 0% forested and herbaceous wetlands, 1% hardwood, 9% agriculture/food plot, 19% evergreen pine plantation, 1% barren land/urban, and 31% open water. Agricultural fields occur along the northern border of the property and no agricultural fields or food plots occur within the property. Like the Jones Center, the primary natural vegetation management tool used on Silver Lake WMA is prescribed fire, on an approximately 2-year burn rotation. Prior to becoming a WMA, most prescribed fires were conducted during the dormant-season, with few occurring during the growing-season. However, under new management the property is burned more frequently during the growing-season, and the scale of burns were reduced to promote landscape diversity by creating a larger array of stands with varying burn histories. To create a diverse fire-maintained upland plant community that provides quality wildlife habitat for game and non-game species, management is focused on restoration of native groundcover, reduction of undesirable hardwoods, such as water oak (*Quercus nigra*), and establishment of desirable fire-tolerant upland hardwoods, such as post oak (*Quercus stellata*) and southern red oak (*Quercus falcata*), in certain upland sites. Additional management for species, such as the northern bobwhite quail, has also created a diverse habitat mosaic of small openings within the forested stands. The property provides hunting and other opportunities for the general public.

Capture and Radio Telemetry

Female wild turkeys were captured with rocket nets at bait sites of cracked corn distributed throughout the 2 study sites during the winter (December – March) of 2010-2011, summer (June-August) of 2011, and winter of 2011-2012. Bait sites were checked twice daily, and capture attempts were made after consistent use of sites by females. Once captured, turkeys were removed from the net, classified as adults or juveniles (Williams and Austin 1988), and placed into cardboard boxes designed specifically to accommodate wild turkeys (76.2 × 35.6 × 61-cm). All captured females were fitted with serially numbered, butt-end (left leg) and riveted (right leg) aluminum leg bands (National Band and Tag Co., Newport, KY). A mortality-sensing VHF radio-transmitter, weighing approximately 60-g, (Sirtrack, Havelock North, New Zealand; and Telenax, Playa del Carmen, México) was attached backpack-style to all captured females. All birds were released at the capture site immediately after processing. Capture and handling followed protocols approved by The University of Georgia Institutional Animal Care and Use Committee, Permit number A2010 7-120.

Radio-tagged females were located by triangulation from roads (Cochran and Lord 1963) using a hand-held 3-element Yagi antenna and Wildlife Materials TRX 2000S receiver (Wildlife Materials, Murphysboro, Illinois). Locations were calculated by triangulation of azimuth readings recorded in the field using a mobile phone fitted with Location Of A Signal-SD (LOAS-SD) software (Ecological Software Solutions, LLC) and a Bluetooth-GPS unit.

Nest ecology and brood ecology was studied during the 2011 and 2012 nesting seasons. Females were located 3 times per week from August to early March, and ≥1 time per day during the nesting season to ensure all nesting activity was detected. A female was assumed to have initiated incubation when she was found in the same location for 2 consecutive days. Once a female was determined to be incubating, the nest was approached to within 25-m and compass bearings were recorded toward the nest to facilitate locating the nest after hatch or nest loss. Several nests were also located opportunistically by the Jones Center and Silver Lake WMA staff, and these nests were used to increase our sample size for our nest success analysis. Several nests were also located opportunistically by the Jones Center and Silver Lake WMA staff, and these nests were also used for nest site selection analyses.

After termination of incubation the nest was located and its location was recorded using a GPS unit. If a nest could not be located, the estimated nest location was used as the nest site. Radio-telemetry and backdating of nests were used to determine nest initiation dates. Clutch size, brood size, and nest fate were also recorded. Clutch size was determined from counts of unhatched eggs and egg caps. Initial brood size was defined as the number of hatched eggs in each nest. Nests were categorized as successful (if ≥1 egg hatched) or unsuccessful (if no eggs hatched). Nests were considered depredated if eggs were found destroyed, trampled, or carried away from the nest site. Nests were considered abandoned if the nest site seemed undisturbed and an intact clutch of eggs was found.

During the brood flightless period (up to 14 days post-hatch), ground-roost sites were located 30 minutes before dawn by locating ground-roosting females. Ground-roosts were approached to within 15-m and compass bearings were recorded toward the ground-roost to facilitate locating site. After brood departure, the ground-roost site was located and its location was recorded using a GPS unit.

Habitat Analyses

Microhabitat variables associated with the nests, ground-roosts, and random sites were measured to determine if microhabitat influenced nest and ground-roost site selection. Variables included understory vegetation height, percent canopy cover, and percent ground cover. Understory vegetation height at nests, ground-roosts and random sites were taken using a Robel pole (Robel et al. 1970). The robel pole was placed at the center of the site and minimum, average, and maximum understory vegetation height readings were taken from the 4 cardinal directions at a distance of 15 m from the center, while facing the pole at approximately 1-m in height. All 4 readings for each of the 3 vegetation height measurements were then averaged. A spherical densiometer was used to estimate canopy cover at nests, ground-roosts and random sites (Lemmon 1956). Five readings were taken and then averaged using the densiometer—1 reading at the center of the site and 4 at 15-m away from the center in each cardinal direction. A 1-m^2 Daubenmire frame was used to measure ground cover type percentages at nests, ground-roosts and random sites (Daubenmire 1959). Five readings were taken and then averaged using the Daubenmire frame—1 reading at the center of the site and 4 at 15-m away from the center in each cardinal direction. Ground cover was partitioned into 7 cover types, including bare ground, debris, fern, forb, grass, vine, and woody.

To investigate nest and ground-roost site selection at the landscape level point data at nests, ground-roosts and random sites was intersected with land cover and time-since-burn data in ArcGIS 9.3 (ESRI 2008). Nine habitat types were created within ArcGIS 9.3 (ESRI 2008): mature pine, mature pine-hardwood, shrub/scrub, forested/herbaceous wetlands, mature hardwood, agriculture field/food plot, evergreen pine plantation, barren land/urban, and open water. Land cover polygons for nest and ground-roost sites located outside property boundaries were manually digitized in ArcGIS 9.3 (ESRI 2008) from 2010 digital orthophoto quarter quadrangles (NAIP 2010). Detailed burn history data from January 2009—to present was compiled for each study site in ArcGIS 9.3 (ESRI 2008). Years-since-burn for nest, ground-roost sites and random locations were determined, and point distances (m) were calculated in meters to the nearest road, open water, edge between forest habitats and openings, and all 9 habitat types in ArcGIS 9.3 (ESRI 2008).

For each nest and ground-roost site a random site was selected using a random point generator in ArcGIS 9.3 (ESRI 2008). Random sites were used to compare actual nest and ground-roost sites as a basis for determining habitat selection by females prior to nesting or ground-roosting. Nest and ground-roost sites were sampled within 2 weeks after nesting or ground-roosting ended to ensure sampling of site vegetation characteristics similar to those that would have been present when the sites were selected by females. Random sites were sampled an average of 6 days from the associated nest or ground-roost site sampling date.

Data Analyses

To include relevant microhabitat and landscape-level variables within nest and ground-roost site selection models, univariate statistics (*t*-tests, for unequal variances) were used to first identify significant ($P < 0.1$) variables (Johnson 1981; Rexstad et al. 1988, 1990; Taylor 1990; Table 3-1; Table 3-6). The number of variables included in model construction was further reduced by eliminating highly correlated ($|r| > 0.7$) variables (Brennan et al. 1986).

Logistic regression (Hosmer and Lemeshow 2000) was used to develop models to predict whether nest site and ground-roost site selection were associated with microhabitat and landscape-level variables, study site variables, and temporal variables (e.g., year) using the GLM procedure (R Core Team, Vienna, Austria). Nests, ground-roosts, and random sites were used as the dichotomous response variable in the model, and the predictor variables consisted of microhabitat and landscape-level variables, site variables, and temporal variables (e.g., year). Nineteen models were developed using variables from univariate and correlation filters to describe nest site selection (Table 3-2), and 9 models to describe ground-roost site selection (Table 3-7). I then used the second-order Akaike's Information Criteria (AIC_c) to determine the weight of evidence in support of those models (Akaike 1973, Burnham and Anderson 2002). The model with the lowest AIC_c was considered to be the best model, and all models with $AIC_c < 4.0$ units from the best model as the best set of approximating models. Akaike weights (w_i) for each model were then calculated as an estimate of the probability of the model being the most predictive of the developed models (Table 3-2; Table 3-7). Model-averaging was then used to calculate parameter estimates and unconditional standard errors (Burnham and Anderson 2002) of the top-performing models within 4 AIC_c based on their adjusted w_i (Table 3-3; Table 3-8). Model-averaged parameter weights and their variable weights and 95% confidence intervals were then calculated. Only those parameter estimates with 95% confidence intervals that excluded zero were considered important predictors (Miller and Conner 2007; Table 3-4; Table 3-9).

Results

Sixty-two nests were discovered; 57 were associated with radio-tagged females and 5 were found opportunistically. Of all nests, 7 were affected by growing-season prescribed fire and were removed from nest site selection analyses because vegetation could not be sampled. Thus, 52 nests were used for nest site selection analysis, 23 from Silver Lake WMA and 29 from Jones Center. I monitored 23 broods and 2 survived past 30 days when they became indistinguishable in size from the females (Table 2-8). Only 1 brood was lost to a growing-season fire that occurred immediately after hatch. The highest loss of broods (65%) occurred during the first 14 days after hatching (Table 2-8). A total of 31 ground-roosts were used for the ground-roost site selection analysis, 11 from Silver Lake WMA and 20 from Jones Center.

For the nest site selection analysis, the site and microhabitat (CC, Debris, Woody, VOmax, VOmin) model was the best model of the set (w_i = 0.350; Table 3-2), but it was only slightly better than the microhabitat (w_i = 0.241), site, year, microhabitat and landscape (w_i = 0.190), and year and microhabitat models (w_i = 0.167). Model-averaged parameter estimates based on the top-performing models (Table 3-3) suggested that percent canopy closure, minimum vegetation height, and percent woody ground cover were important variables (Table 3-4). Parameter estimates suggested a negative relationship between percent canopy closure and the probability that a female would use a nest site, whereas minimum vegetation height and percent woody vegetation were positively associated with the probability that a female would use a nest site (Table 3-4). The average percent canopy closure at nest sites was 54% compared to random locations (65%), the average minimum vegetation height was 8.5 dm compared to random locations (3.9-dm), and the average percent woody ground cover was 24% compared to random locations (12%) (Table 3-4; Table 3-5).

For the ground-roost site selection analysis, the distance to mature pine model received was the best model of the set (w_i = 0.428; Table 3-7) and it was 2 times better than the next best model (the landscape model) (w_i = 0.203), and nearly 3 times better than the site and landscape model (w_i = 0.187). Model-averaged parameter estimates based on the top-performing models (Table 3-8) suggested that only the distance to mature pine had a parameter estimate that did not include zero in the 95% confidence interval (Table 3-9); thus, this was the only variable useful for predicting ground-roost site selection. The parameter estimate suggested a positive relationship between distance from mature pine stands and probability of use as a ground-roost site, with ground-roosts located on average 134 m from mature pine stands compared to random locations with an average distance of 35 m from mature pine stands (Table 3-9; Table 3-10). Similarities, especially at the microhabitat level, between nest and ground-roost locations relative to random locations are noticeable (Table 3-11).

Discussion

Nest sites were positively associated with a greater minimum vegetation height for both study sites. Previous studies have shown that ground level vegetation cover is an important factor in nest site selection of wild turkey females (Still and Bauman 1990, Chamberlain and Leopold 1998), and concealment from predators may be a driving factor influencing selection of nest sites (Lehman et al. 2008).

Nests in openings, such as fields or food plots, were concealed by a variety of vegetation types, including blackberry (*Rubus* spp.) and various grass and food plot species, while nests in forested areas were concealed by a variety of vegetation types, including vines such as greenbrier (*Smilax* spp.), blackberry (*Rubus* spp.), wiregrass, bracken fern (*Pteridium aquilinum*), small woody shrubs/trees, and woody debris. Nests were negatively associated with greater canopy closure, which likely indicates that increased sunlight led to a greater understory herbaceous ground cover and growth of small woody shrubs or trees that offered nest concealment. Highlighting the importance of understory woody coverage for nest concealment, nests were positively associated with a greater percent woody cover across both study sites. Similarly, other studies have shown that females select nest sites with greater understory vegetation density and woody stem density relative to random sites (Bowman and Harris 1980, Healy 1981, Ransom et al. 1987, Rumble and Hodorff 1993, Badyaev 1995). This negative association with canopy cover could also be indicative of a number of the nests being located near field edges or within food plots on the 2 study sites.

Ground-roosts were more likely to occur further from mature pines stands than random locations across both study sites. Habitat management for the northern bobwhite quail on the 2 study sites created a mosaic of food plots and openings dominated by early successional plant communities within the forested stands. Therefore, brooding females were likely sampling for open areas outside of mature pine stands. These open areas could include food plots, agricultural fields and shrubby areas, which have been shown to be used by broods for their insect abundance and cover (Hillestad and Speake 1970, Hurst and Stringer 1975, Martin and McGinnes 1975, Sisson et al. 1991).

Nesting females selected areas with an open canopy and ground-roosting females selected areas further from mature pine stands. Management on properties in the Southeastern coastal plain, which have high densities of mature pine stands, should focus on maintaining a mosaic of open areas within and around forested stands if the goal is to create or maintain nest and ground-roost cover for wild turkeys. The open canopy areas will allow for herbaceous understory growth (Peitz et al. 2001) facilitating nest and ground-roost concealment. Herbaceous growth and woody stem densities will also increase through a rotating application of small-scale prescribed fires, including growing-season fires, throughout the year (Jones Center 2010). Continued research on these 2 study sites will aid in better understanding the importance of fire in nest and ground-roost site selection.

References

Akaike, H. 1973. Information theory and an extension of the maximum likelihood principle. Pages 267-281 *in* B. N. Petrov and F. Csaki, editors. Proceedings of the Second International Symposium on Information Theory. Akademiai Kiado, Budapest, Hungary.

Allen, A. W., Y. K. Bernal, and R. J. Moulton. 1996. Pine plantations and wildlife in the southeastern United States: an assessment of impacts and opportunities. Information and Technology Report 3, U.S. Department of the Interior, Washington, D.C., USA.

Atkinson, J., J. Brock, and R. Smith. 1996. Operational longleaf pine management at Ichauway. The longleaf alliance annual meeting, Mobile, Alabama, USA.

Badyaev, A. V. 1995. Nesting habitat and nesting success of eastern wild turkeys in the Arkansas Ozark Highlands. The Condor 97:221-232.

Boring, L. R. 2001. The Joseph W. Jones Research Center: Co-directed applied and basic research in the private sector. Pages 233-258 *in* G. W. Barrett and T. L. Barret, editors. Holistic science: the evolution of the Georgia Institute of Ecology (1940-2000). Taylor and Francis, New York, New York.

Bowman, G. B., and L. D. Harris. 1980. Effect of spatial heterogeneity on ground nest depredation. Journal of Wildlife Management 44:807-813.

Brennan, L. A., W. M. Block, R. J. Gutierrez. 1986. The use of multivariate statistics for developing habitat suitability index models. Pages 177-182 *in* J. Verner, M. L. Morrison, and C. J. Ralph, editors. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. University of Wisconsin Press, Madison, USA.

Brennan, L. A., J. M. Lee, E. Staller, S. Wellendorf, and R. S. Fuller. 1997. Effects of seasonal fire applications on bobwhite brood habitat and hunting success. Quail IV: Fourth National Quail Symposium.

Brennan, L. A., C. L. Hardy, L. W. Burger, and T. Sharpe. 1998. Assessing bobwhite population and habitat response to dormant and lightning prescribed fire in the North Carolina Sandhills: Preliminary report. North Carolina Wildlife Resources Commission, Raleigh, North Carolina, USA.

Burk, J. D., D. R. Smith, G. A. Hurst, B. D. Leopold, and M. M. Melchiors. 1990. Wild turkey use of loblolly pine plantations for nesting and brood rearing. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 44:163-170.

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

Cain, M. D., T. B. Wigley, and D. J. Reed. 1998. Prescribed fire effects on structure in uneven-aged stands of loblolly and shortleaf pines. Wildlife Society Bulletin 26:209-218.

Chamberlain, M. J., and B. D. Leopold. 1998. Microhabitat characteristics of wild turkey prenest and nest site selection in central Mississippi. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 52:274-282.

Daubenmire, R. F. 1959. A canopy coverage method of vegetational analysis. Northwest Science 33:43-64.

Dickson, J. G. 1981. Effects of forest burning on songbirds. Pages 67-72 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Environmental Systems Resource Institute (ESRI). 2008. ArcMap 9.3. ESRI, Redlands, California, USA.

Exum, J. H. 1988. Turkey management in southeastern pine woods. Proceedings of the Game Bird Seminar. Tall Timbers Research, Inc., Tallahassee, Florida, USA.

Georgia Department of Natural Resources (DNR). 2009. Silver Lake Wildlife Management Area 50-Year Habitat Plan. Georgia Department of Natural Resources Internal Report.

Harper, C. A., J. K. Know, D. C. Guynn, Jr., J. R. Davis, and J. G. Williams. 2001. Invertebrate availability for wild turkey poults in the southern Appalachians. Proceedings of the National Wild Turkey Symposium 8:145-156.

Healy, W. M. 1981. Habitat requirements and habitat management for the wild turkey in the southeast. Virginia Wild Turkey Foundation, Ellison, Virginia, USA.

Hillestad, H. O, and D. W. Speake. 1970. Activities of wild turkey hens and poults as influenced by habitat. Proceedings of the Southeastern Association of Game and Fish Commissions 24:244-251.

Hosmer, D.W., and S. Lemeshow. 2000. Applied logistic regression. John Wiley and Sons, New York, New York, USA.

Hurst, G. A. 1981. Effects of prescribed burning on the eastern wild turkey. Pages 81-88 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Hurst, G. A., and J. G. Dickson. 1992. Eastern turkey in southern pine-oak forests. Pages 265-285 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Hurst, G. A., and B. D. Stringer. 1975. Food habits of wild turkey poults in Mississippi. Proceedings of the National Wild Turkey Symposium 3:76-85.

Johnson, D. H. 1981. The use and misuse of statistics in wildlife habitat studies. Pages 11-19 *in* D. E. Capen, editor. The use of multivariate statistics in studies of wildlife habitat. U.S. Forest Service General Technical Report RM-87, Fort Collins, Colorado, USA.

Jones, B. C., J. E. Inglis, and G. A. Hurst. 2005. Wild turkey brood habitat use in relation to prescribed burning and red-cockaded woodpecker management. Proceedings of the National Wild Turkey Symposium 9:209-215.

Joseph W. Jones Ecological Research Center (Jones Center). 2010. The prescribed fire management program at Ichauway 1994-2009. <http://www.jonesctr.org/conservation/prescribed_fire/RxFireReport_2009.pdf>. Accessed 15 September 2012.

Komarek, E. V., Sr. 1964. The natural history of lightning. Proceedings Tall Timbers Fired Ecology Conference 3:139-183.

Landers, J. L. 1981. The role of fire in bobwhite quail management. Pages 73-80 *in* G.W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, South Carolina, USA.

Landers, J. L., and B. S. Mueller. 1986. Bobwhite quail management: a habitat approach. Tall Timbers Research Station Miscellaneous Publication 6, Tallahassee, Florida, USA.

Lehman, C. P., M. A. Rumble, L. D. Flake, and D. J. Thompson. 2008. Merriam’s turkey nest survival and factors affecting nest predation by mammals. Journal of Wildlife Management 72:1765-1774.

Lemmon, P. E. 1956. A spherical densiometer for estimating forest overstory density. Forest Science 2:314-320.

Lotti, T. 1956. Eliminating understory hardwoods with summer prescribed fires in Coastal Plain loblolly pine stands. Journal of Forestry 54:191-192.

Main, M. B., M. J. Barry, K. Portier, B. J. Harper, and G. Allen. 2000. Effects of fire on soil nutrients, forage quality, and community composition on the Florida Panther NWR. Final Report to the United States Fish and Wildlife Service Florida Panther NWR. SWFREC-IMM-2000-03, Immokalee, Florida, USA.

Martin, D. D., and B. S. McGinnes. 1975. Insect availability and use by turkeys in forest openings. Proceedings of the National Wild Turkey Symposium 3:70-75.

Miller, D. A., and L. M. Conner. 2007. Habitat selection within seasonal use areas of female eastern wild turkeys in a managed pine landscape in Mississippi. Journal of Wildlife Management 71:744-751.

McGlincy, J. A. 1985. Wild turkeys and industrial forestry. Proceedings of the Tall Timbers Game Bird Seminar. Tall Timbers Research, Inc., Tallahassee, Florida, USA.

National Agriculture Imagery Program (NAIP). 2010. United States Department of Agriculture Farm Service Agency. Washington, D.C., USA.

Palmer, W. E. 1990. Relationships of wild turkey hens and their habitat on Tallahala Wildlife Management Area. Thesis, Mississippi State University, Mississippi State, Mississippi, USA.

Peitz, D. G., M. G. Shelton, and P. A. Tappe. 2001. Forage production after thinning natural loblolly pine-hardwood stand to different basal areas. Wildlife Society Bulletin 29:697-705.

Phalen, P. S., G. A. Hurst, and W. J. Hamrick. 1986. Brood habitat use and preference by wild turkeys in central Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 40:397-404.

Provencher, L., N. M. Gobris. H. L. Rodgers, D. R. Gordon, and J. P. McAdoo. 1998. Scientific coordination and adaptive management and experimental restoration of longleaf pine community structure, function, and composition. Annual Report 3 (Dec 97-30 Mar 98). University of Florida, Gainesville, Florida, USA.

Pyne, S. J. 1982. Fire in America: a cultural history of wildland and rural fire. Princeton University Press, Princeton, New Jersey, USA.

R Core Team. 2012. A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria.

Ransom, D., Jr., O. J. Rongstad, and D. H. Rusch. 1987. Nesting ecology of Rio Grande turkeys. Journal of Wildlife Management 51:435-439.

Rexstad, E. A., D. D. Miller, C. H. Flather, E. M. Anderson, J. W. Hupp, and D. R. Anderson. 1988. Questionable multivariate statistical inference in wildlife habitat and community studies. Journal of Wildlife Management 52:794-798.

Rexstad, E. A., D. D. Miller, C. H. Flather, E. M. Anderson, J. W. Hupp, and D. R. Anderson. 1990. Questionable multivariate statistical inference in wildlife habitat and community studies: a reply. Journal of Wildlife Management 54:189-193.

Robbins, L. E., and R. L. Myers. 1992. Seasonal effects of prescribed burning in Florida: a review. Tall Timbers Research, Inc., Miscellaneous Publication No. 8. Tallahassee, Florida, USA.

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

Rumble, M. A., and R. A. Hodorff. 1993. Nesting ecology of Merriam’s turkeys in the Black Hills, South Dakota. Journal of Wildlife Management 57:789-801.

Seiss, R. S., P. S. Phalen, and G. A. Hurst. 1990. Wild turkey habitat and success rates. Proceedings of the National Wild Turkey Symposium 6:18-24.

Sisson, D. C., and D. W. Speake. 1994. Spring burning for wild turkey brood habitat: an evaluation. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 48:134-139.

Sisson, D. C., D. W. Speake, and J. L. Landers. 1991. Wild turkey brood habitat use in fire-type pine forests. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 45:49-57.

Sisson, D. C., D. W. Speake, J. L. Landers, and J. L. Buckner. 1990. Effects of prescribed burning on wild turkey habitat preference and nest site selection in south Georgia. National Wild Turkey Symposium 6:44-50.

Speake, D. W., T. E. Lynch, W. J. Fleming, G. A. Wright, and W. J. Hamrick. 1975. Habitat use and seasonal movements of wild turkeys in the Southeast. Proceedings of the National Wild Turkey Symposium 3:122-130.

Still, H. R., Jr., and D. P. Bauman, Jr. 1990. Wild turkey nesting ecology on the Francis Marion National Forest. Proceedings of the National Wild Turkey Symposium 6:12-18.

Stransky, J. J., and R. E. Harlow. 1981. Effects of fire on deer habitat in the southeast. Pages 135-142 *in* G. W. Wood, editor. Prescribed fire and wildlife in southern forests. Belle W. Baruch Forest Science Institute of Clemson University, Georgetwon, South Carolina, USA.

Taylor, J. 1990. Questionable multivariate statistical inference in wildlife habitat and community studies: a comment. Journal of Wildlife Management 54:186-189.

Waldrop, T. A., D. L. White, and S. M. Jones. 1992. Fire regimes of pine-grassland communities in the southeastern United States. Forest Ecology and Management 47:195-210.

Williams, L. E., Jr., and D. H. Austin. 1988. Studies of the wild turkey in Florida. Florida Game and Freshwater Fish Commission, Technical Bulletin 10, Gainesville, USA.

Table 3-1. Results from *t*-tests for unequal variances identifying all significant ($P < 0.1$) microhabitat and landscape-level variables to be included in nest site selection models of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

	Random		Nest		
Variable	Mean (*N*=52)	SD	Mean (*N*=52)	SD	*P*
%Bare Ground	10.75	15.30	8.15	9.50	0.30
%Debris	33.83	23.03	22.60	17.20	0.01[a]
%Fern	3.72	6.88	3.71	6.81	1.00
%Forb	11.06	8.62	13.28	11.56	0.27
%Grass	21.64	18.83	17.76	12.41	0.22
%Vine	6.78	9.34	10.49	13.61	0.11
%Woody	12.23	10.50	24.00	14.76	0.00[a]
%Canopy Closure (%CC)	64.67	30.05	54.22	29.49	0.08[a]
Average Visual Obstruction (VOavg)	6.90	4.08	11.06	2.89	0.00[a]
Maximum Visual Obstruction (VOmax)	11.30	4.05	14.47	1.96	0.00[a]
Minimum Visual Obstruction (VOmin)	3.88	3.41	8.51	3.06	0.00[a]
Distance to Mature Pine (Dist1)	47.01	92.67	93.82	226.44	0.17
Distance to Mature Pine-Hardwood (Dist2)	301.66	355.52	359.03	459.49	0.48
Distance to Shrub/Scrub (Dist3)	240.69	172.61	169.62	129.70	0.02[a]
Distance to Wetland (Dist4)	1914.25	2373.82	1969.31	2363.92	0.91
Distance to Mature Hardwood (Dist5)	407.18	387.73	390.76	372.01	0.83
Distance to Agriculture/Food Plot (Dist6)	783.05	925.32	736.86	865.36	0.79
Distance to Pine Plantation (Dist7)	216.63	222.97	157.34	227.53	0.18
Distance to Barren Land/Urban (Dist8)	759.77	719.56	827.02	621.52	0.61
Distance to Open Water (Dist9)	614.21	572.06	558.47	511.80	0.60
Distance to Edge	167.76	142.10	105.16	100.91	0.01[a]
Distance to Roads	60.89	41.69	55.15	54.28	0.55
Time-Since-Burn	1.21	0.94	1.23	0.76	0.91

[a] Indicates significant $P < 0.1$.

Table 3-2. Models, number of variables (*K*), distance from the second-order Akaike's Information Criterion (ΔAIC*c*), and model weights (w_i) for models explaining the effects of microhabitat variables (% canopy closure, % debris, % woody, maximum visual cover [VOmax] and minimum visual cover [VOmin]), landscape-level variables (distance to shrub/scrub [3] and edge), and site and year on nest site selection of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Model	*K*	ΔAIC*c*	w_i
Site + Microhabitat (CC, Debris, Woody, VOmax, VOmin)	7	0.00	0.35
Microhabitat	6	0.74	0.24
Site + Year + Microhabitat + Landscape (Dist3, DistEdge)	10	1.22	0.19
Year + Microhabitat	7	1.48	0.17
Microhabitat +Landscape	8	4.51	0.04
VOmin	2	6.30	0.01
VOmax	2	23.76	0.00
Woody	2	28.42	0.00
Debris	2	40.97	0.00
DistEdge	2	42.00	0.00
Dist3	2	43.29	0.00
Landscape	3	43.49	0.00
Site + Landscape	4	44.93	0.00
Year + Landscape	4	45.64	0.00
CC	2	45.70	0.00
Null	1	46.82	0.00
Year	2	48.89	0.00
Site	2	48.90	0.00
Site + Year	3	51.02	0.00

Table 3-3. Top-performing models, number of variables (*K*), distance from the second-order Akaike's Information Criterion (ΔAIC*c*), and adjusted model weights (w_i) explaining the effects of microhabitat variables (% canopy closure, % debris, % woody, maximum visual cover [VOmax] and minimum visual cover [VOmin]), landscape-level variables (distance to shrub/scrub [3] and edge), and site and year on nest site selection of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Model	*K*	ΔAIC*c*	Adjusted w_i
Site + Microhabitat (CC, Debris, Woody, VOmax, VOmin)	7	0.0	0.37
Microhabitat	6	0.74	0.25
Site + Year + Microhabitat + Landscape (Dist3, DistEdge)	10	1.22	0.20
Year + Microhabitat	7	1.48	0.18

Table 3-4. Model-averaged parameter estimates, standard errors, 95% confidence intervals, and odds ratios where appropriate, for parameters used to predict nest site selection of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Effect	Model-Averaged Parameter Estimate	SE	Variable Weight	Lower 95% CI	Upper 95% CI	Odds Ratio[b]
CC	-0.026	0.012	1.000	-0.050	-0.003	0.974[a]
Debris	0.010	0.018	1.000	-0.025	0.045	
VOmax	0.218	0.139	1.000	-0.054	0.491	
VOmin	0.362	0.113	1.000	0.141	0.583	1.436[a]
Woody	0.055	0.027	1.000	0.003	0.107	1.057[a]
Dist3	0.001	0.001	0.200	-0.001	0.003	
DistEdge	-0.002	0.002	0.200	-0.005	0.001	
Site	0.739	0.510	0.569	-0.262	1.739	
Year	0.330	0.347	0.376	-0.350	1.010	

[a] Indicates 95% CI does not contain zero.
[b] Increase in probability of a nest site by wild turkeys per unit increase in variable.

Table 3-5. Mean and standard error of important parameters—percent canopy closure, minimum vegetation height (VOmin), and percent woody ground cover—used to predict nest site selection of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

	Nest		Random	
Parameter	Mean (*N*=52)	SE	Mean (*N*=52)	SE
CC[a]	54.22	4.09	64.67	4.17
VOmin[b]	8.51	0.42	3.88	0.47
Woody[a]	24.00	2.05	12.23	1.46

[a] Parameter measured in percent.

[b] Parameter measured in decimeters.

Table 3-6. Results from *t*-tests for unequal variances identifying all significant ($P < 0.1$) microhabitat and landscape-level variables to be included in ground-roost site selection models of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

	Random		Ground-roost		
Variable	Mean (*N*=31)	SD	Mean (*N*=31)	SD	*P*
%Bare Ground	13.48	13.88	9.16	10.23	0.17
%Debris	25.78	22.78	26.50	20.23	0.90
%Fern	3.90	9.06	3.94	10.05	0.99
%Forb	16.01	14.47	18.68	20.28	0.55
%Grass	16.52	13.85	16.72	16.30	0.96
%Vine	5.17	6.91	6.65	10.99	0.53
%Woody	19.15	14.36	18.35	12.29	0.82
%Canopy Closure (%CC)	51.55	30.10	44.10	35.56	0.38
Average Visual Obstruction (VOavg)	8.90	4.42	8.69	3.06	0.83
Maximum Visual Obstruction (VOmax)	14.14	2.39	13.41	2.81	0.28
Minimum Visual Obstruction (VOmin)	5.53	4.20	5.71	2.54	0.84
Distance to Mature Pine (Dist1)	34.94	60.51	134.10	227.46	0.02[a]
Distance to Mature Pine-Hardwood (Dist2)	364.08	490.22	260.59	457.29	0.39
Distance to Shrub/Scrub (Dist3)	202.10	196.01	186.73	138.30	0.72
Distance to Wetland (Dist4)	1172.32	1721.85	1060.93	753.74	0.74
Distance to Mature Hardwood (Dist5)	423.32	462.40	281.06	339.73	0.17
Distance to Agriculture/Food Plot (Dist6)	837.50	1096.67	740.12	778.91	0.69
Distance to Pine Plantation (Dist7)	302.19	252.37	268.84	271.04	0.62
Distance to Barren Land/Urban (Dist8)	770.69	635.84	547.11	446.27	0.11
Distance to Open Water (Dist9)	632.01	593.16	492.34	463.39	0.31
Distance to Edge	110.70	127.22	121.88	106.35	0.71
Distance to Roads	53.16	41.79	75.26	59.20	0.10[a]
Time-Since-Burn	0.74	0.89	1.03	0.84	0.19

[a] Indicates significant $P < 0.1$.

Table 3-7. Models, number of variables (*K*), distance from the second-order Akaike's Information Criterion (ΔAIC*c*), and model weights (w_i) for models used to explain the effects of landscape-level variables (distance to mature pine [1] and roads), and site and year on ground-roost site selection of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Model	*K*	ΔAIC*c*	w_i
Dist1	2	0.00	0.43
Landscape (Dist1, DistRoads)	3	1.49	0.20
Site + Landscape	4	1.65	0.19
Year + Landscape	4	3.75	0.07
Site + Year + Landscape	5	3.99	0.06
DistRoads	2	5.49	0.03
Null	1	6.29	0.02
Site	2	8.43	0.01
Year	2	8.43	0.01

Table 3-8. Top-performing models, number of variables (*K*), distance from the second-order Akaike's Information Criterion (ΔAIC*c*), and adjusted model weights (w_i) explaining the effects of landscape-level variables (distance to mature pine [1] and roads), and site and year on ground-roost site selection of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Model	*K*	ΔAIC*c*	Adjusted w_i
Dist1	2	0.00	0.45
Landscape (Dist1, DistRoads)	3	1.49	0.22
Site + Landscape	4	1.65	0.20
Year + Landscape	4	3.75	0.07
Site + Year + Landscape	5	3.99	0.06

Table 3-9. Model-averaged parameter estimates, standard errors, 95% confidence intervals, and odds ratios where appropriate, for parameters used to predict ground-roost site selection of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Effect	Model Averaged Parameter Estimate	SE	Variable Weight	Lower 95% CI	Upper 95% CI	Odds Ratio[b]
Dist1	0.01	0.00	1.00	0.00	0.02	1.01[a]
DistRoads	0.00	0.00	0.55	0.00	0.01	
Site	0.24	0.25	0.26	-0.24	0.73	
Year	0.00	0.08	0.13	-0.16	0.16	

[a] Indicates 95% CI does not contain zero.
[b] Increase in probability of a ground-roost by wild turkeys per unit increase in variable.

Table 3-10. Mean and standard error of important parameter—distance to mature pine (1)—used to predict ground-roost site selection of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

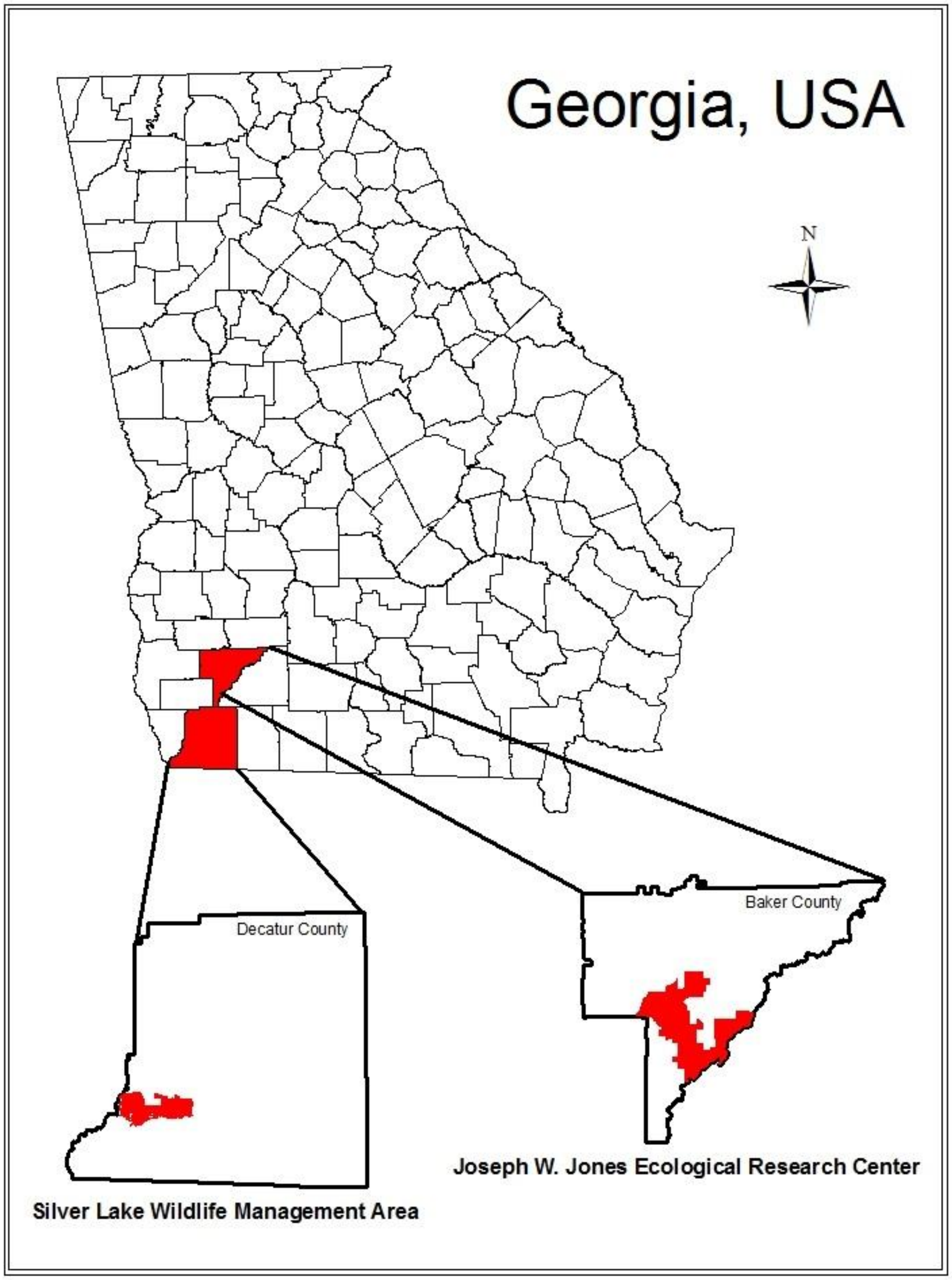
	Ground-Roost		Random	
Parameter	Mean (*N*=31)[a]	SE	Mean (*N*=31)[a]	SE
Dist1	134.10	40.85	34.94	10.87

[a] Parameter measured in meters.

Table 3-11. Mean and standard deviation of habitat and variables measured at nests, ground-roosts and random locations of eastern wild turkeys at the Joseph W. Jones Ecological Research Center and Silver Lake Wildlife Management Area, southwestern Georgia, USA, 2011-2012.

Variable	Nest Mean (*N*=52)	SD	Ground-Roost Mean (*N*=31)	SD	Random Mean (*N*=83)	SD
%Bare Ground	8.2	9.5	9.2	10.2	11.8	14.8
%Debris	22.6	17.2	26.5	20.2	30.8	23.1
%Fern	3.7	6.8	3.9	10.1	3.8	7.7
%Forb	13.3	11.6	18.7	20.3	12.9	11.3
%Grass	17.8	12.4	16.7	16.3	19.7	17.2
%Vine	10.5	13.6	6.6	11.0	6.2	8.5
%Woody	24.0	14.8	18.4	12.3	14.8	12.5
%Canopy Closure	54.2	29.5	44.1	35.6	59.8	30.6
Average Visual Obstruction	11.1	2.9	8.7	3.1	7.6	4.3
Maximum Visual Obstruction	14.5	2.0	13.4	2.8	12.4	3.8
Minimum Visual Obstruction	8.5	3.1	5.7	2.5	4.5	3.8
Distance to Mature Pine	93.8	226.4	134.1	227.5	42.5	81.9
Distance to Mature Pine-Hardwood	359.0	459.5	260.6	457.3	325.0	409.2
Distance to Shrub/Scrub	169.6	129.7	186.7	138.3	226.3	181.5
Distance to Wetland	1969.3	2363.9	1060.9	753.7	1637.1	2172.5
Distance to Mature Hardwood	390.8	372.0	281.1	339.7	413.2	414.5
Distance to Agriculture/Food Plot	736.9	865.4	740.1	778.9	803.4	986.5
Distance to Pine Plantation	157.3	227.5	268.8	271.0	248.6	236.6
Distance to Barren Land/Urban	827.0	621.5	547.1	446.3	763.8	685.5
Distance to Open Water	558.5	511.8	492.3	463.4	620.9	576.5
Distance to Edge	105.2	100.9	121.9	106.4	146.4	138.8
Distance to Roads	55.2	54.3	75.3	59.2	58.0	41.6
Time-Since-Burn	1.2	0.8	1.0	0.8	1.0	0.9

Figure 3-1. The Joseph W. Jones Ecological Research Center at Ichauway and the Georgia Department of Natural Resources' Silver Lake Wildlife Management Area in southwestern Georgia, USA.



CHAPTER 4

CONCLUSIONS

My study introduces new information on the effects of growing-season prescribed fire on wild turkey nest and poult survival. I also provide information on wild turkey nest rates and nest success, as well as nest and ground-roost site selection in southwestern Georgia.

Wild turkey nest survival has a critical influence on their population dynamics (Roberts and Porter 1998), and nest success has been cited as a major influence on annual population abundance in mixed agricultural and forested environments (Roberts et al. 1995, Roberts and Porter 1996). In the absence of growing-season prescribed fire my estimate of nest success (56%) was greater than in previous studies (34.8%, Smith-Blair 1993; 47.8%, Holbrook et al. 1987), indicating that nest success is good and there is low evidence of population declines in the 2 southwestern Georgia populations.

Predation was the greatest cause of nest failure, followed by growing-season fire. However, 75% of females renested after their initial nests were destroyed by fire and one nest was burned and yet hatched successfully 5 days post-burn. The successful hatching of nests exposed to fire was also observed in a South Carolina study (Carlisle 2003). Growing-season fires are an important factor in maintaining optimal understory conditions of increased early-successional habitat and herbaceous vegetation for wild turkey nesting and ground-roosting cover; however, I speculate that large-scale growing-season fire may be detrimental to nesting, and should be applied judiciously until further studied.

Poult survival was 35% for broods from 1-14 days and 17% for broods from 15-30 days, with a combined survival of 52% for the first 30 days post-hatch. The low poult survival in the first 2 weeks agrees with other poult survival studies (Glidden and Austin 1975, Lehman et al. 2001, Spears et al. 2007). The 30-day period survival is greater compared to other studies in coastal plain pine forests—9% (Peoples et al. 1995) and 13% in Alabama (Exum et al. 1987), and 10% in Georgia (Sisson et al. 1991). Only 2 broods survived to become indistinguishable in size from the female. Poult survival after the 14-day period increased significantly once the brood could fly and roost in trees (Barwick et al. 1971). Poult loss was largely due to predation, but 1 brood was lost to a growing-season prescribed fire just after hatch. This is the first documented brood loss attributed to prescribed fire, and is likely unimportant from a management perspective.

The greater nesting rates and nest success on the Jones Center relative to Silver Lake WMA may be from year-round agricultural field and food plot availability, supplemental feeding for northern bobwhite quail management, and lower abundances of nest predators. It has been reported that wild turkey females will not attempt to nest if they are in poor nutritional condition (Pattee 1977, Porter et al. 1983), and studies also have shown that habitat quality for wild turkeys is greater in areas with more openings, agricultural fields and pastures (Wigley et al. 1986, Godwin et al. 1994). The Jones Center annually removes and average of 218 mesopredators from approximately 4,856-ha of the property for northern bobwhite quail management. The majority of predators removed are northern raccoons (*Procyon lotor*) and Virginia opossums (*Didelphis* *virginiana*) (L. Mike Conner, personal communication), which are considered major wild turkey nest predators (Speake 1980, Miller and Leopold 1992, Williams and Austin 1988).

The greater poult survival on Silver Lake WMA relative to the Jones Center may be indicative of a different predator community or abundances than that of the Jones Center. Silver Lake WMA has a lower percentage of agricultural fields and food plots and a greater percentage of open water compared to the Jones Center. Although the Jones Center has a greater percentage of hardwoods relative to Silver Lake WMA, there is a greater spatial dispersion between hardwood habitats on the Jones Center due to the extensive hardwood removal. The raccoon is the primary nest predator of wild turkeys throughout their range (Speake 1980, Miller and Leopold 1992, Williams and Austin 1988). Conversely, the Jones Center likely has a predator community more commonly associated with agricultural edges and early successional forest communities, such as bobcats (*Lynx rufus*) and coyotes (*Canis latrans)*, than Silver Lake WMA (Conner et al. 1992, Cochrane 2003, Doughty 2004). These predators are also more commonly associated with depredation of wild turkey poults (Peoples et al. 1995). Therefore, Silver Lake WMA likely has a predator community more associated with bottomland hardwood systems, such as northern raccoons (*Procyon lotor*), which are more likely to occur in habitats, such as bottomland hardwoods, that have a greater hardwood refugia and water component (Atkenson and Hulse 1953, Sanderson 1987, Leberg and Kennedy 1988, Gehrt and Fritzell 1998).

Nest sites were negatively associated with greater canopy cover and positively associated with greater woody ground cover. Less canopy cover would allow for growth of understory herbaceous ground cover, including small woody shrubs/trees that provide better concealment of nests. This result could also be indicative of a number of nests being located near field edges or within food plots. Greater herbaceous ground cover, including woody stem densities, at nests agrees with other studies showing that ground level vegetation cover is an important factor in nest site selection (Bowman and Harris 1980, Healy 1981, Ransom et al. 1987, Badyaev 1995, Still and Bauman 1990, Chamberlain and Leopold 1998). Concealment from predators by the vegetation may also be a driving factor for nest site selection (Lehman et al. 2008). Habitat management for the northern bobwhite quail on the 2 study sites created a mosaic of food plots and openings dominated by early successional plant communities within and around forested stands. Therefore, brooding females were likely sampling for open areas outside of mature pine stands. These open areas could include food plots, agricultural fields and shrubby areas, which have been used by broods for their insect abundance and cover (Hillestad and Speake 1970, Hurst and Stringer 1975, Martin and McGinnes 1975, Sisson et al. 1991).

Management on properties in the Southeastern coastal plain, which have larger densities of mature pine stands, should focus on maintaining a mosaic of open canopy areas within and around stands for nesting and ground-roosting cover. The open canopy areas will allow for herbaceous understory growth (Peitz et al. 2001) facilitating nest and ground-roost concealment. Herbaceous growth and woody stem densities within the open canopy areas will increase through a rotating application of small-scale prescribed fires, including growing-season fires, throughout the year (Jones Center 2010). Land management through growing-season fires should be used because of its benefits for wild turkeys habitats (McGlincy 1985, Landers and Mueller 1986, Exum 1988, Provencher et al. 1998). Negative effects on wild turkey reproduction should be considered, as the long-term effects of growing-season fires on wild turkey populations are still somewhat uncertain. However, as long as growing-season fires are used in a rotating, small-scale application (< 20 ha) the effects on wild turkey populations will be minimal and the benefits to the entire ecosystem will be great. Invasive hardwood removal in the longleaf pine ecosystem should also be considered to further reduce nest predator refugia (Atkenson and Hulse 1953, Sanderson 1987, Leberg and Kennedy 1988, Gehrt and Fritzell 1998). Mesopredator removal, at least during the wild turkey nesting season, should also be considered as a potential management tool as it has been concluded that wild turkey nest success can improve after intensive predator control (Miller and Leopold 1992). Continued research on these 2 study sites will aid in better understanding the importance of fire in nest success, nest survival, poult survival, and nest and ground-roost site selection.

References

Atkenson, T. Z., and D. C. Hulse. 1953. Trapping versus night hunting for controlling raccoons and opossums within sanctuaries. Journal of Wildlife Management 17:159–162.

Badyaev, A. V. 1995. Nesting habitat and nesting success of eastern wild turkeys in the Arkansas Ozark Highlands. The Condor 97:221-232.

Barwick, L. H., D. H. Austin, and L. E. Williams. 1971. Roosting of young turkey broods during summer in Florida. Proceedings of the Southeastern Association of Fish and Willdife Agencies 24:231-243.

Bowman, G. B., and L. D. Harris. 1980. Effect of spatial heterogeneity on ground nest depredation. Journal of Wildlife Management 44:807-813.

Carlisle, W. D. 2003. The relationships between weather, mast production, and the breeding ecology of eastern wild turkeys in South Carolina. Thesis, Clemson University, Clemson, South Carolina, USA.

Chamberlain, M. J., and B. D. Leopold. 1998. Microhabitat characteristics of wild turkey prenest and nest site selection in central Mississippi. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 52:274-282.

Cochrane, J. C. 2003. Ecology of bobcats in a longleaf pine forest in southwestern Georgia. Thesis, University of Georgia, Athens, Georgia, USA.

Conner, L. M., B. D. Leopold, and K. J. Sullivan. 1992. Bobcat home range, density, and habitat use in east-central Mississippi. Proceedings of the Annual Conference of the Southeastern Association of Fish and Wildlife Agencies 46:147-158.

Doughty, J. 2004. Bobcat (Lynx rufus) ecology in a longleaf pine ecosystem in southwestern Georgia. Thesis, University of Georgia, Athens, Georgia, USA.

Exum, J. H., J. A. McGlincy, D. W. Speake, J. L. Buckner, and F. M. Stanley. 1987. Ecology of the eastern wild turkey in an intensively managed pine forest in southern Alabama. Tall Timbers Research Station Bulletin 23, Tallahassee, Florida, USA.

Exum, J. H. 1988. Turkey management in southeastern pine woods. Proceedings of the Game Bird Seminar. Tall Timbers Research, Inc., Tallahassee, Florida, USA.

Gehrt, S. D., and E. K. Fritzell. 1998. Resource distribution, female home range dispersion, and male spatial interactions: group structure in a solitary carnivore. Animal Behavior 55:1211–1227.

Glidden, J. W., and D. E. Austin. 1975. Natality and mortality of wild turkey poults in southwestern New York. Proceedings of the National Wild Turkey Symposium 3:48-54.

Godwin, K. D., G .A. Hurst, and B. D. Leopold. 1994. Movements of wild turkey gobblers in central Mississippi. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 48:117-122.

Healy, W. M. 1981. Habitat requirements and habitat management for the wild turkey in the southeast. Virginia Wild Turkey Foundation, Ellison, Virginia, USA.

Hillestad, H. O, and D. W. Speake. 1970. Activities of wild turkey hens and poults as influenced by habitat. Proceedings of the Southeastern Association of Game and Fish Commissions 24:244-251.

Holbrook, H. T., M. R. Vaughan, and P. T. Bromley. 1987. Wild turkey habitat preference and recruitment in intensively managed piedmont forests. Journal of Wildlife Management 51:182-187.

Hurst, G. A., and B. D. Stringer. 1975. Food habits of wild turkey poults in Mississippi. Proceedings of the National Wild Turkey Symposium 3:76-85.

Joseph W. Jones Ecological Research Center (Jones Center). 2010. The prescribed fire management program at Ichauway 1994-2009. <http://www.jonesctr.org/conservation/prescribed_fire/RxFireReport_2009.pdf>. Accessed 15 September 2012.

Landers, J. L., and B. S. Mueller. 1986. Bobwhite quail management: a habitat approach. Tall Timbers Research Station Miscellaneous Publication 6, Tallahassee, Florida, USA.

Leberg, P. L., and M. L. Kennedy. 1988. Demography and habitat relationships of raccoons in western Tennessee. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 42:272–282.

Lehman, C. L., L. D. Flake, A. P. Leif, and R. D. Shields. 2001. Comparative survival and reproduction of sympatric eastern and Rio Grande wild turkey females in northeastern South Dakota. Proceedings of the National Wild Turkey Symposium 8:123-135.

Lehman, C. P., M. A. Rumble, L. D. Flake, and D. J. Thompson. 2008. Merriam's turkey nest survival and factors affecting nest predation by mammals. Journal of Wildlife Management 72:1765-1774.

Martin, D. D., and B. S. McGinnes. 1975. Insect availability and use by turkeys in forest openings. Proceedings of the National Wild Turkey Symposium 3:70-75.

Mayfield, H. F. 1975. Suggestions for calculating nest success. Wilson Bulletin 87:456-466.

McGlincy, J. A. 1985. Wild turkeys and industrial forestry. Proceedings of the Tall Timbers Game Bird Seminar. Tall Timbers Research, Inc., Tallahassee, Florida, USA.

Miller, J. E., and B. D. Leopold. 1992. Population influences: predators. Pages 119-128 *in* J. G. Dickson, editor. The wild turkey: biology and management. Stackpole Books, Harrisburg, Pennsylvania, USA.

Pattee, O. H. 1977. Effects of nutrition on wild turkey reproduction in south Texas. Dissertation, Texas A&M University, College Station, Texas, USA.

Peitz, D. G., M. G. Shelton, and P. A. Tappe. 2001. Forage production after thinning natural loblolly pine-hardwood stand to different basal areas. Wildlife Society Bulletin 29:697-705.

Peoples, J. C., D. C. Sisson, and D. C. Guynn, Jr. 1995. Mortality of wild turkey poults in coastal plain pine forests. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 49:448-453.

Porter, W. F., G. C. Nelson, and K. Mattson. 1983. Effects of winter conditions on reproduction in northern wild turkey populations. Journal of Wildlife Management 47:281-290.

Provencher, L., N .M. Gobris. H. L. Rodgers, D. R. Gordon, and J. P. McAdoo. 1998. Scientific coordination and adaptive management and experimental restoration of longleaf pine community structure, function, and composition. Annual Report 3 (Dec 97-30 Mar 98). University of Florida, Gainesville, Florida, USA.

Roberts, S. D., J. M. Coffey, and W. F. Porter. 1995. Survival and reproduction of wild turkeys in New York. Journal of Wildlife Management 59:437-447.

Roberts, S. D., and W. F. Porter. 1996. Importance of demographic parameters to annual changes in wild turkey abundance. Proceedings of the National Wild Turkey Symposium 7:15-20.

Roberts, S. D., and W. F. Porter. 1998. Influence of temperature and precipitation on survival of wild turkey poults. Journal of Wildlife Management 62:1499-1505.

Sanderson, G. C. 1987. Raccoon. Pages 486-499 *in* M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, editors. Wild furbearer management and conservation in North America. Ontario Ministry of Natural Resources, Ontario.

Sisson, D. C., D. W. Speake, and J. L. Landers. 1991. Wild turkey brood habitat use in fire-type pine forests. Proceedings of the Southeastern Association of Fish and Wildlife Agencies 45:49-57.

Smith-Blair, A. E. 1993. Rio Grande wild turkey hen habitat and edge use, survival, and reproduction characteristics in the Texas Rolling Plains. Thesis, Texas Tech University, Lubbock, Texas, USA.

Speake, D. W. 1980. Predation on wild turkeys in Alabama. Proceedings of the National Wild Turkey Symposium 4:86-101.

Spears, B. L, M. C. Wallace, W. B. Ballard, R. S. Phillips, D. P. Holdstock, J. H. Brunjes, R. Applegate, M. S. Miller, and P. S. Gipson. 2007. Habitat use and survival of preflight wild turkey broods. Journal of Wildlife Management 71:69-81.

Still, H. R., Jr., and D. P. Bauman, Jr. 1990. Wild turkey nesting ecology on the Francis Marion National Forest. Proceedings of the National Wild Turkey Symposium 6:12-18.

Wigley, T. B., J. M. Sweeney, M. E. Garner, and M. A. Melchiors. 1986. Wild turkey home ranges in Ouachita Mountains. Journal of Wildlife Management 50:540-544.

Williams, L. E., Jr., and D. H. Austin. 1988. Studies of the wild turkey in Florida. Florida Game and Freshwater Fish Commission, Technical Bulletin 10, Gainesville, USA.