



Management Practices to Support Increased Biodiversity in Managed Loblolly Pine Plantations¹

Michael Andreu, Kevin Zobrist, and Thomas Hinckley²

Introduction

When European settlers first arrived in North America, it is estimated that the southern U.S. had 200 million acres in pine, mixed oak, and other forest systems. Pine savannahs and open woodlands containing longleaf (*Pinus palustris* Mill.), loblolly (*Pinus taeda* L.), shortleaf (*Pinus echinata* Mill.), slash (*Pinus elliottii* Engelm.), and pond (*Pinus serotina* Michx.) pine were dominant. Of these species, it is estimated that longleaf pines and associated ecosystems may have covered over 60 million acres (Bragg 2002, Wahlenberg 1946). Longleaf pine stands were often characterized by a single species overstory, a sparse mid-story/shrub layer, and a well-developed and species-rich ground layer. Frequent, low intensity fires, natural or anthropogenic in origin, were the primary disturbance regime (Noss 1988, Van Lear et al. 2004). These stands were also known for the diversity of wildlife they harbored, particularly game species. Trees in these stands were often very large. Many of them were more than six centuries old.

Nearly 90% of the forestland in the South today is in private ownership (Wicker 2002), and much of it is comprised of dense plantations of fast-growing loblolly pine. The management intensity of these plantations has been increasing in recent decades. At the same time, private landowners are facing an increasing demand to provide for broad, non-timber values such as biodiversity on these lands, which can lead to conflict over forest management practices.

Forest plantations have long been characterized as biological "deserts" in which concern for wildlife is limited to key game species. While it is true that today's dense loblolly pine plantations are different from the natural, open pine stands that were historically prevalent throughout the South, these intensively managed forests can still contribute to biodiversity on the landscape (Wigley et al. 2000). Land devoted to managed forests may not be as biologically diverse as natural forest land, but it often compares favorably to land used for agriculture or urbanization (Moore and Allen 1999).

Due to their prevalence in the region, intensively managed plantations have a significant potential

-
1. This document is FOR183, one of a series of the School of Forest Resources and Conservation Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Original publication date March, 2008. Visit the EDIS Web Site at <http://edis.ifas.ufl.edu>.
 2. Michael G. Andreu, Assistant Professor, School of Forest Resources and Conservation, Florida Cooperative Extension Services, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611; Kevin W. Zobrist, Forest Stewardship Educator, Washington State University, Snohomish and Skagit County Extension, 600 128th St SE, Everett, WA 98208-6353 ; and Thomas M. Hinckley, Professor, University of Washington, College of Forest Resources.

The Institute of Food and Agricultural Sciences (IFAS) is an Equal Opportunity Institution authorized to provide research, educational information and other services only to individuals and institutions that function with non-discrimination with respect to race, creed, color, religion, age, disability, sex, sexual orientation, marital status, national origin, political opinions or affiliations. U.S. Department of Agriculture, Cooperative Extension Service, University of Florida, IFAS, Florida A. & M. University Cooperative Extension Program, and Boards of County Commissioners Cooperating. Larry Arrington, Dean

impact on the level of biodiversity. Stand-level management changes in these plantations can significantly improve biodiversity values (Hartley 2002, Johnson et al. 1975). Some of these changes may complement timber production and economic goals; others may involve some costs and trade-offs (Allen et al. 1996, Buongiorno et al. 2004, Hunter 1990). In the following sections we review the literature to identify a spectrum of practices that support increased biodiversity in intensively managed loblolly pine plantations.

Management Practices to Support Increased Biodiversity

Biodiversity has several definitions, the simplest being a variety of life. Many authors further specify that the definition includes not only all types of organisms but also genotypes and even ecological processes and their inter-relationships (Hunter 1990, Oliver 1992, Reid and Miller 1989). There is no single forest type or structure that maximizes biodiversity. Different species have different habitat requirements, which means that structures that support some species may not support others. Even individual species require habitat diversity. Thus, the best way to support a variety and abundance of species is to provide a diversity of structure and vegetation (Allen et al. 1996, Harris et al. 1979, Marion et al. 1986, Sharitz et al. 1992). This includes both within- and between-stand diversity (Marion and Harris 1982, Thill 1990).

An important way to increase within-stand structural diversity is to maintain a lower overstory density. A more open canopy allows a diverse understory to develop, which provides forage and habitat for wildlife. Even plantations established with intensive site preparation are often very diverse in the early years as long as the canopy is open, but as the canopy closes this diversity rapidly decreases (Baker and Hunter 2002). Once the canopy closes, the stand moves into the stem exclusion stage that shades out the understory vegetation and subsequently lacks wildlife (Oliver and Larson 1990). Minimizing this stage can allow a stand to support more biodiversity over a given rotation. Maintaining an open canopy with a productive understory also makes plantations more similar to the diverse, natural pine communities

that existed historically in this region (Bragg 2002, Noss 1988, Van Lear et al. 2004).

Planting fewer trees per acre is one way to maintain lower stand density for biodiversity. A wide spacing, such as 12 feet or more, delays canopy closure, extending the more diverse early-successional stages (Dickson 1982, Johnson et al. 1975, Melchior 1991). In addition to delaying canopy closure, a wide spacing between rows can also allow disking or mowing to help maintain a productive understory. A wide planting spacing may be undesirable, though, because of the resulting decreased wood quality. In this case, it might be better to plant closely and periodically thin to maintain the understory diversity. (Van Lear et al. 2004).

In fact, thinning is perhaps the most important way to establish and maintain an open, diverse structure. Thinning has been found to benefit numerous individual wildlife species such as deer (Blair 1960, Halls 1973, Hurst and Warren 1980), quail (Dougherty 2004), small mammals (Mengak and Guynn 2003), turkeys (Mississippi State University Extension Service 2004), and nuthatches (Wilson and Watts 1999) and other birds (Turner et al. 2002). Thinning early and often is widely recognized as an important component of an overall strategy to increase biodiversity (Hunter 1990, Marion et al. 1986). Thinning minimizes the duration of the stem exclusion stage and can maintain and further develop an open, diverse structure throughout the rotation. In addition to stimulating the herbaceous understory by allowing light to reach the forest floor, thinning also facilitates additional understory management such as disking or burning, and it increases the understory response to such treatments (Melchior 1991, Tucker et al. 1998).

Van Lear et al. (2004) suggest that a commercial thinning be done by the time a plantation reaches age 15. Hurst and Warren (1980) suggest that it be done as early as age 12 if no pre-commercial thinning was done. The recommended frequency of thinning to maintain an open stand structure is usually around five years (Blair and Enghardt 1976, Conroy et al. 1982, Halls 1973, Hunter 1990, Schultz 1997). Maintaining an open stand structure for biodiversity

requires heavier thinning than for timber production, with a target of 50-70 ft²/acre of residual basal area (Blair and Enghardt 1976, Halls 1973, Van Lear et al. 2004). A residual basal area of 80 ft²/acre is usually considered a minimum for timber production and economic return (Siry 2002, Siry et al. 2001).

A potential problem with thinning to open up the pine overstory is that it can allow understory hardwoods to develop into a dense midstory. Hardwoods produce heavy shade that inhibits understory vegetation. Thinning can also increase vines and shrubs, which further shade out the herbaceous layer. Thus, without controlling hardwoods and other woody vegetation, thinning can ultimately result in a less productive and less diverse understory (Blair and Feduccia 1977, Hunter 1990). A hardwood midstory can add vertical stratification and benefit some midstory-associated birds. However, a hardwood midstory is generally undesirable for most wildlife, including deer, small mammals, and other birds (Dickson 1982, Lohr et al. 2002, Melchior 1991, Wilson and Watts 1999).

While a dense midstory is undesirable, some hardwoods are necessary for supporting biodiversity. Mature hardwoods such as oaks provide hard mast that is important for many wildlife species. Maintaining a desirable component of hardwoods can improve wildlife habitat (Tappe et al. 1993). When controlling hardwoods, it can be beneficial to select individual fruit- or mast-producing trees to retain. It is also very important to maintain some whole areas of hardwoods. An interspersed hardwood and pine forest type provides good wildlife habitat (Shultz 1997). Hardwoods should especially be maintained in sensitive areas such as bottomlands and drainages. Hardwood maintenance should generally stay focused on hardwood sites.

In intensively managed plantations, prescribed burning can be used in conjunction with thinning to achieve conditions that support increased biodiversity. In historic, natural pine stands, frequent low-intensity fires helped to control hardwoods and maintain an open stand structure with a productive

and diverse understory. Frequent low-intensity fires tend to favor growth of herbaceous vegetation by suppressing hardwoods and other woody vegetation (Reed et al. 1994). Many of the plants and animals associated with southern pine communities are adapted to or even dependent on fire, and wildlife mortality from fire is generally very low (Landers 1987, Means and Campbell 1981, Moorman 2002). Regular burning improves habitat for many species, including deer, quail, turkey, amphibians and reptiles, and Bachman's sparrow (Tucker et al. 1998). To help provide for a broad suite of species in the short and long term, areas should not be burned evenly; instead, leave patches of unburned areas to provide for nesting and cover.

Prescribed burning is recommended when dominant pine trees are at least 15 feet tall. Recommended burning intervals range from 3-6 years. Marion et al. (1986) suggest 3-5 years to allow enough time for browse and cover to develop, and for enough fuel to accumulate to carry the next fire. Historically, longleaf pine communities in Florida burned naturally every 2-5 years (Noss 1988). Prescribed burning should not be overdone, or the cumulative impacts could become negative in the long term. Burning every year, for example, can eliminate hardwoods altogether (Grano 1970), and complete loss of the hardwood component would greatly inhibit biodiversity.

Winter prescribed burns are commonly recommended in pine plantations. Robbins and Myers (1992) note, however, that varying both the season and the frequency of burning avoids favoring only one suite of species. Adding this element of variability can increase overall stand diversity. Coordinating burning with thinning is also important. Thinning increases the effectiveness of prescribed burning for wildlife (Hurst and Warren 1982, Melchior 1991, Tucker et al. 1998). Burning before thinning can make thinning easier, and it avoids the problem of the fire burning too intensely in the slash from the thinned trees.

An alternative to prescribed burning for the control of non-pine woody vegetation is to use herbicides (Dickson and Wigley 2001, Harrington and Edwards 1999). Herbicides can be less costly

than burning and may be especially desirable where burning opportunities are limited (Wigley et al. 2002). Normal applications of herbicides are generally not directly toxic to wildlife (McComb and Hurst 1987). Herbicides may have a longer residual effect on understory diversity than prescribed burning or mechanical vegetation control (Hunter 1990). Nonetheless, vegetation seems to recover quickly within 1-3 years (Keyser et al. 2003, Reed et al. 1994). A long term study found no significant impact on floristic diversity 11 years after herbicide treatment (Miller et al. 1999).

Site preparation to control vegetation at the beginning of a rotation can affect biodiversity; it's important to consider various methods and intensities, depending on the goal for the site. More intensive site preparation favors grass and forbs, while less intensive site preparation favors vines and woody vegetation (Johnson 1975, Locascio et al. 1990). More intensive site preparation also reduces the availability of fruit for wildlife (Hunter 1990, Stransky and Roese 1984). Thus, while intensive site preparation can benefit some game species like deer, less intensive site preparation is generally better for a diversity of wildlife. Locascio et al. (1990) found that moderate intensity site preparation produced the greatest understory biomass in piedmont loblolly pine plantations, and moderate intensity treatments may be the most cost effective, especially for non-industrial landowners. In terms of site preparation methods, Locascio et al. (1991) observed that mechanical site preparation (shearing, chopping, disking, etc.) did not seem to diminish understory plant diversity. Mechanical methods may provide for greater understory diversity and food production compared to herbicides (Fredericksen et al. 1991, Keyser et al. 2003). Additionally, burning may be a desirable option. Burning increases biodiversity by stimulating stored seeds.

Other management activities like fertilization and pruning can also impact biodiversity. Use of fertilization in pine plantations has increased in recent decades, though it is mostly done on industry lands (Siry 2002). The impacts of fertilization on biodiversity are somewhat mixed. Fertilization can improve understory food production for wildlife, especially in stands that have been thinned (Hunter

1990, Hurst and Warren 1982, Melchior 1991). However, fertilization can also accelerate canopy closure, which can offset wildlife benefits (Dickson and Wigley 2001). Thus, fertilization treatments should be done in conjunction with thinning to maximize wildlife benefits. Pruning can also benefit biodiversity by increasing understory vegetation as well as creating more horizontal openings.

Another way to support increased biodiversity in pine plantations is to retain key structural features such as snags, coarse woody debris, and mature live trees. These elements add additional structural complexity that benefits a wide range of wildlife. Maintaining riparian buffers, or streamside management zones, can provide for some of these elements. Riparian buffers further contribute to biodiversity by providing for aquatic species and water quality, and by providing habitat connectivity.

All of the management practices described above will be most effective if they are done in conjunction with long rotations (Sharitz et al. 1992). Pulpwood rotations can be as short as 18 years. Short rotation management limits pine plantations to early successional structures and does not provide for species needing older seral stages. Because of the dominance of short rotations, older seral stages are becoming rare in the region (Allen et al. 1996). Rotations of 40-100 years can provide for long-term wildlife forage as well as key habitat elements such as hardwood mast, snags, and cavities.

Longer rotations can impact economic returns. Because future revenues are discounted, longer rotations must produce significantly more revenue to be economically competitive with shorter rotations. Dean and Chang (2002) found that economic performance decreased with increasing rotation length. In contrast, Biblis et al. (1998) noted that 50-year sawtimber rotations performed better economically than 20-year pulpwood rotations if the target rate of return was 7% or less. Ultimately, ideal rotation length depends on the relative prices of pulpwood and sawtimber and the rate of return that is acceptable to the landowner.

Other Considerations

The management practices described in this paper are geared towards increasing stand-level biodiversity. Ultimately, though, a landscape-level approach is needed. A variety of different stand structures and age classes should be present on the landscape in order to support the full range of biodiversity (Marion et al. 1986, Moore and Allen 1999, Oliver 1992). The size, shape, and spatial arrangement of these structures are also important. For landowners with large areas of contiguous holdings, a landscape management approach to providing for biodiversity may be feasible. When the landscape is broken up among different ownerships, landscape management requires coordination between different landowners with different needs and goals. The issues involved with such coordination are beyond the scope of this review. However, maintaining biodiversity at the landscape level depends on a collection of stand-level decisions. If individual landowners employ practices to increase stand-level biodiversity, their practices are likely to support significant increases in biodiversity across the landscape.

Another important consideration when managing for biodiversity is land use history. Hedman et al. (2000) found that understory vegetation composition and abundance is driven more by previous land use (i.e. agriculture) than by forest management practices within the past 35 years. Plantations established on old field sites do not have biological legacies such as seeds and rootstocks that are present in plantations established on cutover lands (Baker and Hunter 2002). Because of this, old field sites tend to have low understory diversity regardless of management practices (Hedman et al. 2000, Marion and Harris 1982, Marion et al. 1986). On the other hand, old field sites have greater pine growth and yield and can produce more wood per area of land (Yin and Sedjo 2001). Thus, intensive timber management that maximizes wood production and economic return could be focused on old field sites where biodiversity is likely to be poor regardless of management practices. Likewise, practices to improve biodiversity should be targeted to cutover lands.

Finally, economic considerations may influence options to increase biodiversity. Intensively managed plantations are business enterprises for which landowners will expect some level of economic return. There are various costs associated with managing for increased biodiversity which create trade-offs between biodiversity and economic returns. If management practices are too costly, they are unlikely to be implemented on private lands. Management strategies that balance both biodiversity and economic objectives should be identified.

The potential for increased hunting lease revenue may help offset the costs of managing for increased biodiversity. Hunting leases can provide significant revenue, especially if there is quality wildlife habitat (Baker and Hunter 2002, Johnson 1995, Jones et al. 2001). However, ownership size may limit these opportunities.

Summary

Maintenance of biodiversity is a concern in the intensively managed loblolly pine plantations that are increasingly prevalent in the southeastern United States, but it is feasible with a number of stand-level management practices. The overall key to providing for biodiversity is to provide structural diversity. An open stand structure with a diverse, productive grass-herb understory is similar to the natural, fire-maintained pine communities that were historically present and can support a broad suite of plants and wildlife.

Maintaining an open canopy with a diverse understory can be achieved by thinning early and often in the rotation. However, this may allow a dense hardwood midstory to develop which would shade out the understory and negate the benefits of thinning. Consequently, it will be necessary to control hardwoods, either by prescribed burning or with mid-rotation herbicide applications, but hardwoods should not be eliminated entirely because a mast-producing component is necessary to provide wildlife food and structural diversity.

Light to moderate site preparation is best for biodiversity, and mechanical methods may perform better in this respect than herbicides. Fertilization can benefit wildlife by increasing understory growth, but

it should be done in conjunction with thinning to maximize benefits. Key structural features such as snags, coarse woody debris, and mature trees should be maintained, along with riparian buffers to protect aquatic areas and provide for habitat connectivity. Long rotations are necessary to provide a broader range of age classes, though the economic impacts may need to be considered.

Biodiversity is ultimately achieved at the landscape level, but stand-level changes can go a long way towards making improvements and can be implemented regardless of ownership pattern. Land use history is an important consideration, as old field sites are unlikely to support a diverse stand structure regardless of management practices. Economics should also be considered, since management practices to increase biodiversity must be economically viable if they are to be successful on private lands. Opportunities for hunting lease revenue may offset some of the costs of managing for biodiversity.

Literature Cited

- 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*. U. S. Dept. of the Interior, National Biological Service, Information and Technology Report 3. 32 p. Available online at http://www.nwrc.usgs.gov/wdb/pub/others/1996_03.pdf; last accessed June 2005.
- Baker, J.C. and W.C. Hunter. 2002. Effects of forest management on terrestrial ecosystems. Pages 91-112 in D.N. Wear and J.G. Greis, eds. *Southern Forest Resource Assessment*. General Technical Report SRS-53. USDA Forest Service, Southern Research Station, Asheville, NC.
- Biblis, E.J., H. Carino, and L. Teeter. 1998. Comparative economic analysis of two management options for loblolly pine timber plantations. *Forest Products Journal* 48(4):29-33.
- Blair, R.M. 1960. Deer forage increased by thinnings in a Louisiana loblolly pine plantation. *Journal of Wildlife Management* 24(4):401-405.
- Blair, R.M. and H.G. Enghardt. 1976. Deer forage and overstory dynamics in a loblolly pine plantation. *Journal of Range Management* 29(2):104-108.
- Blair, R.M. and D.P. Feduccia. 1977. Midstory hardwoods inhibit deer forage in loblolly pine plantations. *Journal of Wildlife Management* 41:677-684.
- Bragg, D.C. 2002. Reference conditions for old-growth pine forests in upper west Gulf Coastal Plain. *Journal of the Torrey Botanical Society* 29(4):261-288.
- Buongiorno, J., B. Schulte, and K.E. Skog. 2004. *Quantifying trade-offs between economic and ecological objectives in uneven-aged mixed-species forests in the southern United States*. General Technical Report FPL-CTR-145. USDA Forest Service, Forest Products Laboratory, Madison, WI. 5 p.
- Conroy, M.J., R.G. Oderwald, and T.L. Sharik. 1982. Forage production and nutrient concentrations in thinned loblolly pine plantations. *Journal of Wildlife Management* 46(3):719-727.
- Dean, T.J. and S.J. Chang. 2002. Using simple marginal analysis and density management diagrams for prescribing density management. *Southern Journal of Applied Forestry* 26(2):85-92.
- Dickson, J.G. 1982. Impact of forestry practices on wildlife in southern pine forests. Pages 224-230 in *Proceedings of the 1981 Convention of the Society of American Foresters*.
- Dickson, J.G. and T.B. Wigley. 2001. Managing forests for wildlife. Pages 83-94 in Dickson, J.G., ed. *Wildlife of Southern Forests: Habitat and Management*. Hancock House Publishers, Blaine, WA.
- Dougherty, D. 2004. Think habitat: Creating "usable space" for quail. *Forest Landowner* 63(3):5-8.
- Fredericksen, T.S., H.L. Allen, and T.R. Wentworth. 1991. Competing vegetation and pine growth response to silvicultural treatments in a

six-year-old Piedmont loblolly pine plantation. *Southern Journal of Applied Forestry* 15(3):138-144.

Grano, C.X. 1970. *Eradicating understory hardwoods by repeated prescribed burning*. Resource Paper SO-56. USDA Forest Service, Southern Forest Experiment Station, New Orleans, LA.

Halls, L.K. 1973. Managing deer habitat in Loblolly-Shortleaf pine forests. *Journal of Forestry* 71(12):752-757.

Harrington, T.B. and M.B. Edwards. 1999. Understory vegetation, resource availability, and litterfall responses to pine thinning and woody vegetation control in longleaf pine plantations. *Canadian Journal of Forest Research* 29:1055-1064.

Harris, L.D., D.H. Hirth, and W.R. Marion. 1979. The development of silvicultural systems for wildlife. Pages 65-80 in C.L. Shilling and J.R. Toliver, eds. *Recreation in the South's third forest*. Twenty-eighth Annual Forestry Symposium, Louisiana State University, Baton Rouge, LA.

Hartley, M.J. 2002. Rationale and methods for conserving biodiversity in plantation forests. *Forest Ecology and Management* 155:81-95.

Hedman, C.W., S.L. Grace, and S.E. King. 2000. Vegetation composition and structure of southern coastal plain pine forests: an ecological comparison. *Forest Ecology and Management* 134:233-247.

Hunter, M.L., Jr. 1990. *Wildlife, forests, and forestry: Principles of managing forests for biological diversity*. Prentice Hall, Englewood Cliffs, NJ. 370 p.

Hurst, G.A. and R.C. Warren. 1980. Intensive pine plantation management and white-tailed deer habitat. Pages 90-102 in R.H. Chabreck and R.H. Mills, eds. *Integrating timber and wildlife management in southern forests*. Twenty-ninth Annual Forestry Symposium, Louisiana State University, Baton Rouge, LA.

Hurst, G.A. and R.C. Warren. 1982. Impacts of silvicultural practices in loblolly pine plantations on white-tailed deer habitat. Pages 484-487 in E.P. Jones, ed. *Proceedings of the second biennial Southern Silvicultural Research Conference*. General

Technical Report SE-24. USDA Forest Service, Southeastern Forest Experiment Station, Asheville, NC.

Johnson, R. 1995. Supplemental sources of income for southern timberland owners. *Journal of Forestry* 93(3):22-24.

Johnson, A.S., J.L. Landers, and T.D. Atkeson. 1975. Wildlife in young pine plantations. Pages 147-159 in *Proceedings of the symposium on management of young pines*. USDA Forest Service, Southeast Area, State and Private Forestry, Atlanta, GA.

Jones, W.D., U.A. Munn, S.C. Grado, and J.C. Jones. 2001. *Fee hunting—An income source for Mississippi's non-industrial, private landowners*. Resource Bulletin #FO 164, Forestry and Wildlife Resource Center, Mississippi State University, Mississippi State, MS. 15 p.

Keyser, P.D., V.L. Ford, and D.C. Guynn, Jr. 2003. Effects of herbaceous competition control on wildlife habitat quality in Piedmont pine plantations. *Southern Journal of Applied Forestry* 27(1):55-60.

Landers, J.L. 1987. Prescribed burning for managing wildlife in southeastern pine forests. Pages 19-27 in J.G. Dickson and O.E. Maughan, eds. *Managing southern forests for wildlife and fish, a proceedings*. General Technical Report SO-65. USDA Forest Service, Southern Forest Experiment Station, New Orleans, LA.

Locascio, C.G., B.G. Lockaby, J.P. Caulfield, M.G. Edwards, and M.K. Causey. 1990. Influence of mechanical site preparation on deer forage in the Georgia Piedmont. *Southern Journal of Applied Forestry* 14(2):77-80.

Locasio, C.G., B.G. Lockaby, J.P. Caulfield, M.B. Edwards, and M.K. Causey. 1991. Mechanical site preparation effects on understory plant diversity in the Piedmont of the southern USA. *New Forests* 4:261-269.

Lohr, S.M., S.A. Gauthreaux, and J.C. Kilgo. 2002. Importance of coarse woody debris to avian communities in loblolly pine forests. *Conservations Biology* 16(3):767-777.

- Marion, W.R. and L.D. Harris. 1982. Relationships between increasing forest productivity and fauna in the flatwoods of the southeastern coastal plain. Pages 215-222 in *Proceedings of the 1981 Convention of the Society of American Foresters*.
- Marion, W.R., M. Werner, and G.W. Tanner. 1986. *Management of pine forests for selected wildlife in Florida*. Circular 706. Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Available online at http://wfrec.ifas.ufl.edu/range/pdf_docs/tanner/cir-706.pdf; last accessed June 2005.
- McComb, W.C. and G.A. Hurst. 1987. Herbicides and wildlife in southern forests. Pages 28-37 in J.G. Dickson and O.E. Maughan, eds. *Managing southern forests for wildlife and fish, a proceedings*. General Technical Report SO-65. USDA Forest Service, Southern Forest Experiment Station, New Orleans, LA.
- Means, D.B. and W.H. Campbell. 1981. Effects of prescribed burning on amphibians and reptiles. Pages 89-97 in G.W. Wood, ed. *Prescribed fires and wildlife in southern forests: Proceedings of a symposium*. Belle W. Baruch Forest Science Institute of Clemson University, Georgetown, SC.
- Melchioris, M.A. 1991. Wildlife management in southern pine regeneration systems. Pages 391-420 in M.L. Duryea and P.M. Dougherty, eds. *Forest Regeneration Manual*. Kulwer Academic Publishers, The Netherlands.
- Mengak, M.T. and D.C. Guynn Jr. 2003. Small mammal microhabitat use on young loblolly pine regeneration areas. *Forest Ecology and Management* 173:309-317.
- Miller, J.H., R.S. Boyd, and M.B. Edwards. 1999. Floristic diversity, stand structure, and composition 11 years after herbicide site preparation. *Canadian Journal of Forest Research* 29(7):1073-1083.
- Mississippi State University Extension Service. 2004. *Forest management for wild turkeys*. Publication 2033. Available online at <http://msucares.com/pubs/publications/p2033.htm>; last accessed June 2005.
- Moore, S.E. and H.L. Allen. 1999. Plantation forestry. Pages 400-433 in M.L. Hunter Jr., ed. *Maintaining biodiversity in forest ecosystems*. Cambridge University Press, New York.
- Moorman, C. 2002. Burnin' for wildlife. *Forest Landowner* 61(3):5-7.
- Noss, R.F. 1988. The longleaf pine landscape of the Southeast: Almost gone and almost forgotten. *Endangered Species Update* 5(5):1-8.
- Oliver, C.D. 1992. A landscape approach: Achieving and maintaining biodiversity and economic productivity. *Journal of Forestry* 90(9):20-25.
- Oliver, C.D. and B.C. Larson. 1990. *Forest stand dynamics*. McGraw Hill, New York. 419 p.
- Reed, D.P., R.E. Noble, and T.R. Clason. 1994. Effects of timber management activities on understory plant succession in loblolly pine plantations. Pages 109-113 in *Proceedings of the 47th Annual Meeting of the Southern Weed Science Society*.
- Reid, W.V. and K.R. Miller. 1989. *Keeping options alive: the scientific basis for conserving biodiversity*. World Resources Institute, Washington, DC. 128 p.
- Robbins, L.E. and R.L. Myers. 1992. *Seasonal effects of prescribed burning in Florida: A review*. Miscellaneous Publication No. 8. Tall Timbers Research, Inc, Tallahassee, FL. 96 p.
- Schultz, R.P. 1997. Multiple-use management of loblolly pine forest resources. Pages 9-3 – 9-14 in *Loblolly Pine: The Ecology and Culture of Loblolly Pine* (Pinus taeda L.). Agriculture Handbook 713. USDA Forest Service, Washington, DC.
- Sharitz, R.R., L.R. Boring, D.H. Van Lear, and J.E. Pinder, III. 1992. Integrating ecological concepts with natural resource management of southern forests. *Ecological Applications* 2(3):226-237.
- Siry, J.P. 2002. Intensive timber management practices. Pages 327-340 in D.N. Wear and J.G. Greis, eds. *Southern Forest Resource Assessment*.

General Technical Report SRS-53. USDA Forest Service, Southern Research Station, Asheville, NC.

Siry, J., F. Cabbage, and A. Malmquist. 2001. Potential impact of increased management intensities on planted pine growth and yield and timber supply in the South. *Forest Products Journal* 51(3):42-48.

Stransky, J.J. and J.H. Roese. 1984. Promoting soft mast for wildlife in intensively managed forests. *Wildlife Society Bulletin* 12(3): 234-240.

Tappe, P.A., M.G. Shelton, and T.B. Wigley. 1993. Overstory-understory relationships in natural loblolly pine-hardwood stands: implications for wildlife habitat. Pages 613-619 in J.C. Brissette, ed. *Proceedings of the Seventh Biennial Southern Silvicultural Research Conference*. General Technical Report SO-93. USDA Forest Service, Southern Forest Experiment Station, New Orleans, LA.

Thill, R.E. 1990. Managing southern pine plantations for wildlife. Pages 58-68 in *Proceedings of the 19th IUFRO World Congress*. Canadian International Union of Forestry Research Organizations, Montreal, Canada.

Tucker, J.W., Jr., G.E. Hill, and N.R. Holler. 1998. Managing mid-rotation pine plantations to enhance Bachman's sparrow habitat. *Wildlife Society Bulletin* 26:342-348.

Turner, J.C., J.A. Gerwin, and R.A. Lancia. 2002. Influences of hardwood stand area and adjacency on breeding birds in an intensively managed pine landscape. *Forest Science* 48(2):323-330.

Van Lear, D.H., R.A. Harper, P.R. Kapeluck, and W.D. Carroll. 2004. History of Piedmont forests: implications for current pine management. Pages 127-131 in K.F. Connor, ed. *Proceedings of the 12th biennial southern silvicultural research conference*. General Technical Report SRS-71. USDA Forest Service, Southern Research Station, Asheville, NC.

Wahlenberg, W.G. 1946. Longleaf Pine: Its use, ecology, regeneration, protection, growth, and management. Charles Lathrop Pack Forestry Foundation, Washington, DC.

Wicker, G. 2002. Motivation for private landowners. Pages 225-237 in D.N. Wear and J.G. Greis, eds. *Southern Forest Resource Assessment*. General Technical Report SRS-53. USDA Forest Service, Southern Research Station, Asheville, NC.

Wigley, T.B., W.M. Baughman, M.E. Dorcas, J.A. Gerwin, J.W. Gibbons, D.C. Guynn Jr., R.A. Lancia, Y.A. Leiden, M.S. Mitchell, and K.R. Russell. 2000. Contributions of intensively managed forests to the sustainability of wildlife communities in the South. In *Sustaining southern forests: The science of forest assessment*. Southern Forest Resource Assessment. Available online at <http://www.srs.fs.usda.gov/sustain/conf/ppr/wigley-ssf2000.pdf>; last accessed June 2005.

Wigley, T.B., K.V. Miller, D.S. deCalesta, and M.W. Thomas. 2002. Herbicides as an alternative to prescribed burning for achieving wildlife management objectives. Pages 124-138 in M.W. Ford, K.R. Russell, and C.E. Moorman, eds. *The role of fire for nongame wildlife management and community restoration: traditional uses and new directions*. Proceedings. General Technical Report NE-288. USDA Forest Service, Northeastern Research Station, Newton Square, PA.

Wilson, M.D. and B.D. Watts. 1999. Response of brown-headed nuthatches to thinning of pine plantations. *Wilson Bulletin* 111(1):56-60.

Yin, R. and R.A. Sedjo. 2001. Is this the age of intensive management? A study of loblolly pine on Georgia's Piedmont. *Journal of Forestry* 99(12):10-17.