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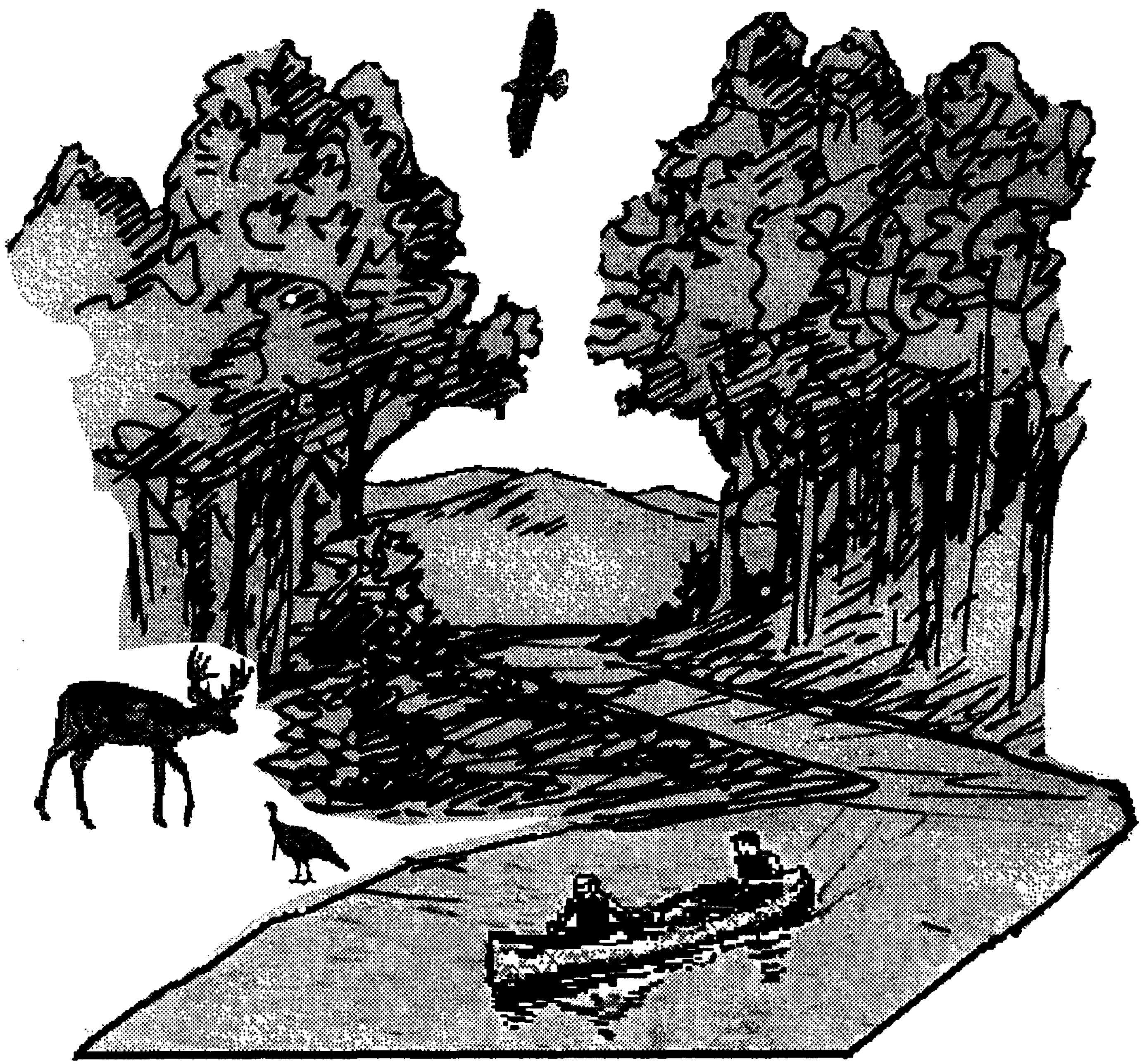
Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings



Proceedings of the Symposium on

ECOSYSTEM MANAGEMENT RESEARCH IN THE OUACHITA MOUNTAINS: PRETREATMENT CONDITIONS AND PRELIMINARY FINDINGS

Hot Springs, Arkansas
October 26-27, 1993

Compiled by

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PREFACE

In August 1990, USDA Forest Service researchers from the Southern Forest Experiment Station and resource managers from the Ouachita and Ozark National Forests embarked on a major ecosystem management (then called New Perspectives) research program aimed at formulating, implementing, and evaluating partial cutting methods in shortleaf pine-hardwood stands as alternatives to clearcutting and planting. The program consisted of three phases: Phase I-an umeplicated stand-level demonstration project; Phase II-a scientifically based, replicated stand-level study; and Phase III-a large-scale watershed or landscape study.

Harvesting treatments for the stand-level (Phase II) study were implemented during the summer of 1993. However, soon after the test stands were selected in 1990, pretreatment monitoring of various parameters was begun by a research team comprised of more than 50 scientists and resource managers from several Federal and State agencies and universities (a list of the research team follows). The pretreatment monitoring continued through the summer of 1993.

A symposium, cosponsored by the USDA Forest Service Southern Forest Experiment Station and Ouachita and Ozark National Forests, the University of Arkansas at Monticello School of Forest Resources, the Arkansas Cooperative Extension Service, and the Ouachita Society of American Foresters, was held in Hot Springs, AR, on October 26-27, 1993, to present these pretreatment conditions and preliminary findings. This Proceedings includes those presentations.

I would like to express my gratitude to all of the participants in this symposium, and especially to the authors who have contributed to this effort. Also, there are a number of individuals whose contributions made the meeting a success, and they deserve a special note of thanks. They include:

> Dr. Larry Willett, Arkansas Cooperative Extension Service, Monticello, AR. Larry handled the symposium announcements and registration and many other logistical chores that helped the symposium to run smoothly.
>
> Dave Hammond, O.D. Smith, Larry Hedrick, Bill Walker, Dan Nolan, Frank Yerby, and Frank Lewis USDA Forest Service, Ouachita and Ozark National Forest staff officers and rangers who served as moderators for the various sessions of the symposium and kept us on schedule.
>
> The sponsors, without whose support the symposium could not have been held.

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Evolution of Ecosystem Management and Research on the Ouachita and Ozark-St. Francis National Forests

Mike Curran[1]

ABSTRACT

Progressive change has surrounded the development and management by the USDA Forest Service of the Ouachita National Forest since its establishment in 1907. Destructive logging practices that left the land in poor condition were followed by a period of restoration and protection. As the forest matured, its valuable timber products were once again in demand. Controversy erupted as the public saw national forest lands being managed similar to timber industry lands. A protracted period of planning, appeals, and lawsuits led to changes that contributed to the agency's movement into an ecosystem-based form of management. In 1993, the USDA Forest Service management on the Ouachita and Ozark-St. Francis National Forests and researchers at the Southern Forest Experiment Station were presented the first USDA Forest Service Chiefs Ecosystem Management Award.

INTRODUCTION

At the turn of the century, public lands were being exploited throughout the country for their timber reserves. Destructive logging practices that showed little regard for the future resulted in eroded soils and damaged watersheds. These deteriorating conditions caught the attention of then President Theodore Roosevelt, prompting the establishment of national forests that would be managed by the USDA Forest Service.

In a span of 85 years, the Ouachita National Forest progressed from that period of environmental disobedience to become a national leader in ecosystem management. Once known as that "inaccessible burning and bleeding wilderness, " the forest now enjoys the proud distinction of being known as a laboratory for progressive change.

In the early years, forest managers gently tinkered with the parts while awaiting the restoration of the forest's resilient biological systems. In the absence of fire, forests returned, not as before, but as nature would have it, reincarnated as a new forest with a new look and a new life. As nature replenished the forest, the public's recognition of, and fondness for, these new forest lands also evolved.

Following World War II, and accelerating into the 1960's, dramatic change was occurring on a regional scale as millions of acres of forest industry lands were converted to plantations. National forest lands were following suit, and the unfavorable public response was inevitable. Just as surely as the commercial potential of these productive lands once fostered exploitation, so has their restored beauty developed a passion for protection.

THE 1986 FOREST PLAN

The first version of a comprehensive Forest Land Management Plan for the Ouachita National Forest was completed in the spring of 1986. Controversy over the strong timber emphasis and wide use of clearcutting erupted with multiple administrative appeals and a drive by the environmental community to generate public support. Powerful coalitions were developing, which aggressively promoted media interest and political support. Controversy surrounding the management of the Ouachita National Forest provided the opportunity for Forest Service management to promote change from within and to experiment with bold new initiatives.

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[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

[2] Forest supervisor, Ouachita National Forest, Hot Springs, AR 71902.

With a new, but already tarnished Forest Plan some 10 years in the making, management's task was to convince agency leadership of the need to return to the planning process. It was clear that the plan did not have broad public support, and that weaknesses in the plan would not survive numerous substantive appeals. With a willingness on the part of Forest Service personnel to reevaluate the issues in good faith, the opportunity existed to forge a closer working relationship with alienated public interests.

THE NEW FOREST PLAN

Chief Dale Robertson agreed to suspend action on the appeals and allow the Forest Service to **re-enter** the planning process. Interim guidelines for management were defined for the period of time required to supplement the original Forest Plan. However, the decision to supplement the Plan was not without considerable fanfare. Some greeted the decision with anticipation, while others viewed it with skepticism.

In an attempt to demonstrate sincerity and generate a climate for constructive resolution of the issues, the Forest Service announced to the media that "clearcutting was on the way out and selection logging was on the way in." Enthusiasm was beginning to build as most interests looked forward to a new day. However, the timber industry felt betrayed as they thought they had already made numerous concessions in developing the original Forest Plan.

An important decision was made at the onset of planning to involve the public in all aspects of the decision process. With Forest Service credibility rapidly declining, the intent was to draw all interests back into the planning process with the hope of fashioning resolution on all or part of the issues. A comprehensive public participation plan was developed that included periodic bulletins, news releases, public forums, and workshops. A high priority was placed on individual and group contact on a continuing basis. Consensus building occurred throughout the process but resulted in limited success. Some successful negotiations did occur: with the Wild Turkey Federation that resulted in the establishment of walk-in turkey areas; with Tom McClure of the Wilderness Society that provided for the expansion and protection of special areas; with the Oklahoma Department of Wildlife Conservation who successfully fought for the retention of hardwoods in all pine stands; and with the timber industry that allowed for the further reduction of clearcutting.

Others, however, like the Ouachita Watch League (OWL) and the Sierra Club, chose to take advantage of public indignation over clearcutting and pursued administrative and legal procedures to maximize their objectives. Given the social/political climate surrounding forest management in Arkansas and Oklahoma at the time, it is doubtful that further consensus building with these groups would have been possible.

A variety of issues including timber harvest methods, herbicide use, road construction, and recreation emphasis were reevaluated. The overriding issue was, and still remains, the fear of change or reduction of hardwood composition within the pine-vegetative type. The supplemental plan succeeded in attaining increased support from the public and most appellants. In spite of the many changes incorporated into the new Forest Plan to accommodate the concerns of the environmental community, OWL and the Sierra Club appealed the supplemental plan and filed a lawsuit.

The new plan issued in March 1990 reflects innovation and public responsiveness in forest management. Highlights include:

- Continuous and substantive involvement by the public in the decision-making process.
- Major reduction in clearcutting from 16,000 acres per year to 5,200 acres per year, and presently, with recent amendments, virtual elimination of clearcutting.
- Increase in seed tree and shelterwood methods.
- Experimental use of 15,000 acres per year of selection-harvest methods.
- Significant increases in thinning.
- Hardwood retention within pine stands.
- Restricted timber harvest in hardwood types.
- Maximum protection for stream corridors, which precludes any timber removal.
- Major expansion of special areas (scenic, biologic, etc.)
- Addition of two *new* wilderness areas and a National Recreation Area in Oklahoma.
- Two new Wild & Scenic River designations for the Cossatot and Little Missouri Rivers.
- Two new Scenic Byways for Hwy. '7 and the Talimena Scenic Drive.
- Major increase in trail construction and reconstruction.
- Initiation and completion of the first botanical inventory of the Ouachita National Forest.

As a result of the considerable efforts made to resolve the issues, the Forest Service was recognized with awards from both the Arkansas and Oklahoma Wildlife Federations and in 1991 was the recipient of the Chevron Conservation Award and the United Nations Environmental Programme Award.

NEW PERSPECTIVES

In August of 1990, an event of historic significance occurred when Chief Dale Robertson met with Arkansas Senator David Pryor to discuss the continued use of clearcutting in the Ouachita National Forest. Labeled the "Walk in the Woods" by the media, the meeting signaled the agency's movement away from clearcutting as a predominant harvesting method. More importantly, it signaled a move toward an ecosystem approach to management. In fact, the Walk in the Woods led to the designation of the forest as a lead forest under the New Perspectives Program, opening the way for a unique partnership between national forest management, researchers, and the public. Progressive change and innovation were the hallmarks of this effort.

In order to capitalize on this opportunity, the Southern Forest Experiment Station, on the research side of the Forest Service, took prompt action to co-locate researchers with the Ouachita National Forest headquarters. Other Southern Station researchers were assigned to assist this effort from their home units. What had been an arms-length relationship in the past became a hands-on partnership for the future. The willingness of these two distinct sides of the organization to close ranks in this manner was undoubtedly the biggest factor in the effort's immediate success. Success in this case was measured by the ability to move quickly to demonstrate and evaluate new ways of harvesting timber and sustaining forests of pine and hardwood. With this narrow role as a starting point, the New Perspectives enthusiasm spread and grew throughout the Ouachita. In an attempt to capitalize on the opportunity, the districts began developing their own demonstration projects. Once again, research was available to provide support and assistance.

Two years later, the Ouachita National Forest management had developed a forest-wide old-growth policy, and two ranger districts were developing their own large-scale old-growth management efforts. These projects emphasized the importance of old-growth forest conditions to the biological diversity of the forest. Another ranger district focused its attention on aquatic ecology and has since developed an aquatic learning center, which includes accelerated research, monitoring, and protection efforts. The learning center also provides environmental education opportunities.

The most unique and comprehensive project includes three ranger districts and encompasses *over 100,000* acres. This landscape-scale project is designed to restore the pine-bluestem ecosystem to a portion of its historic range. This area is also the home of the few remaining colonies of red-cockaded woodpeckers (RCW) in the forest. Because this ecosystem represents ideal habitat for the RCW, optimism for recovery of the species is high. Several research studies have accompanied this project in an attempt to characterize this ecosystem in terms of responses by other bird and animal species. Studies to determine the effects of black rat snake and flying squirrel predation on the woodpecker are currently underway. This project benefitted from the assistance of research and the willing participation of the public during its formative stages.

Another by-product of the Walk in the Woods was the establishment of a much closer working partnership with the public. Chief Robertson authorized the designation of a technical advisory committee to work with the Ouachita National Forest management and research scientists in defining what New Perspectives meant from their own varied backgrounds and perspectives. Intellectual archetypes, such as the advisory committee, have a potential for eliciting a significant influence over stalled environmental debate. The Chiefs intent was to take advantage of the collective intellectual consciousness of this elite group of individuals.

Ecologist Bill Pell was hired to coordinate the New Perspectives program and to serve as a close liaison with the advisory committee and the research community. For 2 years, the advisory committee met and debated a variety of issues. The first year was spent developing a generic desired future condition statement for the Ouachita National Forest. The opportunity to review and comment on Phase II (stand-level research) was also provided. Considerable time was spent discussing the importance of the social context of resource planning. In 1992, in cooperation with Winrock International, the Ouachita National Forest, and Southern Forest Experiment Station, a social science workshop was conducted. As a result of this interest by the advisory committee, considerable attention has been placed on assessing the social context in which the Ouachita National Forest exists.

DEMONSTRATIONS FOR THE PUBLIC

Due to considerable public interest generated in viewing New Perspectives practices and concepts on the ground, demonstration projects to showcase these practices classified as Phase I areas were developed. Within a year, hundreds of people were touring these sites, which proved extremely popular and were effective in demonstrating some of the practices the districts were employing across the Ouachita National Forest. These sites also served as a prelude to the stand-level research on alternative management practices (Phase II), which was then in its planning phases. It quickly became apparent that spatial and temporal constraints of implementing this stand-level research would necessitate the need for a third phase of research at the landscape or watershed scale to better address ecosystem values. This Phase III research will focus *on* establishing and evaluating ecosystem functioning for different desired future conditions at the watershed scale over several decades.

Two years after the advent of the New Perspectives program, then President George Bush announced a further reduction of clearcutting nationwide and an emergence of ecosystem management as the new approach to the management of all national forests. The Chief of the Forest Service announced the agency's move toward Ecosystem Management on June 4, 1992, saying that national forest management would never be the same. Deputy Chief James Overbay followed with a policy statement that delineated the magnitude and importance of embracing this new concept. It emphasized managing ecosystems to sustain both their diversity and productivity in a way that is sensitive to social values. The intent was to chart a course for making this concept the foundation for sound, multiple use, sustained-yield management.

Shortly thereafter, the Ouachita and Ozark-St. Francis National Forest management and the Southern Forest Experiment Station researchers were awarded the Chiefs Ecosystem Management Award for their ongoing efforts. Perhaps the highest compliment bestowed came from President Bill Clinton. The President, while participating in the timber summit in Oregon, complimented the Chief for the leadership shown by the Ouachita National Forest in initiating ecosystem management. He encouraged the Chief to expand these principles and changes across the entire agency.

CONCLUSION

Thus; we see the genesis of Ecosystem Management as a means to blend the needs of people and environmental values in such a way that the national forests and grasslands represent diverse, healthy, productive, and sustainable systems. We don't have all of the answers, nor is all of the needed research yet in place. However, this shall not prevent us from adapting to the inevitable change necessary to accommodate the needs of the people we serve. Our credibility as an agency and as responsible stewards of the land depends on this.

Roles of Science and Research in Implementing Ecosystem Management on the Ouachita National Forest[1]

William F. Pell[2]

ABSTRACT

On the Ouachita National Forest, USDA Forest Service management appears to be "out in front of research" because management is more adaptive and less "cookbook" than in the 1970's and 1980's, particularly now that ecosystem management is being pursued aggressively. Science and research play significant roles in Ouachita National Forest efforts to develop, refine, and implement ecosystem management solutions, notably in terms of evaluating viable alternative strategies, enhancing understanding of system structure, function, and dynamics and acknowledging uncertainties. Because those who seek to apply ecosystem management are faced with a variety of potentially sustainable alternatives, public participation and the multitude of values and relationships with the land that people want to sustain are as vitally important to the process as scientific information.

INTRODUCTION

Over the last 3 years, many have said that what Ouachita National Forest management is doing on an operational basis, at least in terms of silviculture, is "out in front of [the] research." Some observers have gone a step further and said that ecosystem management, as currently attempted on the Ouachita National Forest, is "unscientific" or even "bad forestry."

These comments and notions are worth thinking about. They reflect some deeper assumptions about the role of research and therefore of science in land management. But they also suggest that neither the context nor the need for ecosystem management research on the Ouachita National Forest have been clearly understood. These deficiencies will be addressed by answers to the following four questions:

(1) Is management of the Ouachita "out in front" of research in the sense that managers are implementing practices before they have been thoroughly studied?
(2) Is the way the Ouachita is currently pursuing ecosystem management "scientific?"
(3) Will research define (or is research defining) what is, and what is **not,** ecosystem management?
(4) To what extent should--or can--ecosystem management (or any kind of land management) be scientifically based?

DISCUSSION

The way it is phrased, the answer to the first question is easy: "Yes, of course, the Ouachita is out in front of research in the sense of implementing management practices before they have been thoroughly studied."

The Ouachita National Forest, for example, is implementing treatments such as single-tree selection and modified shelterwood and seedtree harvests that researchers have only studied in the Ouachita Mountains since 1989. Managers are using streamside management zones; aiming to retain more downed woody material on land and in streams; retaining snags and multiple species of mature trees in all stands; protecting seeps and glades; and moving toward old-growth restoration. None of these modifications or strategies have been thoroughly studied yet.

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[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

[2] Ecologist/Ecosystem Management Coordinator, USDA Forest Service, Ouachita National Forest, Hot Springs, AR, 71902.

Twenty or more years ago when clearcutting emerged and then became the predominant harvest method,the situation may have been similar to the current one. Most foresters today certainly know more about regenerating pines under a clearcut-and-plant regime than under partial harvesting and natural regeneration. But how long did it take for foresters to achieve high rates of success at artificial regeneration? Wasn't management of the Ouachita "out in front of research" in another sense until the mid to late 1980's (Bamett 1992)?

Clearcutting and artificial regeneration can be said to be more "scientific" than partial harvesting and natural regeneration *only* because successful tree regeneration is currently more predictable in the former. This is an extremely limited view of science, though. Certainly knowledge of whole systems was no better under clearcutting than it is today. The effects of different landscape vegetation patterns on forest interior species, for instance, was scarcely considered, let alone understood. Just as poorly understood were the social consequences of extensive and highly visible clearcutting.

Part of the reason management now seems even further "out in front of research" is that, although managers and researchers now have a great deal of knowledge about harvesting, planting, and using trees, knowledge about forest systems as a whole remains limited. Most forestry research has focused on production and utilization. The biology of noncommercial organisms, the function and dynamics of ecosystems, and the many human or social dimensions of ecosystems have received little attention (National Research Council 1990). It is no coincidence that reports as varied as "Forestry Research: A Mandate for Change" (National Research Council 1990), "the Sustainable Biosphere Initiative" (Lubchenco and others 1991), and the Society of American Forester's "Task Force Report on Sustaining Long-term Forest Health and Productivity" (Society of American Foresters 1993) all call for increased emphasis on understanding ecosystems and the many roles and values of people in those ecosystems.

Managers of the Ouachita are fortunate to have the Phase II research team and other scientists helping to develop more knowledge about Ouachita Mountain ecosystems. From now on, though, whenever someone suggests that "management is out in front of research," maybe it should be suggested that this is the way it must be; that land management, by nature, is "a continual experiment and learning opportunity"[3] backed only partially by good science.

The second question, "Is the way the Ouachita is currently pursuing ecosystem management 'scientific?,'" has already been answered at least in part. But take a deeper look at some of the changes taking place in the Ouachita National Forest, a sampling of which is included in Table 1. Since 1989 the pace of change and adaptation on this national forest has been remarkable, at least by most standards. Some of that rapid evolution has been fueled by ongoing dialogue with researchers, and most of the changes made to date have some basis in science. It is clear, on the other hand, that these changes have not been driven by compelling *scientific evidence* that change was imperative. The charge that the adoption by the Ouachita of some or all of these changes has been "unscientific" suggests that management acted without scientific proof that course corrections would head off or reduce the probability of environmental catastrophe(s). It is true that such scientific proof is lacking in most cases. It is equally *true* that waiting for such proof can be the utmost folly. *In an* adaptive management framework, it makes far more sense to respond as best possible to persistent, genuine concerns rather than waiting for disasters to manifest--even if those concerns, including biological diversity, esthetics, water quality, and long-term productivity, are fed by both scientific and anecdotal observations.

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[3] Robertson, F.D. 1992. Ecosystem management of the National Forests and Grasslands. Letter from Chief of the USDA Forest Service to regional foresters and station directors, June 4, 1992. On file with: Office of the Chief, U.S. Department of Agriculture, Forest Service, Washington, DC.

Table 1. - *Ecosystem management: What's really changing on the Ouachita National Forest?*

- Less emphasis on commodities (though still important) and increasing emphasis on land health: The beauty, ecological integrity, and native diversity of Ouachita National Forest (ONF) lands are becoming at least as important as forest products.

Examples:	Maintaining forests that look like forests, with greater structural and species diversity; more hardwoods and older forests.
	Partial harvesting substituted for clearcutting throughout the forest.
	Scenic byways and other scenic road corridors; wild and scenic rivers; expanded heritage resources, trails, and interpretive programs.

- Increasing emphasis on larger scale and more ecologically meaningful units--watersheds, landscapes, ecoregions--for planning and evaluation.

Examples:	Watershed-level project planning on many districts.
	Ecological classification system under development for the ONF, Region, and United States.
	Participation in statewide gap analysis programs.

- Expanded focus on meaningful public participation

Examples:	Wilderness steering committees
	Ecosystem Management Advisory Committee
	Pre-decisional public involvement

- Concern for maintaining ALL native plants and animals, not just the ones that are harvested; more hardwoods; more emphasis on stream protection.

Examples:	Mature hardwoods retained in all harvested stands
	Rare plant inventories and protection
	Red-cockaded woodpecker recovery
	Aquatic-sensitive species and basin-area surveys; streamside protection zones

The Ouachita's response has been that although additional credible information is certainly needed and desired, public and scientific uncertainty about these issues is sufficient to justify changes before all of the scientific information is in. It makes more sense ecologically and from an adaptive management stance to designate streamside management zones and to set standards for dead and downed woody material, snags, and mixed species stands than to wait for exhaustive knowledge about such variables. Similarly, with the knowledge available now, it appears that partial harvesting should meet most, if not all, management objectives including less fragmentation of forest interior habitat and more attractive landscapes. But these are still hypotheses, and it will take years before they can be rejected or accepted on rigorous scientific terms.

Ecosystem management on the Ouachita National Forest is still evolving and, very likely, always will be. It may be helpful to think of ecosystem management as an iterative flow process, one that requires 1) broad and current knowledge of the ecosystems of concern, 2) effective, ongoing public involvement and interdisciplinary planning aimed at understanding existing conditions and making decisions about desired ecosystem conditions, 3) actions to move toward desired conditions, and 4) periodic monitoring and evaluation of results. Each of these steps or processes is a source of changing information, needs, and concerns that will contribute to continued evolution.

The third question is "Will research define ***(or*** is research defining) what is, and what is not, ecosystem management?" Most managers and researchers realize that there really is ***no*** simple scientific or technical answer to the issue of how the Ouachita National Forest should be managed. There is no single scientifically correct solution. In terms of ecological potential, the land can produce many different kinds of communities, and does. In terms of silviculture, there is a broad range of techniques to choose from, but not one that can meet all needs. Wherever one looks, there are multiple options, not singlesolutions.

If ecosystem management was confined simply to technical understanding and evaluation of those options, ecosystem management might indeed be defined solely by science or scientists. But if ecosystem management is viewed as a more inclusive, framework for integrating ecological, social-cultural, and resource use concerns, both very technical and non-technical issues and perspectives should be considered. Ecosystem management, in other words, is not another attempt to provide a technological "fix" for the complex challenges of public land management. Although we must have the best technical and scientific information available, forest managers also must be attuned to the desires, and have the consent and support of, a diverse society. Building recognition, credibility, and trust between citizens and public land managers, in other words, are goals as vital to ecosystem management as promoting ecological integrity and sustainable land use. The Ecosystem Management Advisory Committee has pointed this out repeatedly.

Scientists, managers, and citizens must work together to achieve these goals. Although scientists play a major role, they can, at best, contribute to the search for answers, not provide the definitive solutions. Scientific ingenuity is particularly needed to help address ***issues,*** patterns, and processes at large scales over long time periods. Researchers will increasingly be called on to engage in participatory research and to go beyond traditional agricultural experimental designs.

Research is a prominent part of sound ecosystem management. But is also takes other dynamic components, interacting with research much like different components of an ecosystem interact, to produce the outcome called ecosystem management. Some of the other components of ecosystem management include (1) inventory, mapping, and classification, (2) planning and decision-making, (3) monitoring and evaluation, (4) citizen participation, (5) information management, and (6) information sharing and interpretation. Citizen participation and partnerships are actually woven throughout ecosystem management, and cannot be treated as ancillary or separate processes. Extra attention is given to it here, in part, to recognize the importance of extraordinary efforts to more effectively engage citizens in dialogue and deliberations about their (public) lands.

The final question is, "To what extent should--or can--ecosystem management be science-based?" Issues such as biodiversity, long-term productivity, regeneration of pine-hardwood mixes, and cumulative impacts on streams simply must be addressed with solid data in hand. Social concerns from local economic dependence to public participation in decision-making also demand good science.

In an ecosystem-based approach to evaluating management options, science plays a strong role. So too does public participation and the multitude of values and relationships with the land that people want to sustain. Science and values must be woven together throughout the process and throughout the kinds of work that will make ecosystem management a reality.

Scientists have a major role to play, first, in terms of providing citizens and managers with sound information about ecosystems, including their many cultural and social dimensions, and second, by providing or contributing to formation of reliable ***alternatives*** for ecosystem management (Mrowka 1993, Sesco 1992).

LITERATURE CITATIONS

Bamett, J.P. 1992. History of shortleaf pine artificial regeneration task force and objectives of the workshop. In: Proceedings of the Shortleaf Pine Regeneration Workshop; 1991 October 29-3 1; Little Rock, AR. Gen. Tech. Rep. SO-90. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station:

Lubchenko, J.; Olson, A.M.; Brubaker, L.B.; (and others). 1991. The sustainable biosphere initiative: an ecological research agenda. Ecology. 72:#371-412.

Mrowka, R. 1993. What is different about ecosystem management? Timber Talk. Washington, DC. 2 **p**.

National Research Council. 1990. Forestry research: a mandate for change. Washington, DC: National Academy Press. 84 p.

Sesco, J. 1992. The role of research in taking an ecological approach to land and resource management. In: Taking an ecological approach to management: Proceedings of the National Workshop; April 27-30, 1992; Salt Lake City, UT. Washington, DC: U.S. Department of Agriculture, Forest Service: 16-22.

Society of American Foresters. 1993. Task force report on sustaining long-term forest health and productivity. Bethesda, MD: Society of American Foresters. 83 p.

Implementing Ecosystem Management Research: Bringing Researchers, Managers, and Citizens Together[1]

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ABSTRACT

Ecosystem management encourages increased interaction among researchers, managers, and citizens to resolve national forest issues. Ecosystem Management Research on the Ouachita and Ozark National Forests has been an early example of such collaboration. We recount the history of Phase I and II implementation, highlighting researcher/manager/citizen interactions in accomplishing stand selection, compliance with the National Environmental Policy Act, sale preparation, harvest, and site preparation. We also share insights about interactions among these three groups and offer recommendations to enhance collaboration for ecosystem management.

INTRODUCTION

Two primary themes of ecosystem management are: (1) increasing interactions between researchers and managers and (2) improving public involvement (Overbay 1992, Robertson 1993). Ecosystem Management Research on the Ouachita and Ozark National Forests has been one of the earliest and most highly profiled opportunities to bring these two themes together in an operational program. As such, it is fruitful to examine its implementation and the resulting interactions among researchers, managers, and citizens. Lessons learned here should be valuable to future efforts because it seems clear that public land management will be increasingly defined through the shared influence of researchers, managers, and citizens. It will take bringing together the perspectives and expertise of all three of these groups, in a working network or community, to successfully and sustainably manage ecosystems for all the diverse uses and values that society demands.

Our objectives here are to: (1) describe the history of Phase I and II implementation, focusing especially on those elements relevant to relationships among researchers, managers, and citizens, and (2) share our insights on the interactions among these three groups.

A HISTORY: IMPLEMENTATION OF PHASES I AND 11

Phase I

The Ecosystem Management Research Program originated in August, 1990, during "The Walk in the Woods," a seminal field trip on the Ouachita National Forest that included Arkansas Senator David Pryor and USDA Forest Service Chief Dale Robertson. Discussions during this trip resulted in the elimination of clearcutting on the Ouachita National Forest in favor of alternative methods of reproduction cutting. The Ouachita National Forest was designated as a lead forest for the fledgling New Perspectives program; the USDA Forest Service Southern Forest Experiment Station was charged with supporting the Ouachita's move to alternative silvicultural systems.

To meet this charge, Southern Station scientists met with cooperating scientists from universities and other agencies and forest managers in October 1990 to begin research planning. Researchers viewed Chief Dale Robertson's instructions--to immediately demonstrate alternative silvicultural methods--as too limiting to allow rigorous scientific examination of many important questions. Sampling bias resulting from use of existing sales was a major concern. Therefore, a three-phase

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approach was designed: Phase I - to get demonstrations in place as quickly as possible; Phase II - to take a statistically valid look at effects of alternative silviculture; and, Phase III - to address questions relevant to scales larger than the stand scale.

The Southern Station and the Ouachita National Forest both committed full-time personnel to spearhead research implementation. The Southern Station placed a full-time scientist in the Forest Supervisor's office; the Ouachita National Forest provided a full-time liaison and forestry technician, as well as additional assistance from the Forest's New Perspectives coordinator.

Beginning in January 1991, researchers worked with district managers to select 25 stands to serve as Phase I demonstrations (Guldin and others 1993), representing 8 even-aged and 14 uneven-aged partial cutting methods, plus 3 clearcuts for comparison. Some of these stands had already been harvested, some had been sold and were awaiting harvest, and some were being prepared for sale. Most had completed the National Environmental Policy Act (NEPA) process. Stands this close to implementation were chosen intentionally to ensure that demonstrations would be in place quickly. All stands were identified and harvested by October 1991.

Modification of original prescriptions was necessary in some cases to demonstrate a full range of methods. Negotiations among researchers, district staff, and timber purchasers made these changes possible. Cooperation was excellent. Researchers assisted managers in remarking some stands.

Phase I provided an important opportunity for researchers and managers to begin working together in an applied setting. Disagreements occurred but always resulted in positive and good-natured discussion. Citizen involvement in Phase I establishment was limited due to use of sales that had already completed the formal involvement processes required by NEPA. Phase I stands have proven invaluable, however, as a tool for stimulating public involvement and awareness. Thousands of people from citizens' organizations, professional societies, other national forests, the Forest Service Regional and Washington offices, and the USDA Secretary's office have visited these sites on field trips. Our willingness to discuss and debate silvicultural decisionmaking--even among ourselves in front of our guests--has earned us credibility and has stimulated essential dialogue among both external and internal audiences.

Phase II

Stand Selection

Selection of the 52 stands (4 replicates of 13 treatments; Baker, this volume) needed for the more rigorous Phase II study also began in January 1991. Stand selection turned out to be much more difficult than originally envisioned, primarily because of constraints set by both researchers and managers. Study plans identified target characteristics for pretreatment stands including that they be mature, pine-dominated forests, on predominately south or west slopes, of more than 35 acres, and within subpopulation strips (Guldin and others 1993). In addition, researchers sought to minimize variation in initial stand conditions by eliminating from consideration areas with a recent history of tire, extensive grazing, abundant advance regeneration, or noticeably "untypical" forest composition or structure. A blocky shape to minimize edge were also necessary characteristics for wildlife research.

National forest managers placed constraints on stand selection through Forest Plan standards and guidelines. Such constraints included limiting adjacency to recent harvests, limiting the percentage of area in regeneration, and restricting certain harvest methods in visually sensitive zones.

Candidate stands were identified by randomly selecting administrative compartments from within subpopulation strips. Aerial photos, topographic maps, and stand maps were then used to identify all 40-acre blocks within a compartment that met selection criteria. District staff with knowledge of the areas were asked to confirm or reject these areas as suitable for reproduction cutting using any of the methods to be used in the study, including clearcutting. One stand was then selected at random from those suitable stands within a compartment. Often compartments contained no candidate stands.

The first 15 candidate stands identified in this way within each experimental block (Baker, this volume) then received an 8 to 10 percent inventory of woody vegetation using 1/5-acre fixed-radius plots. These inventories were done by district personnel using direction provided by researchers. Researchers reviewed inventory results for unusual stand characteristics and visited each stand for a cursory visual examination before accepting it as a study stand. If a stand was rejected, the next stand on the candidate list replaced it and an additional alternate stand was selected and inventoried. In this way, 52 stands and alternates were identified for carrying into the environmental analysis process required by NEPA.

Despite this involved selection process, some stands in the study have characteristics that we may have wished to exclude: some are much wetter than average, some are much rockier than average, some are more multi-canopied than we desired, one has a lot of eastern red cedar (Juninerus virginiana L.), one contains a great blue heron (Ardea herodias L.) rookery. In addition, reports of potentially confounding factors continually arise (e.g., this stand has free roaming cattle, this stand has motorcycle tracks, this stand has a southern pine beetle infestation, and on and on).

These examples illustrate the difficulty of controlling unwanted variation in experimental units at this operational scale. Researchers wish to control unwanted variation because fewer replicates are needed to document treatment effects at a given level of confidence. To managers who confront this variety of conditions every day when making management decisions, the effort to exclude confounding factors has sometimes been seen as a narrowing of the problem space to the extent that research results may be correspondingly narrow in their applicability.

The NEPA Process

By mid-July 1991, initial stand selections and treatment assignments had been made, and NEPA analysis began. The initial goal for Phase II implementation was to have harvest treatments completed by September 1992. This placed us on the extremely ambitious schedule of completing public involvement, cultural resource surveys, biological evaluations, environmental analysis, document write-up, the 45day appeal period, and sale preparation, advertisement, and awarding within about 7 months--not to mention collection of pretreatment data. In addition, selected stands continued to change as analysis proceeded: extensive cultural resources were found in one stand, red-cockaded woodpeckers in another, and public opposition scuttled others.

Given this tight schedule, we viewed an administrative appeal of the project decision as a highly undesirable event--one that would almost certainly eliminate implementation in 1992, putting the entire project in doubt. Our goal for public involvement therefore, in addition to gathering substantiative input from a wide variety of citizens, was to develop close relationships with potential appellants, most of whom were members of the Ouachita Watch League. We wanted to ensure that they had excellent access to the process. We wished to eliminate surprises--for them and for us. We had great faith that with enough communication, potential appellants in the environmental community would agree that this project was in their interest and was an honest response to issues they had championed.

Yet, making this communication was difficult because of the deep chasm of mistrust that existed. Suspicions abounded. For example, some of these citizens feared the research was a guise for cutting more timber. Some suspected research stands were sales they had opposed earlier that had been "dumped" by ranger districts into the research project. We were accused of being timber fixated because of the focus on silviculture. At the *same* time, many researchers and managers felt these citizens would torpedo the project for political gain if given an opening, despite what they might say in face-to-face meetings.

We pursued a strategy of pleasantly relentless communication with potential appellants. Letters, phone calls, dinner meetings, and house visits all played a part. We included them in research planning meetings. We listened and were as responsive as possible. At least partly as a result of their input, we added unmanaged controls to the study design, eliminated stands from the Lake Ouachita Management Area, and greatly strengthened research on soil, water, and diversity of plants and insects. We also became more cognizant of our need to focus on ecosystem description, as well as looking at effects of management. Researchers and managers alike recognize that the research program is better today as a result of this interaction with citizens.

Trust and mutual respect grew. Exposure to researchers played a big role in developing this trust and respect. For the most part, researchers came to be viewed as relatively objective and independent, earnestly interested in good science rather than defending a particular position. Managers gained credibility in the eyes of these citizens through association with researchers.

This intensive interaction was but part of the larger, formal public involvement process. Two large mailings were made, one in August 1991 to approximately 1,800 individuals and organizations and another in November to approximately 250 individuals and organizations. The first gave a broad overview of New Perspectives, including the research program; the second described the research and proposed stand locations and treatments in detail. We also produced a press release in December 1991 to reach a wider audience. From all of these efforts, we received responses from 37 people. As with the frequent appellants, we did our best to ensure that no issue was left unresolved, and that a personal touch was part of each response.

Before a decision notice was signed, we released a draft of the environmental assessment (EA) to all who had been involved in the process. This is not usually done for EA's, but we were determined to ensure that no one would be surprised by any aspect of the project. We sent out 80 copies and received 9 responses, resulting in some changes even at this late date.

The New Perspectives Advisory Committee, a group of 13 citizen experts charged with reviewing and advising the Ouachita National Forest's move to new management approaches, was also part of the public involvement process. They reviewed study plans and the EA. Like many other citizens, they desired to see a broadening of emphasis from silviculture to other disciplines, particularly the social sciences. Their satisfaction with Phase II grew as its scope broadened. A cultural resources component was added at their suggestion.

As the planning process proceeded, the tight implementation schedule began to require comer cutting. Opportunities to collect pretreatment data would be limited, along with opportunities for expanding the scope of research. Timber marking and sale preparation would be rushed, with limited opportunity for review and adjustments.

On October 2, 1991, at a meeting of researchers aimed at designing interdisciplinary sampling plots, the subject was broached: could we delay harvest treatments 1 year to summer 1993? Researchers agreed it would improve the quality of the research. Within two weeks, the decision was made to extend pretreatment measurements for a year. Anticipation of a poor cone crop in 1992 provided additional justification for this change in plans.

This was a critical decision to Phase II. Without it, a pretreatment symposium probably would have been unnecessary. It also took pressure off of the relationships forming around Phase II, allowing researchers, managers, and citizens the time to interact effectively.

The Decision Notice for Phase II was signed jointly on April 14, 1992, by Forest Supervisors Mike Curran (Ouachita) and Lynn Neff (Ozark). No appeals were filed.

Timber Sales

With the NEPA process complete and time available to implement carefully, we moved to sale preparation. Using stand inventories taken during stand selection, researchers prepared stand-specific marking guidelines, detailing numbers of trees in each diameter class to be harvested to meet target residual stands.

These guidelines, along with background information, were presented to timber markers and timber managers from 11 districts at a 2-day marking workshop held in Mena, AR, on May 21-22, 1992. The second day was reserved for a field exercise. The field exercise resulted in considerable discussion and disagreement between seasoned timber markers and equally seasoned researchers as to which were "cutters" and which were "keepers" under various silvicultural systems. Researchers carried the day by accepting responsibility for any silvicultural disasters that might result. This opportunity for interaction, beyond its necessity for research implementation, was extremely educational to both the researchers and managers involved.

After marking Phase II stands, districts submitted actual marking tallies to the Silviculture Group for review, where comparisons were made with prescribed tallies. On several occasions, districts were asked to modify their marking to more closely match research prescriptions.

Our goal was to keep sale preparation and harvesting as close to operational as possible while still meeting research needs. However, it became apparent that in our decentralized agency, the 11 districts varied widely in their implementation. Differences in extent and layout of streamside zones, and use of different paint colors to designate unit boundaries, inclusions, temporary road rights-of-way, caused some confusion among researchers and concern about standardization.

Treatment of hardwoods also varied by district. Some districts commonly sold hardwoods for the firewood and pulpwood markets, whereas others had little market and so rarely, if ever, sold hardwoods. To standardize hardwood treatment, we required districts to include hardwoods in the sale if volumes exceeded approximately two cunits per acre, in essence forcing purchasers to harvest trees they normally would not. This is an example of the kind of compromise of operational implementation that was required to meet researchers' desires for standardization.

The 48 harvested units were grouped into 24 timber sales. Most sale contracts were prepared and advertised by the end of September 1992; the remaining followed shortly after. All units were sold by the end of 1992. Total volume sold was 17.2 million board feet at a total revenue of over $2.2 million. Sale volumes, prices, and purchasers are listed in Table 1.

Harvesting began in some stands on May 15, 1993, and was complete in all stands by our target date of September 30, 1993. Sales were administered by districts in the manner used for nonresearch sales. Site preparation began in October 1993 and will proceed through the winter.

NEW RELATIONSHIPS

What have researchers, managers, and citizens learned about each other through the process of implementing Phases I and II?

We must preface our answer to this question with the recognition that what follows are the perspectives of the authors. Although we have been closer to Phase I and II implementation than most, many others undoubtably have gained valuable insights on the interactions among researchers, managers, and citizens through their experience with this project. We would like to see a more comprehensive assessment of these perspectives conducted through a survey of those involved, so that the full value of our experience can be shared with others.

Researchers and Managers

In general, bringing researchers and managers together for this project has been a very positive experience for both. We have learned a great deal about each other and about what had previously been our surprisingly separate professions. Even those who have prided themselves on being "applied" researchers have learned much about the constraints managers face. This can't help but improve the usefulness of the information these researchers will generate.

On the other hand, managers have learned about the constraints necessary to maintain scientific rigor and the limits to legitimate scientific inference. They have also been exposed to new or at least more accessible sources of expertise. Many

Table 1.--*limber sale volumes and prices for Phase II research stands. Ouachira and Ozark National Forests, 1992-93*

Stand	Treatment*	Sale No.	Acres	Volume Sold† Pine Saw	Volume Sold† Pine Pulp	Volume Sold† Hwd Pulp	Price per unit of volume Pine Saw	Price per unit of volume Pine Pulp	Price per unit of volume Hwd Pulp	Purchaser
Caddo 27-1	PHSWns	1	39	309	165	0	$192.27	$8.27	NA	Weyerhaeuser
Caddo 62-8	LISTSs	1	42	82	14	0	$192.27	$8.27	NA	Weyerhaeuser
Caddo 35-41	PSWs	2	35	239	134	0	$215.05	$6.53	NA	Anthony Timberlands
Caddo 35-42	PHGSns	2	52	248	76	0	$215.05	$6.53	NA	Anthony Timberlands
Kiamichi 218-l 1	PHSWs	3	36	160	212	0	$156.10	S7.52	NA	Travis Lumber
Choctaw 62-6	PHGSns	3	70	250	75	0	$156.10	$7.52	NA	Travis Lumber
Fourche 428-2	PHSTSs	4	49	307	50	0	$191.43	$6.52	NA	Bibler Brothers
Fourche 443-3	PSWs	5	40	205	81	0	$181.00	$5.90	NA	Bean Lumber
Fourche 456-9	PHSWs	6	41	216	164	0	$188.22	$8.98	NA	Weyerhaeuser
Fourche 457-12	PHSWns	6	40	369	108	0	$188.22	$8.98	NA	Weyerhaeuser
Fourche 458-10	PSTs	6	41	373	150	77	$188.22	$8.98	$1.74	Weyerhaeuser
Fourche 458-16	CCns	6	41	496	148	177	$188.22	$8.98	$1.74	Weyerhaeuser
Jessieville 609-9	PHSTSns	7	41	98	24	0	$158.10	$1.00	NA	Dewey Halsell
Kiamichi 231-17	LISTSs	8	47	167	31	0	$165.27	$5.17	NA	K.A. Shug Morris
Kiamichi 246-17	PHSTSns	8	51	101	82	76	$165.27	$5.17	$1.51	K.A. Shug Morris
Kiamichi 248-6	PHSTs	8	37	280	128	42	$165.27	$5.17	$1.51	K.A. Shug Morris
Magazine 14-18	PGSns	9	51	361	45	0	$212.13	$13.68	NA	Deltic Farm & Timber
Magazine 46- 18	PHGSns	10	48	185	29	35	$198.10	$6.80	$1.21	Deltic Farm & Timber
Magazine 70- 10	PHSTSns	10	46	296	36	0	$198.10	$6.80	NA	Deltic Farm & Timber
Mena 833-1	PHSWns	11	34	220	88	60	$187.11	$1.65	$0.60	Weyerhaeuser
Mena 845-6	PSTs	12	35	368	49	147	$192.15	$6.00	$0.76	Weyerhaeuser
Mena 895-1	PSWs	13	33	171	92	69	$165.00	$6.43	$1.05	Bean Lumber
Oden 1036-17	PHSTs	14	33	216	268	99	$158.10	$6.60	$1.46	Charles Forga
Oden 1044-3	PSTSs	14	81	289	69	284	$158.10	$6.60	$1.46	Charles Forga
Oden 1067-15	CCns	15	32	210	191	64	$172.71	$6.27	$1.80	Weyerhaueser
Oden 1073-10	PHSTSs	15	57	344	99	0	$172.71	$6.27	NA	Weyerhaueser
Oden 1077-19	LISTSs	16	52	139	49	104	$156.62	$4.43	$1.83	Bean Lumber
Oden 1084-7	PSTs	16	33	193	288	66	$156.62	$4.43	$1.83	Bean Lumber
Oden 1094-4	PHSWs	17	30	105	87	0	$170.00	$4.86	NA	Bean Lumber
Oden 1097-6	PSWs	17	36	104	230	144	$170.00	$4.86	$0.60	Bean Lumber
Oden 1106-9	PGSns	17	53	282	119	0	$170.00	$4.86	NA	Bean Lumber
Oden 1119-5N	PHSWns	18	36	222	167	72	$189.15	$9.88	$1.65	Weyerhaueser
Oden 1119-5S	PHSTs	18	39	383	195	117	$189.15	$9.88	$1.65	Weyerhaueser
Oden 1124-11	PHGSns	18	53	270	60	0	$189.15	$9.88	NA	Weyerhaueser
Oden 1125-5	PSTSs	18	43	133	37	0	$189.15	$9.88	NA	Weyerhaueser
PI. Hill 367-04	LISTSs	19	45	208	0	0	$248.86	NA	NA	Bibler Brothers
Poteau 1284- 1	PSTSs	20	31	155	125	41	$165.15	$5.81	$4.69	Weyerhaueser
Poteau 1286-19	PGSns	20	37	218	83	0	$165.15	$5.81	NA	Weyerhaueser
Poteau 1292-2	CCns	21	37	410	169	45	$178.65	S9.67	f4.72	Travis Lumber
Poteau 1314-16	PHSTSs	21	40	244	82	0	$178.65	$9.67	NA	Travis Lumber
Womble 1646-B	PSTs	22	40	458	143	140	$192.10	S2.95	$0.60	Weyerhaeuser
Womble 1654-16	PHSTSs	22	54	132	18	92	$192.10	$2.95	$0.60	Weyerhaeuser
Womble 1658-16	PSTSs	22	47	138	12	94	$192.10	$2.95	$0.60	Weyerhaeuser
Womble 1658-5	CCns	22	39	415	94	76	$192.10	$2.95	$0.60	Weyerhaeuser
Womble 1648-1	PGSns	23	41	178	62	0	$197.72	$9.41	NA	Bean Lumber
Womble 165 1-6	PHSTs	23	40	369	234	100	$197.72	$9.41	$2.31	Bean Lumber
Womble 16606	PHSWs	23	35	98	71	112	S197.72	$9.41	$2.31	Bean Lumber
Womble 1649-13	PHSTSns	24	47	255	70	85	$204.15	$10.64	$4.38	Weyerhaeuser
Totals			2,060	11,669	5,003	2,418				

* CC--Clearcut
PST--Pine seedtree
PHST--Pine/hardwood seedtree
PSW--Pine shelterwood
PHSW--Pine/hardwood shelterwood
PGS--Pine group selection
PHGS--Pine/hardwood group selection
PSTS--Pine single-tree selection
PHSTS--Pine/hardwood single-tree selection
LISTS--Low impact single-tree selection
s--stand will be divided or "split" for comparing methods of vegetation management
ns-stand will not be divided or "split" for comparing methods of vegetation management

† Pine sawtimber volume in thousands of board feet; pine and hardwood pulpwood volumes in hundreds of cubic feet

have spent their time with researchers in a steady flow of questions. For these reasons, the Ecosystem Management Research Program has been tremendously successful in beginning dialogue between researchers and managers.

Both researchers and managers have also benefitted from sharing costs and labor to accomplish a project of mutual desire. Through partnership, researchers and managers have engaged issues that increase the relevance and importance of both to society.

Yet, in addition to these successes, we have also recognized differences that must be addressed. Even the authors still have some disagreement on the proper roles of researchers and managers in this new relationship. Although we share a focus on natural resources, researchers and managers are part of two very different professional subcultures.

The researcher's goal is to produce knowledge through relatively well-defined means--generally referred to as the "scientific process"-- staunchly maintained through peer review. The goal of the public land manager is to produce goods and services for citizens, while caring for the land. This is accomplished through a variety of means. Researchers' results are usually precisely defined, often with a level of certainty attached. Manager's results are often ambiguous with unknown levels of certainty attached. Researchers try to control many sources of variability in order to isolate factors and causes and effects. Managers must embrace all sources of variability in order to shepherd entire systems of cause-and-effect relationships toward desired states.

These differences leave a wide gulf--one that contains important work to be done. Who is going to gather, analyze, and make useful all of the information available outside the realm of formal scientific experiments, especially that complex, empirical and experiential information created when management actions are implemented? Who has the time? Who has the expertise? Who has the incentive?

Managers would like researchers to get in the trenches with them to help them understand the complexities they face every day. No matter how statistically significant research results turn out to be, unknown levels of uncertainty are present when these results are carried into actual field situations, complete with all their additional sources of variability. This is particularly true if those sources of variability were excluded from experimental designs. Managers would like help setting up monitoring programs, identifying tendencies, and forming best guesses, even though statistical probabilities are unknown or fall short of traditional significance levels. To a manager, this is important information necessary to supplement formal published studies. Managers recognize they should be involved in generating this knowledge because they are implementing the actions and will be primary users of the information. Yet, they are limited by their need to continue producing expected services, and most do not have the expertise to rigorously design and analyze complex data.

In our experience, researchers generally have not been eager to fill this role. Some are philosophically agreeable, but hesitate because results from this kind of effort are rarely publishable; others genuinely have no interest in getting this close to the job of management. This approach to knowledge generation is not given much weight in the peer review process. Therefore, there are few professional rewards for this kind of involvement. Yet, researchers have an important role to play here: it is closely allied to their professional charge to produce knowledge, and they have much expertise in extracting knowledge from data.

Phase II splits some of these differences. It has expanded the realm of traditional replicated research by its scale and operational nature, both of which have made high levels of variability inevitable. In the final analysis, we will likely get useful results from both traditional analyses and from case-study descriptions that will be necessary to explain unexpected outcomes in some stands.

What about Phase II as a model for research/management interaction? It has obviously been useful for getting us together and is suited for addressing big issues such as the Ouachita's move from clearcutting to other methods. The future, however, lies in developing a more integrated day-today interaction through which good working hypotheses are generated and modified--working hypotheses that can guide managers in their decision making and researchers in setting priorities for directed studies.

Researchers and Citizens

Significant interaction of citizens and researchers has been a relatively new phenomena for both. NEPA analysis has provided the impetus and the forum for most of these interactions. Researchers generally have been very wary of NEPA. Not only is it replete with arcane regulations and legal trip wires requiring expertise to navigate, it also subjects their research plans to public review. It has been difficult for researchers to subject their study plans to public review because of fears that citizens will not be knowledgeable enough to comment intelligently, but may be politically powerful enough to force modification of such plans.

The Phase II experience however has resulted quite positively. Researchers have been impressed by the intelligence of public comments, and modifications made as a result have strengthened the research. In addition, the scrutiny provided by public review has required researchers to be more precise and definitive in their planning. This too has strengthened the research, and has helped internal communications. And, contrary to what many believed, it has been possible to generate acceptable alternatives to original study proposals that meet research objectives and address environmental issues identified through the NEPA process.

The ability and willingness of researchers to be active and skilled participants in public involvement will be increasingly necessary as we move to an era of large-scale manipulative experiments and adaptive management approaches.

This new relationship between researchers and citizens is causing some researchers to view research as more than just science--but also as an integral part of policy debate. This is viewed ambivalently. Some feel that science is at risk and can be easily compromised. On the other hand, program funding, profile, and relevance can be enhanced by the public support generated through this interaction.

In fact, we may be seeing the rise of an important **new user group of research results. There are many in the public who simply want to know more about the natural systems on their public lands. They are interested in this knowledge for their own enjoyment and for use as participants in the ongoing dialogue about national forest management.**

Managers and Citizens

The relationship between managers and citizens is not a new one, having reached special intensity during recent development of the Forest Plan. We see evidence that Phases I and II have contributed to improving some elements of this relationship, particularly between forest managers and our closest watchdogs in the environmental community. These citizens have expressed general satisfaction with the Phase I demonstrations and have become supporters of Phase II. Their primary desire is to see more.

In addition to having an excellent project in the Ecosystem Management Research Program--one that is very responsive to public concerns--this improvement in relationships can also be attributed to the addition of researchers to the mix. Citizens generally give much more deference to researchers than they do managers. Their credentials as experts are generally better than managers, and they are usually unsullied by the battles over national forest decision making. They are viewed as objective. Managers can gain credibility with citizens by their association with researchers, especially if research independence is maintained. So, while it may be desirable for researchers to join managers in the trenches to some extent, maintaining independence of voice is critical for the three-way dynamic to survive in healthy dialogue.

Key Points

From our experience, we share the following key points:

(1) Colocation of researchers and managers has been critical. Implementing a program like this, as well as generating much ***needed*** **dialogue, cannot be done part-time** ***over*** the phone or at meetings. A full-time liaison, who understands the ***needs*** of both research and management, has also been critical.

(2) Colocation of researchers from multiple disciplines is also needed to encourage interdisciplinary research planning. Dispersion of key researchers has hindered planning and implementation. Cooperative agreements with local universities allow use and involvement of local expertise.

(3) Direct contact between researchers and citizens has been positive and should be encouraged. This does, however, depend somewhat on the personalities available. For these interactions to be productive, researchers must be willing to listen to citizens without condescension or resentment.

(4) Both interdependence and independence of researchers and managers are critical. Researchers and managers should run within different but overlapping circles in order to maintain credibility and the diversity of viewpoints necessary for productive dialogue.

(5) All participants must be forthright but ready to compromise. This is about power sharing. Managers and researchers must be confident enough to disagree in front of citizens. This openness is essential to stimulating dialogue and trust. There is no room for prima donnas or hold-outs.

(6) Sustained funding is needed to stimulate a program such as this one. Congressional support has been essential.

(7) Researchers need incentives to move from traditional roles into cooperative ventures such as this one. Funding and administrative support have been important in our case. Further professional rewards are needed to stimulate widespread voluntary interest.

(8) To progress further, we need nontraditional research protocols especially tailored to scales and processes not suited to traditional research methods. We need champions to integrate research and monitoring. We need improvement in data and information management to close the circle of adaptive management.

CONCLUSION

We, as a society, have a lot of work to do to decide how we are going to relate to natural systems, in general, and national forests, in particular. Much of that work will be done by researchers, managers, and citizens discussing, debating, and deciding together. So, as we look at our early results--and beyond that as we begin the collection of posttreatment data--let's not lose sight of the truly new ground we are breaking by bringing researchers, managers, and citizens together to resolve national forest management issues. Our research results are necessary and important. But, more information will not solve our problems. Our ability to work together will.

REFERENCES CITED

Baker, James B. (1994). Stand-level ecosystem management research: an overview. In: Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: pretreatment conditions and preliminary findings; 1993, October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Guldin, J.M.; Shelton, M.G.; Wittwer, R.F. [and others]. 1993. New Perspectives/Ecosystem Management Research on the Ouachita/Ozark National Forests: silviculture research. Study Plan RWU-4110, FS-SO-4106-81 (Problem 3), U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Monticello, AR 71656.

Overbay, James C. 1992. Ecosystem management. In: Proceedings of the national workshop on taking an ecological approach to management; 1992 April 27; Salt Lake City, UT: U.S. Department of Agriculture, Forest Service, WO-WSA-3: 3-15.

Robertson, F.D. 1993. Letter dated June 4 to Regional Foresters and Station Directors. On file with: Ouachita National Forest, P.O. Box 1270, Hot Springs, AR 71902.

An **Overview of Stand-Level Ecosystem** Management Research **in the Ouachita/Ozark National** Forests[1]

James B. **Baker**[2]

ABSTRACT

A scientifically based, replicated stand-level study (Phase II) was installed in mature, **shortleaf** pine (***Pinus echinatu*** Mill.)-hardwood stands in the Ouachita and Ozark National Forests during the summer of 1993. The study is established to test and evaluate a range of partial cutting methods and vegetation management treatments at an operational scale but imposed in a scientifically rigorous manner. Thirteen treatments include both **even**-aged and uneven-aged reproduction cutting methods, with long-term retention of various densities, compositions, and structures of overstory pines and hardwoods. Two controls, an unmanaged control and a **clearcut** control, are also included as part of the 13 treatments. Four levels of vegetation management treatments (site preparation and release) are also being investigated. The effects of harvesting/vegetation management treatments will be evaluated in terms of multiple resources and noncommodity values, including: plant and animal communities, arthropod and microbial communities, soils, water, cultural resources, scenic quality, recreational opportunities, and harvesting and management costs.

INTRODUCTION

In August 1990, the decision was made by the Southern Region of the USDA Forest Service to discontinue the use of clearcutting and planting as the primary harvesting and reproduction cutting method in stands traditionally classified as pine and pine-hardwood types in the Ouachita National Forest. As alternatives to clearcutting, the USDA Forest Service wanted to use more ecologically sensitive and socially acceptable partial cutting methods that involved long-term retention of a mixed-species overstory and natural regeneration.

Unlike clearcutting and planting, many of the partial cutting methods-particularly with the long-term retention of a **pine**-hardwood overstory-were untried and untested reproduction cutting methods for the shortleaf pine (***Pinus echinatu* Mill.)**-hardwood forests growing in the Ouachita Mountains. Thus, several concerns regarding the implementation of these innovative but untested techniques surfaced. Some of them included:

(1) Would the nontraditional partial cutting methods, with the retention of **midstory** and overstory hardwoods, be biologically sound; that is, would they regenerate and sustain desired pine-hardwood mixtures?
(2) What combinations of residual pine and hardwood overstory densities would allow for establishment and development of both pine **and** hardwood reproduction?
(3) Would partial cutting methods result in stands consisting of pine-hardwood mixtures that represent current species compositions and stand structures?
(4) How would the partial cutting methods affect important resources such as wildlife populations and habitat, **biodiversity,** visual quality, water, and soil?
(5) How would implementation of the partial cutting methods affect logging and management costs and timber supplies and values?

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[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

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To address these and other concerns, researchers and resource managers from the USDA Forest Service Southern Forest Experiment Station and Guachita and Ozark National Forests, in cooperation with several universities, other State and Federal agencies and some special interest groups, formulated a three-phase "New Perspectives" (now called Ecosystem Management) research program. The basis of the overall program was the need and desire to manage National Forest lands using silvicultural practices consistent with sustainable ecosystem management.

Phase I, an unreplicated stand-level demonstration project implemented in the summer of 1991, provided an early operational demonstration of some partial cutting methods that retained various densities, compositions, and structures of pine/hardwood overstories. Phase I has been completed; however, the stands are still being used for demonstration purposes and for preliminary observation of developing trends and conditions.

Phase II is a scientifically based, replicated stand-level study in which a range of partial cutting methods and vegetation management treatments are being tested and evaluated at an operational scale but in a scientifically rigorous manner. Pretreatment evaluations have been completed. Partial cutting treatments were implemented during the summer of 1993, and site preparation treatments will be conducted during the 1993-94 dormant season.

Phase III, still in the final planning stage, will be a large-scale (watershed or landscape) study that will permit the evaluation of biological, physical, and social processes, functions, and linkages at various spatial and temporal scales.

In this paper an overview of the Phase II component of the Ecosystem Management Research Program in the Guachita and Ozark National Forests is provided. The objectives of this stand-level (Phase II) study are to evaluate:

(1) The biologic and economic feasibility of using partial cutting methods and long-term retention of pine-hardwood overstories to establish and maintain mixed pine-hardwood stands that reflect indigenous vegetation and historical stand structure on south-facing slopes of the Guachita Mountains.
(2) The effects and trade-offs of the partial cutting methods on various commodity and noncommodity resources and values.

STUDY AREA

Geology and Soils

The Ouachita Mountains consist of a series of east-west ridges and structural valleys. Narrow-topped mountains with steep side slopes alternate with rolling to gently sloping valleys. Elevations range from about 500 to 2,800 feet above sea level. Parent materials in the area, primarily of sedimentary origin, range in age from the Ordovician to Pennsylvanian periods and consist of cherts, shales, slates, sandstones, and novaculites. All geologic materials have been intricately folded and faulted, and at many places they dip at angles of 40° or more from the horizontal. Because of the inclined and fractured nature of the patent material, tree roots can often penetrate to considerable depths, although the soils are generally shallow (Graney 1992).

Soils common to ridges and upper slopes are shallow (Clibit and Bismark series) with a site index for shortleaf pine ranging from about 40 to 70 feet at 50 years. Soils on middle to lower slopes are deeper and are derived from shales (Camasaw and Bengal series) or sandstone (Sherwood, Pirum, and Zafra series). These soils have a site index for shortleaf pine ranging from about 50 to 80 feet at 50 years (Graney 1992).

Climate

The climate in the Guachitas is characterized by warm and humid summers and mild winters (Skiles 1981). Mean annual temperature ranges from about 57 °F in the northern portion of the Guachitas to about 61 °F in the southern extremities (fig. 1). Mean annual precipitation ranges from about 44 inches in the northern and western extremities of the Guachitas to about 54 inches in the eastern and southern portions of the region. Both mean annual temperature and precipitation generally decrease from the eastern and southern portions to the western and northern portions of the Guachitas.

Ecoregions

The Guachita Mountains are commonly divided into two ecoregions-the Arkansas River Valley Ecoregion and the Ouachita Mountain Ecoregion (Giese and others 1987). The Arkansas River Valley Ecoregion lies between the Boston Mountains to the north and the Guachita Mountains to the south. It is a transitional area between these two uniquely different landforms. The Arkansas River Valley Ecoregion has slowly to moderately permeable soils underlain by folded shales and sandstones. General topography is rolling, but mountains and mesas are also present.

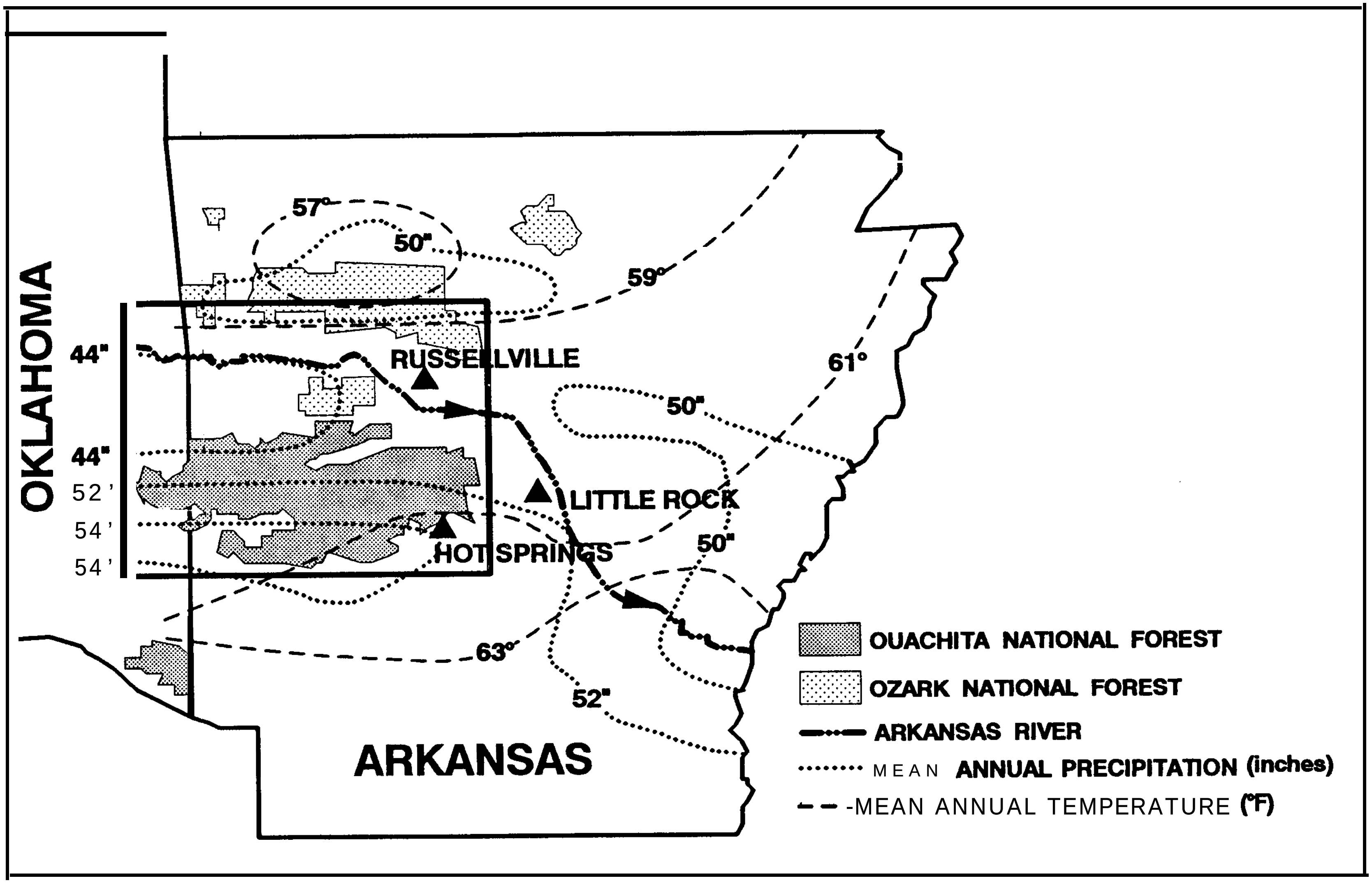

Figure 1. *-Phase II study area shown in box* With *Statewide climatic gradients.*

Since **ecoregions are generally defmed as areas** having homogeneous land surface forms, potential natural vegetation, soil types, and land uses, the Ouachita Mountain Ecoregion has been subdivided into upper and lower sub-ecoregions (Clingenpeel and **Cochran 1992)(fig.** 2). A distinguishing feature between the sub-ecoregions is that streams in the Lower Ouachita Mountain Sub-Ecoregion tend to be perennial, whereas those in the Upper Ouachita Mountain Sub-Ecoregion tend to be ephemeral (USDA FS 1990).

For purposes of this study, the Upper Ouachita Mountain Sub-Ecoregion was divided into eastern and western components, corresponding primarily to mean annual temperature and precipitation gradients. Thus, the following four ecoregions and sub-ecoregions were recognized as having the most similar land forms, vegetation types, and climatic conditions: the **Arkansas** River Valley Ecoregion [N], the Lower Ouachita Mountain Sub-Ecoregion [S], the eastern Upper Ouachita Mountain Sub-Ecoregion **[E],** and the western Upper Ouachita Mountain Sub-Ecoregion **[W](fig.** 2).

METHODS

Treatments

Treatments evaluated in this study include an array of reproduction cutting methods and associated vegetation management techniques. The reproduction cutting methods were imposed in forty-eight **35-** to **40-acre** stands. Four additional stands (controls) will receive no harvest cutting. Vegetation management treatments (site preparation and/or release techniques) will be imposed on **10-acre** subplots within 24 of the 48 stands that are harvested. A subset of 28 of the stands (including 24 of the harvested stands plus the 4 unmanaged controls) will not be subdivided; thus, they will permit **evaluation** of interior forest species (particularly some migrant and resident birds) that require a minimum of 40 acres of similar stand conditions.

Reproduction **Cutting Methods**

The reproduction cutting methods include various nontraditional (untried and untested) partial cutting techniques that retain both pines and hardwoods in various densities, compositions, and structures. Some cutting methods will establish new stands having even-aged structure; others will develop and maintain stands having uneven-aged structure. Harvesting to implement the reproduction cutting methods began in May 1993 and was completed in September 1993. Trees left after the reproduction cut will be retained on the site indefinitely.

Uneven-aged Methods.--The following partial cutting methods, listed in increasing order of harvesting intensity and/or site disturbance, were imposed to develop and maintain uneven-aged pine-hardwood stands:

(1) Low-impact, **pine/hardwood single-tree selection (LI-STS, not split)-Some** pines and hardwoods are harvested on a lo-year cutting cycle using single-tree selection. Residual basal areas of pines and hardwoods range from 60 to 80 **ft^2/acre,** with up to 50 **ft^2/acre** being in hardwoods. Understory woody vegetation will be controlled by manual techniques only when needed to maintain development of pine and hardwood reproduction. No herbicides will be used.

(2) Pine/hardwood single-tree selection (PH-STS, not split)-Some pines and hardwoods are harvested on a lo-year cutting cycle using single-tree selection. Residual basal areas range from 45 to 65 **ft^2/acre,** with **5** to 20 **ft^2/acre** being in hardwoods. Site preparation and release from woody competition will use manual techniques as needed and will be applied uniformly over the site.

(3) Pine/hardwood **single-tree selection (PH-STS, split)-The** *same* **as (2)** except that the harvested area was subdivided (split) to allow comparison of various combinations of site preparation and release treatments (see Vegetation **Management** section that follows).

(4) Pine single-tree selection (P-STS, split)-Some pines are harvested on a lo-year cutting cycle using single-tree selection. Residual basal areas in pines are 45 to 65 **ft^2/acre.** All hardwoods were harvested or removed except those needed to meet den-tree and mast-production standards for wildlife (2 to 5 **ft^2/acre).** The harvested area was subdivided to allow comparison of various combinations of site preparation and release treatments (see Vegetation Management section that follows).

(5) Pine/hardwood group selection (PH-GS, not split)-All pines and some hardwoods were harvested or removed in group openings ranging from about 0.1 to 1.0 acres (representing from one to three times the height of adjacent trees). Residual basal areas of hardwoods within group openings are 5 to 10 **ft^2/acre.** Pines outside group openings were

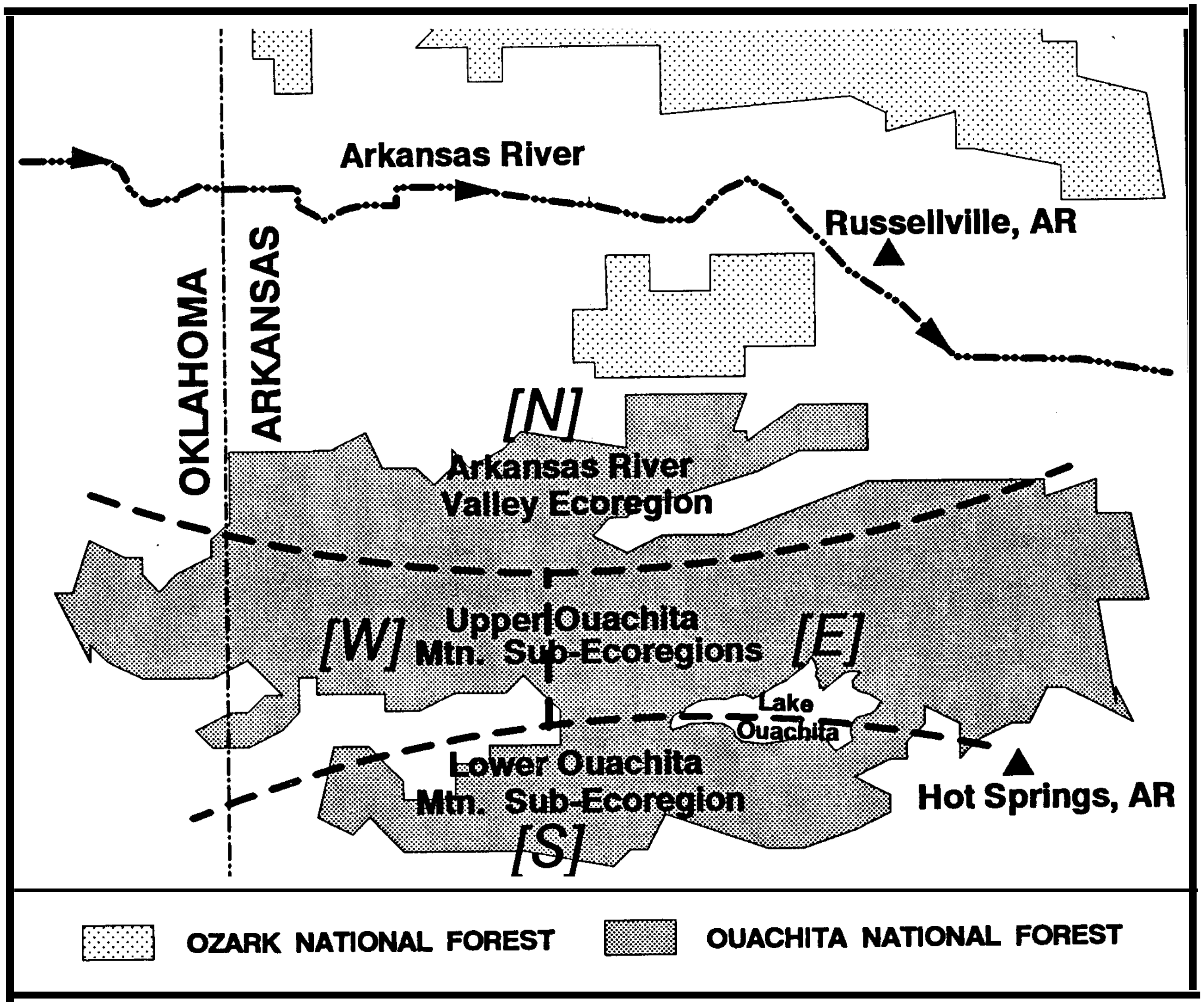

Figure 2. —*Phase II study area divided into ecoregions and sub-ecoregions and corresponding N, S, E, and W blocks.*

thinned to a basal area of 70 to 80 ft²/acre. No hardwoods were harvested or removed outside group openings. Site preparation and release from woody competition will be done within group openings only, using manual techniques as needed.

(6) **Fine** group **selection (P-GS, not split)-The same as (5)** except that no hardwoods were **left** within group openings.

Even-aged ***Methods*.—The** following partial cutting methods, listed in increasing order of harvesting intensity and/or site disturbance, were imposed to establish and maintain even-aged pine-hardwood stands:

(1) **Pine/hardwood** shelterwood (PI-I-SW, **not** split)-A total of 20 to 40 of the largest pines and hardwoods per acre (30 to **40 ft²/acre** of basal area of which **5** to 15 **ft²/acre** are in hardwoods) were retained; all other pines and hardwoods were harvested or removed. Site preparation and release from woody competition will be applied uniformly over the site as 8 manual treatment if needed.

(2) Pine/hardwood **shelterwood (PH-SW, split)-The same as** (1) except that the harvested area was subdivided (split) to allow comparison of various combinations of site **preparation** and release treatments (see **Vegetation Management** section that follows).

(3) **Fine shelterwood (P-SW, split)-A total of 20 to 40** of the largest pines per acre (30 to 40 **ft²/acre** of basal area) were **retained;** all other pines and hardwoods were harvested or removed except those needed to meet den-tree and mast- ` production requirements (2 to 5 **ft²/acre** of hardwoods). The harvested area was subdivided to allow comparison of various combinations of site preparation and release **treatments** (see **Vegetation Management** section that follows).

(4) Pine/hardwood seed-tree (PI-I-ST, split)-A total of 10 to 15 of the largest pines and hardwoods per acre (10 to 20 **ft²/acre** of basal area of which **5** to 15 **ft²/acre** are in hardwoods) were retained; all other **pines** and hardwoods were harvested or removed. The harvested area was subdivided to allow comparison of various combinations of site preparation and release treatments (see **Vegetation Management** section that follows).

(5) Pine seed-tree **(P-ST,** split)-A total of 10 to 15 of the largest pines per acre (10 to 20 **ft²/acre** of basal area) were retained; all other pines and hardwoods were harvested or removed except those needed to meet den-tree and **mast-**production requirements (2 to 5 **ft²/acre** of hardwoods).

The retained trees for all shelterwood and seed-tree cutting methods will be left a minimum of 10 years or indefinitely if reproduction develops at an acceptable rate (at least 6 inches of annual height growth) (Chapman 1945).

***Controls*.—The** control treatments include: (1) an unmanaged stand condition in which the existing stand is not subject to reproduction cutting; and (2) a **clearcut** and plant treatment. The unmanaged control will anchor one end of a continuum in that it represents minimum human-induced disturbance. The **clearcut** control will anchor the other extreme as the most intensive, and possibly the most site disturbing, of the reproduction cutting methods. The following is a description of these two treatments:

(1) **Unmanaged control (UC, not split)-No harvesting will be done. No other** stand management will be done except to provide protection from severe loss to wildfire or insects.

(2) **Clearcut control (CC, not split)-All** pines and hardwoods were harvested or removed except 2 to 5 **ft²** of basal area per acre of hardwoods retained as den trees and mast producers. Site preparation will be done by injecting all **trees** that were not harvested or not planned for retention with **Garlon®** 3A at rates not to exceed 1 .O lb/acre of active ingredient. The site will be mechanically ripped on lo-foot centers to a depth of 6 to 8 inches, and genetically improved shortleaf pine seedlings will be hand planted at 8-foot intervals within the rips. Release from woody competition, if needed, will be done using spot treatment of selected stems with **Garlon®** 4E applied manually from backpack sprayers at **rates** not to exceed 1.0 lb/acre of active ingredient.

Vegetation Management

Site preparation and release treatments to be tested and evaluated in the subdivided (split) stands include:

(1) No site preparation, no release.
(2) No site preparation, manual or herbicide release.
(3) Manual site preparation, manual or herbicide release.
(4) Herbicide site preparation, manual or herbicide release.

Manual site preparation will involve chainsaw felling all unwanted stems 2 inches in d.b.h. and larger. Herbicide site preparation will be done by either injecting or chain saw felling and stump treating unwanted stems 2 inches in d.b.h. and larger with Garlon 3A at rates not to exceed 1.0 lb/acre of active ingredient. These treatments will be implemented during the 1993-94 dormant season.

A need for release will be assessed after two growing seasons following the establishment of pine reproduction. Where manual release is needed, it will be done using chain saws or power brush saws. Where herbicide release is needed, it will be done using injection or cut stump spraying of Garlon 3A and/or directed foliar spray of Garlon 4E at rates not to exceed 1.0 lb/acre of active ingredient using backpack sprayers. Only stems adversely affecting development of desired pines and hardwoods will be treated.

The regeneration objective for the even-aged systems is to have 300 pine and 300 hardwood seedlings and saplings per acre that are free-to-grow 3 to 5 years after the regeneration harvest. For the uneven-aged systems, the objective is to have 100 pine and 100 hardwood seedlings and saplings per acre that are free-to-grow 3 to 5 years after the harvest.

Experimental Design

The 13 harvesting treatments (11 partial cutting methods plus an unmanaged control and a clearcut control) were replicated 4 times in a randomized complete block design. Thus, a total of 52 stands are being used in the study (13 stands in each of 4 blocks). Blocks correspond to the four ecoregions and sub-ecoregions described earlier.

A subset of 28 stands (4 replications of 7 of the treatments-LISTS, PH-STS, PH-GS, P-GS, PH-SW, UC, CC) will be treated in a similar manner regarding the harvest cutting, site preparation, and release treatments. The homogeneous conditions of these stands are needed for some monitoring and evaluation activities, particularly migrant and resident birds.

Another subset of 24 stands (4 replications of 6 of the treatments-PH-STS, P-STS, PH-SW, P-SW, PH-ST, P-ST) will be subdivided into 4 almost equal 10-acre compartments used to test and compare the site preparation and release treatments. For this subset of treatments and stands, a split-plot randomized complete block design will be used. Statistical analyses that are appropriate for these experimental designs include analysis of variance at the stand level and regression analysis at the plot level.

Stand Selection and Randomization

The target population for the study included all mixed shortleaf pine-hardwood stands in the Guachita and Ozark National Forests that were candidates for reproduction cutting and met the following criteria:

1. Tree age: 70+ years.
2. Stand area: >35 acres.
3. Aspect: south- or west-facing.
4. Pine basal area: 60 to 110 ft²/acre.
5. Hardwood basal area: 20 to 50 ft²/acre.

To optimize operational logistics in conducting research measurements, a representative subpopulation of candidate stands was randomly selected from the target population. The subpopulation was selected from four randomly located strips, each a township (6 miles) wide. Two of the strips were oriented north-south, and two were oriented east-west (fig. 3). These strips were randomly selected from contiguous four-township-wide swaths running north-south and east-west that included: (1) the four ecoregions and sub-ecoregions identified in the Ouachita Mountains; and (2) most of the main population of candidate stands. Thirteen stands were then randomly selected from the candidate stands occurring in each of the four blocks (fig. 3), and treatments were randomly assigned to the stands.

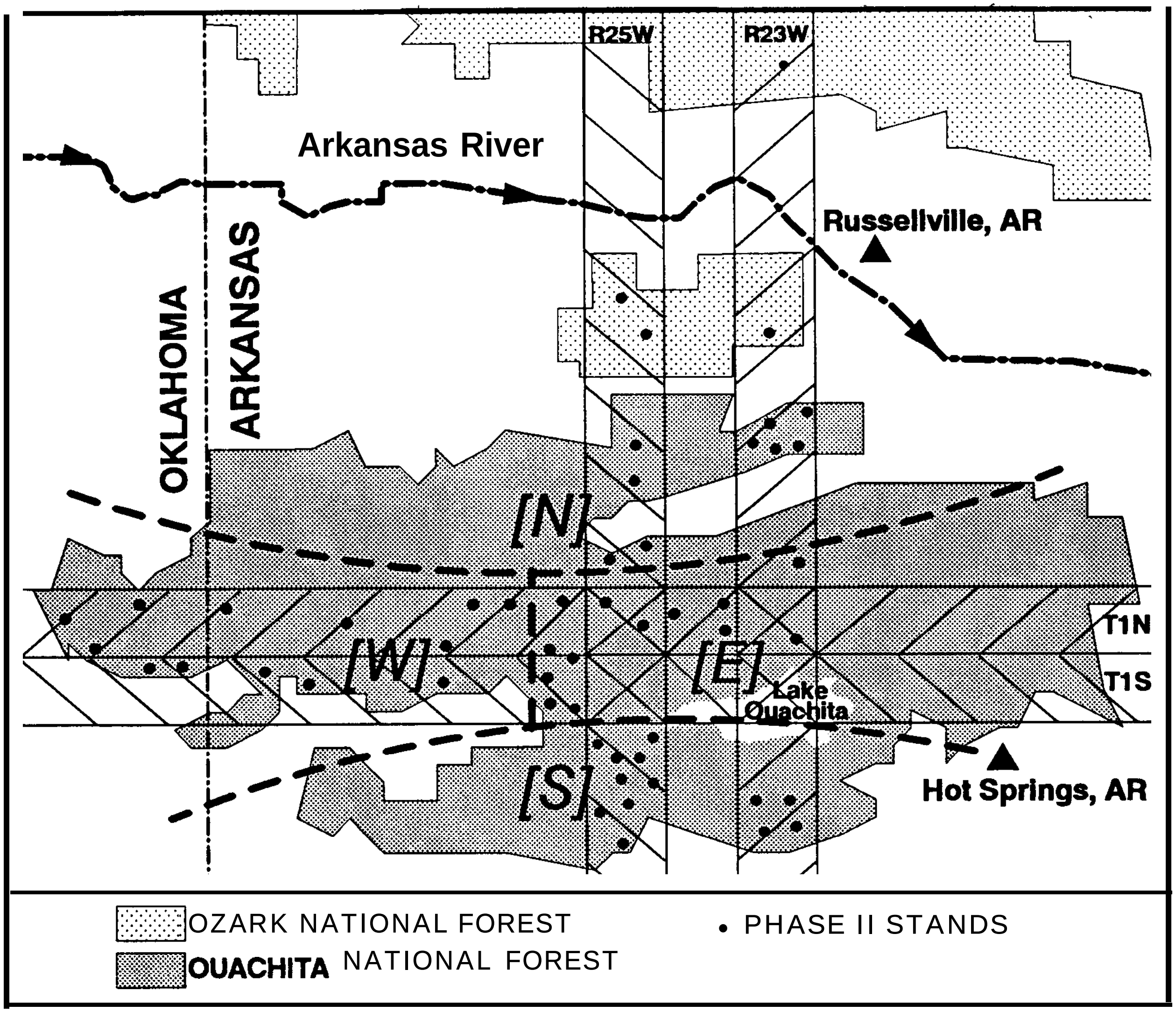

Figure 3. -***Phase II study area illustrating stand location within township-wide corridors and*** blocks.

Sampling Scheme-Permanent and Temporary Plots

A typical 35- to 40-acre stand is illustrated in figure 4A. Stands usually include one or more ephemeral streams surrounded by a streamside protection zone in which there will be no harvesting and no vegetation management.

Stands were stratified into lower, middle, and upper slope positions (fig. 4A). Soil moisture and productivity generally decrease from the lower to the upper slope position. Also, plant species composition generally changes along this elevation gradient. Some stands were also subdivided into quarters of approximately equal areas, arranged perpendicular to the elevation gradient as described earlier (fig. 4A).

A series of both permanent and temporary sample plots and transects were established in the stands to evaluate preharvest conditions and to monitor changes after treatment. An example of the typical layout is shown in figure 4B for the stands that are being used by all research groups. Some plots and transects were randomly located within the stand, whereas others were located systematically. Some sample plots were installed in a nested sample design in which several research groups collect and share data, other sample plots were established for specific monitoring activities.

Research Groups and Monitoring Activities

The research team is organized around six disciplines and seven research groups. The disciplines and research groups associated with the Phase II research program and their monitoring and evaluation activities are as follows:

Plant Communities.-Includes 16 team members from the Silviculture, Plant Diversity, and Wildlife Research Groups.

1. Seed production
2. Seedbed conditions
3. Pine/hardwood regeneration and development
4. Overstory stand development
5. Vegetation management (competition control)
6. Plant diversity

Wildlife Communities.-Includes seven team members from the Wildlife Research Group.

1. Small mammals
2. Flying squirrels
3. Neotropical migratory and resident birds
4. General habitat conditions

Arthropod and Microbial Communities.-Includes nine team members from the Arthropod and Microbial Research Group.

1. Arthropods
2. Cone and seed insects
3. Southern pine beetle hazard ratings
4. Crown health of overstory hardwoods

Water, Soils, and Cultural Resources.-Includes 10 team members from the Water Quality, Soils, and Cultural Resources Research Group.

1. Water chemistry of ephemeral streams
2. Herbicide movement in stream water
3. Stream channel morphology of ephemeral streams
4. Woody debris in ephemeral streams
5. Soil disturbance associated with logging
6. Nutrient cycling
7. Impacts of harvesting activities on cultural resources

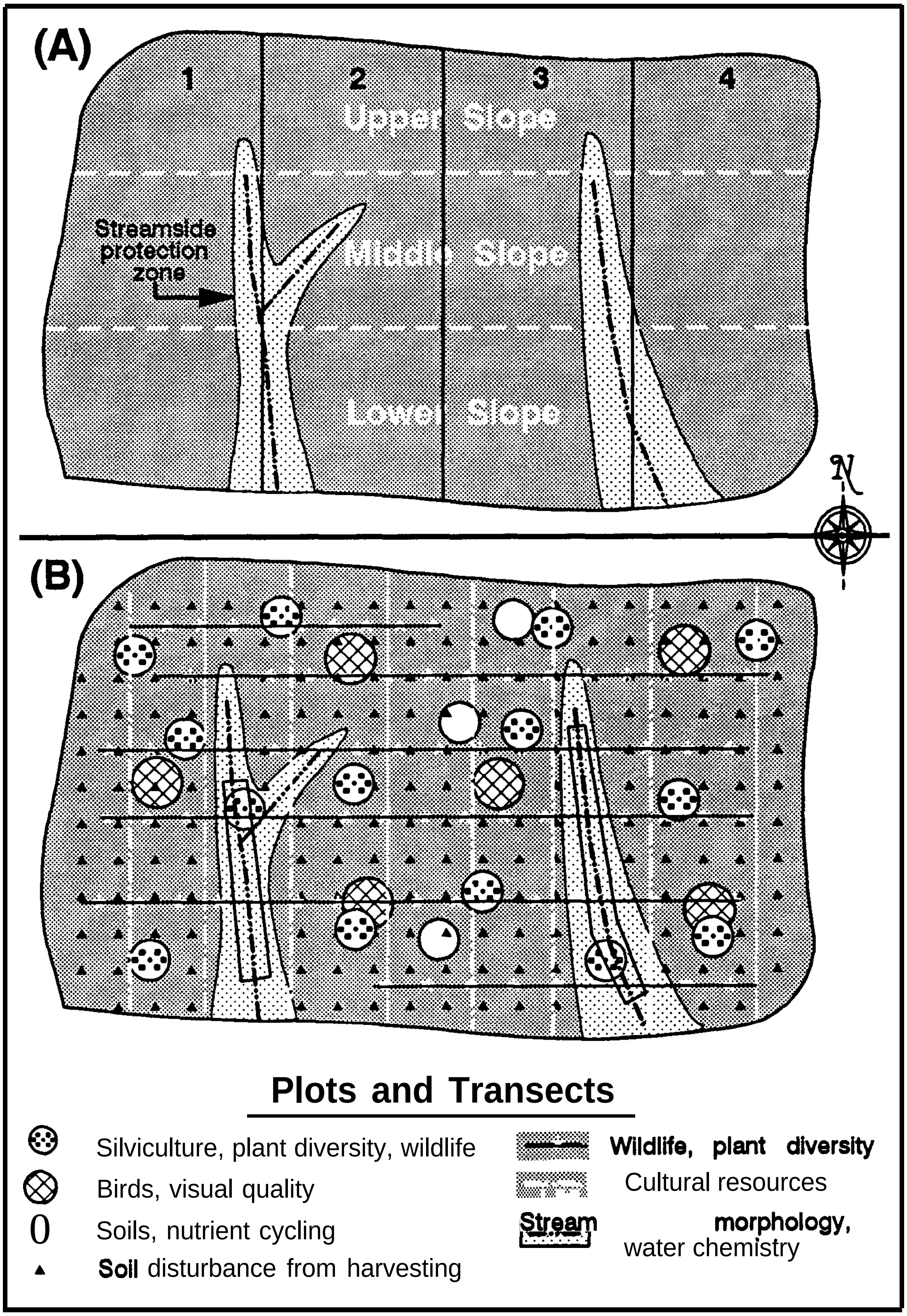

Figure 4. — *A typical 35- to 40-acre stand (A) stratified by slope position and subdivided into quarters, and (B) illustrates the number and distribution of permanent and temporary sample plots and transects.*

Scenic ***Quality*.—Includes** six team members from the Visual Quality/Recreation Research Group.

1. Visual impacts of recently cut stands
2. Customers survey of scenic preferences
3. Effects of hardwood retention, season, and physiography on perceived scenic beauty
4. Contingent **valuation** and acceptance of alternative harvest regimes

H arves ting *and Management Economics*.—Includes six team members from the Harvesting and Management Economics Research Group.

1. Harvesting economics
2. Management costs associated with various reproduction cutting methods
3. People and natural resource relationships

LITERATURE CITATIONS

Chapman, H.H. 1945. The effect of overhead shade on the survival of loblolly pine seedlings. Ecology. 26: 274-282.

Clingenpeel, J. Allen; **Cochran,** Betty G. 1992. Using physical, chemical and biological indicators to assess water quality on the Ouachita National Forest utilizing basin area stream survey methods. **In:** Proceedings Arkansas Academy of Science. 45: 33-35.

Giese, J.; Keith, B.; **Maner,** M. [and others]. 1987. Physical, chemical, and biological characteristics of leastdisturbed reference streams in Arkansas' **ecoregions:** Data analysis. Little Rock, **AR:** State of Arkansas, Department of Pollution Control and Ecology. 148 p. Vol. 2.

Graney, David L. 1992. Site index relationships for shortleaf pine. **In:** Brissette, John C.; Bamett, James P., **comp. Proceedings** of the shortleaf pine regeneration workshop; 1991 October 29-31; Little Rock, AR. Gen. Tech. Rep. SO-90. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: **142-157.**

Skiles, Albert. 1981. Arkansas climate atlas. Little Rock, **AR:** Arkansas Energy Office; Arkansas Industrial Development Commission. 93 p.

U.S. Department of Agriculture, Forest Service. 1990. Amended land and resource management plan-Ouachita National Forest. Hot Springs, AR: U.S. Department of Agriculture, Forest Service, Southern Region: Vol. 1.

Midstory and Overstory Plants in Mature Pine/Hardwood Stands of the Ouachita/Ozark National Forests[1]

James M. Guldin, James B. Baker, and Michael G. Shelton[2, 3]

ABSTRACT

The Phase II silviculture research was established using 728 plots, 14 in each of the 52 stands in the study. Twelve of the fourteen plots were located within the area of the stand where reproduction cutting will occur; two were placed within ephemeral stream protection zones. Each plot contains four nested subplots monitored by the silviculture research group (overstory and midstory) and the understory plant research group (shrubs and ground cover). The average stand in the study has a south-facing aspect of 180.3°, occupies midslope position on an 11 percent slope, and has 91 percent cover. The mean site index of the average stand is 62.2 ft (base 50), derived from mean tree height of 70.4 ft and mean tree age of 64.5 years. The average stand has 323.2 trees per acre and a basal area of 129.5 ft^2/acre (trees 3.6 inches in d.b.h. and larger). Conifers, primarily shortleaf pine (*Pinus echinata* Mill.), comprise 51.1 percent of the trees and 73.5 percent of the basal area. Conifer importance values exceed 50 percent from the 7- to 9-inch size class through the 22- to 24-inch size class, reaching a maximum of 90 percent in the 13- to 15-inch size class. The importance value of hardwoods exceeds that of conifers in the 4- to 6-inch size class and in the 25- to 28-inch and >28-inch diameter classes. Tests for differences in means by block and future treatment reveal significant though ecologically marginal differences for nearly all variables. These differences reflect a high degree of variability among plots, an attribute that will be useful in subsequent analyses.

INTRODUCTION

The goal of ecosystem management research in the Ouachita Mountains is to provide scientific support for implementing a new philosophy of sustainable ecosystem management on Federal lands. In this Phase II research program, silviculture is the common element that unites several different research groups, to broaden the collective understanding of alternative reproduction cutting methods and their multiple resource characteristics, implications, and effects. Silviculture has traditionally been viewed as a timber management activity. But in this research project, it assumes a more holistic role-as the fundamental means to affect the biotic influence of diverse vegetation components in order to promote the desired future condition of individual stands.

In this study, the silviculture research objectives are driven by the desire for mixed pine-hardwood regeneration and retention. There is not enough information on mixed-species regeneration ecology and developmental dynamics to be able to manage mixed pine-hardwood stands effectively in either even-aged or uneven-aged stands (Cooper 1989, Farrar and others 1989). The Phase II study design (Baker, this volume) provides an opportunity to quantify the effects of a mixed-species overstory on regeneration, understory vegetation, and overstory growth and yield. A key element of this is how site preparation and release can be modified to be less intensive yet successful in establishing pine and hardwood regeneration.

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The authors would like to acknowledge the efforts of the field crews-Leif Anderson, Doyle Cain, Gary Sanchez, Linda Smith, Saul Sema, Lisa Washington, Tommy Norton, and Chris Pope-in conducting the fieldwork for this research.

The goal of the silviculture research group is to provide on-the-ground research support, monitoring, and evaluation of traditional and nontraditional reproduction cutting methods. The term "traditional" refers to partial cutting methods (seed-tree, shelterwood, group selection, and single-tree selection) in which the residual overstory is composed primarily of shortleaf pine (*Pinus echinata* Mill.) and in which intensive competition control measures are applied. The term "nontraditional" refers to modifications of the partial cutting methods (seed-tree, shelterwood, group selection, and single-tree selection) in which both pines and hardwoods are retained in the residual overstory. Despite these traditional and nontraditional labels, the research support for these partial cutting methods, applied to shortleaf pine in the Interior Highlands, is virtually nonexistent.

The management and research questions that guide the silvicultural component of this research have been summarized as follows[4]:

(1) Can nontraditional pine-hardwood reproduction cutting methods successfully regenerate pine-hardwood mixtures?

(2) What combination of pine and hardwood residual basal areas allows for establishment and development of pine and hardwood seedlings and advanced regeneration?

(3) Will the natural regeneration systems result in mixed pine/hardwood stands that reflect current species compositions and stand structures?

These translate into a specific study objective for the silviculture research group-to quantify the establishment and development of seedlings and sprouts of both pines and hardwoods under an array of reproduction cutting methods, site preparation treatments, and release treatments.

Included in the silviculture research are several studies whose pretreatment status is not summarized in this paper. A study of seed production will monitor seedfall through several years after reproduction cutting; a subset of this study will investigate differences in genetic diversity in several Phase II stands.[5] Post-treatment analyses of the site preparation and release elements of the study will be conducted within a split-plot framework to assess low-impact methods of site preparation and release.[6,7] Ecophysiological measurements to quantify stand microclimatology will also be taken through several early posttreatment growing seasons.*

METHODS

Stand selection and treatment assignment

Methods for stand selection have been described in detail elsewhere' (Baker, this volume). The end result of the process was the inclusion of 52 stands in the study, 13 in each of 4 ecoregional blocks (north, south, east, and west, related to geological substrate). Treatments were *assigned* randomly to the stands' (Baker, this volume) (table 1).

Baker, James B. 1991. Study plan: New perspectives research on the Ouachita/Ozark National Forests. Study Plan FS-SO-410681 (Problem 3). On file, Southern Forest Experiment Station, USDA Forest Service, Monticello, AR. 71656.

This research is being coordinated by Dr. Robert Wittwer, Department of Forestry, Oklahoma State University, Stillwater, OK 74078.

Assistance in this component of the study will be provided by Dr. Jim Miller, Principal silviculturist, USDA Forest Service, Southern Forest Experiment Station, Auburn, AL 36849.

Guldin, James M.; and others. 1993. New perspectives / ecosystem management research on the Ouachita/Ozark National Forests: Phase II-Silviculture research. Study plan RWU-4110, FS-SO-4106-81 (Problem 3), Southern Forest Experiment Station, USDA Forest Service, Monticello, AR.

This component of the study will occur with the cooperation of Dr. Jim Bamett, Principal ecophysiologist, USDA Forest Service, Southern Forest Experiment Station, Pineville, LA 71360.

Table 1.— *Traditional **and non-traditional** reproduction cutting **methods** assigned **as** Phase **II treatments,** with corresponding posttreatment residual basal area targets. **The** designation "split" indicates the stand will be included in the split-plot site preparation and release study; the designation "not split" indicates the stand will not be included in the split-plot study*

------- ----------- **Reproduction cutting methods** ------ -------------		---- Residual basal area per acre ---	
Treatments	Code	shortleaf pine	hardwoods
		ft²/ac	**ft²/ac**
I. Controls			
Unmanaged control, not split	**UC**	same as pretreatment	same a* pretreatment
Clearcutting, not split	**CCNS**	0	O-5
II. Even-aged methods			
Seed-tree, pine, split	STP	20	**0-5**
Seed-tree, pine-hardwood, split	STPH	IO	IO
Shelterwood, pine, split	SWP	40	O-5
Shelterwood, pine-hardwood, not split	SWW	30	IO
Shelterwood, pine-hardwood, split	SWPH	30	IO
III Uneven-aged methods			
Group selection, pine, not split *	GSP	**50**	IO
Group selection, pine-hardwood, not split †	*GSPH*	**50**	IO
Single-tree selection, pine only, split	STSP	60	O-5
Single-tree selection, pine-hardwood, not split	STSW	**50**	10
Single-tree selection, pine-hardwood, split	STSH	**50**	10
Single-tree selection, low impact, split	STSL	60	IO

*No trees retained in groups; pines and hardwoods retained between groups.
†**Hardwoods** retained within groups; pines and hardwoods retained between groups.

Study plot installation

Within any given stand, plot locations were influenced by plans to quarter the stands for the split-plot study, which dictated that a subset of plots must fall within each quarter of each stand. Since three plots generate the minimum number from which statistical inferences may be collectively drawn, three plots were placed in each quarter of the stand. In order to standardize plot installation across all 52 stands, each stand was so quartered.

On a stand map, each stand was subdivided into quarters of approximately equal area, arranged perpendicular to the elevation gradient. Each quarter of the stand was then subdivided into thirds along the elevation *gradient. One* study plot was then randomly located within each **1/12th** of the stand, with the provision that no plot center was placed within 75 **ft** of the border of the stand or any included streamside zones. Plot centers were established by compass and pacing with azimuth and distance scaled from the stand map.

The silviculture research group and understory plant research group cooperated in establishing the pattern for nested subplots. Four layers of vegetation were sampled. The overstory layer and **midstory** layer were measured by the silviculture research group, and the shrub layer and ground cover layer were measured by the understory plant research group. Successively lower layers were sampled with subplots of decreasing size (table 2). The subplot installation was arranged such that the sample plot for each successively lower vegetation layer was nested within the subplot used to sample the **next-**higher layer (fig. 1).

Overstory woody species (9.6 inches in diameter at breast height (d.b.h.) and larger) were sampled by species and 0. **1-**inch d.b.h. units using variable-radius plots established with a basal area factor (BAF) **5 ft²/acre** prism. This sample scheme was selected rather than 0.2-acre fixed-radius plots because field trials demonstrated that large trees just beyond the 0.2-acre plot radius exert an ecological influence on plants near plot center, whereas small overstory trees near the outer perimeter of the 0.2-acre plot do not. When using a prism with BAF 5, a tree 20 inches in d.b.h. has a horizontal limiting distance of 77.78 ft-which is approximately equal to the height of the tree and represents the marginal degree of overstory influence on subplot ecology (**Pickett** and White 1985).

Table 2.— *Nested subplot elements, dimensions, and vegetation to be sampled in each element by type, size, and research group responsible*

Plot size	Plot dimension8	Number of plots	Vegetation sampled (research group)	Vegetation dimensions
0.001 acre	Square 6.6 ft by 6.6 A	4	Herbaceous plants (understory plant)	all nonwoody
			Woody vegetation (silviculture)	all woody stems ht $<$ 4.5 ft, d.b.h. $\leq$ 0.5 inches
0.001 acre	Circular 3.72 ft radius	2	Woody vegetation (silviculture)	all woody sterna ht $<$ 4.5 A, d.b.h. $\leq$ 0.5 inches
0.004 acre	Square 13.2 A by 13.2 ft	4	Woody and nonwoody understory (understory plant)	all woody stems 0.6 inches $\leq$ d.b.h. $\leq$ 3.5 inches
'0.1 acre	Circular 37.24 ft radius	1	Woody midstory (silviculture)	all woody stems 3.6 inches $\leq$ d.b.h. $\leq$ 9.5 inches
Variable	Variable radius BAF 5.0 ft^2/acre	1	Woody overstory (silvicultufe)	all woody stems d.b.h. $\geq$ 9.6 inches

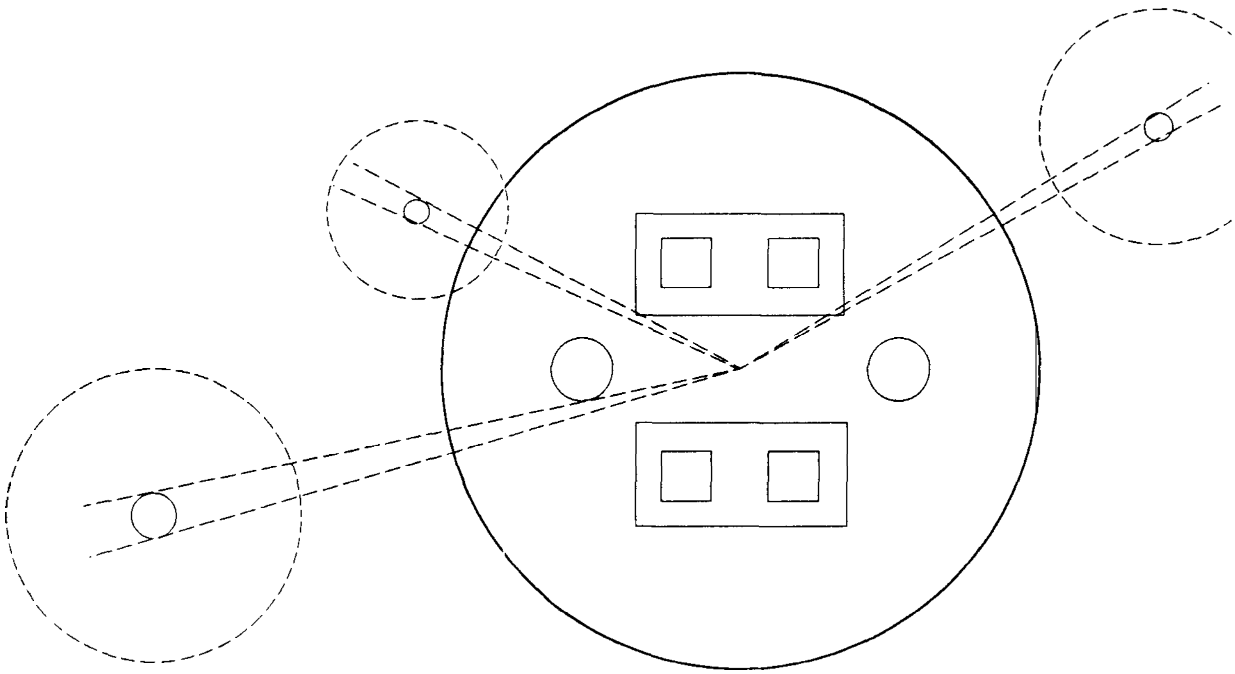

Figure 1- *Overview of nested subplot sample plot configuration. The dashed lines represent the BAF 5 ft^2/acre variable radius plot, for overstory sampling. The large circle (solid line) represents the 0. l-acre fixed radius plot, for midstory sampling. The two rectangles (solid line) represent the shrub layer sample plots; each rectangle consists of two 0.004-acre square subplots. The four small squares and two small circles (solid line) within the large circle represent square and circular milacres, respectively. Plot dimensions are listed in Table 2.*

Midstory trees (3.6 inches in d.b.h. to 9.5 inches in d.b.h., inclusive) were tallied by l-inch classes and species using a 0. l-acre fixed-radius (37.24 ft) subplot. A plot of this size captures the ecologically significant elements of the midstory that affect plants near plot center. In addition, with a prism of BAF 5, the limiting distance to sample a 9.6 inch tree is 37.33 ft, whereas that to sample a 9.5 inch tree is 36.94 ft. This clean break in subsampling enhanced the sample design-all overstory trees 9.6 inches in d.b.h. and larger within the 0. l-acre midstory plot radius will be "in" the prism sample of the overstory, and no midstory trees 9.5 inches in d.b.h. and smaller can be sampled beyond the fixed radius of 37.24 ft.

The pattern and configuration of shrub and regeneration subplots are as follows. All plants having a d.b.h. of 0.6 inches to 3.5 inches inclusive were sampled on four square subplots, each of which is 13.2 ft square with an area of 0.004 acre. Placing two of these shrub plots adjacent to one another essentially creates two 0.00%acre square subplots (fig. 1). Nested within these plots are four O.OOl-acre square subplots, within which all herbaceous vegetation and all woody regeneration from 0.25 ft tall to $\leq$ 0.5 inches in d.b.h. were sampled. Two additional milacre plots were established to supplement the postharvest inventory of woody regeneration. Results from the pretreatment sampling of the shrub and ground cover layers are presented elsewhere in this symposium (Foti and Devall, this volume). Results from analysis of the full spectrum of vegetation, from ground layer to overstory, are also presented elsewhere in this symposium (Foti and Guldin, this volume).

Site variables

The site conditions at each plot were recorded using plot center as the primary reference point. Slope percentage and aspect of plot orientation were measured using a hand-held clinometer and compass to the nearest 1 percent and 1 degree, respectively. Slope position was recorded on a scale of 1 to 5 for ridgetop, upper slope, midslope, lower slope, and floodplain, respectively. On each plot, two dominant or upper codominant shortleaf pine trees were measured for both total height (ft) and ring count at 4 ft; three years were added to each ring count, and site index was determined for each tree from Graney and Burkhart (1992). The average site index was then determined by arithmetic average of the two site index values. A qualitative judgment of site quality, subjectively made in the woods based on vegetation, physiographic, and edaphic factors, was assigned at each plot using a scale of 1 to 4 (poor, medium, good, and excellent, respectively). Microtopography, defined as the topographic variation across the entire plot, was rated using a scale of 1 to 3 (convex, level, and concave, respectively); microtopographic severity was scaled from 1 to 3 (mild, moderate, and severe, respectively). Microrelief, defined as the topographic variation within a plot, was rated as either 1 or 2 (pit-and-mound, and smooth, respectively); microrelief severity was scaled from 1 to 3 (mild, moderate, and severe, respectively).

Stands were identified by treatment and block through the analysis. Stand locations were quantified by plotting the center of each stand on a US Geological Survey topographic quad (1:24000), and reading Universal Transverse Mercator values for latitude (UTM North, meters) and longitude (UTM East, meters).

Data Analysis

Initial data summaries were conducted for trees per acre and basal area per acre in a 3 by 3 contingency table. The x-axis was subdivided as midstory, overstory, and both layers; the y-axis was subdivided as conifer, hardwood, and all species. More detailed summaries were prepared using a matrix of 25 rows and 10 columns representing species by size classes, respectively, as follows. The 25 species consist of 23 individual species, 1 "other" category, and an all-species total (table 3); the 10 size classes represent eight 3-inch classes, a final class for all trees larger than any of the previous classes, and a total (table 4).

Summary tables of trees per acre and basal area per acre were calculated by stand, based on averages of the 14 plots. Relative density was calculated for each species by size class as the quotient of trees per acre in the given species by size class divided by the total number of trees across all species in the given size class; similarly, relative dominance was calculated as the quotient of basal area per acre in the given species by size class divided by the total number of trees across all species in the given size class. Importance values were then derived for each species by size class as the average of relative density and relative dominance.

The final analytical step in this pretreatment analysis was to test for differences in means by block and future treatment. Tests for normality indicated that most variables were not normally distributed; as a result, nonparametric analysis of variance (SAS Institute Inc. 1990) was used to test the null hypothesis of no difference among means for site and summary mensurational data. Statistical significance of results would imply differences among plot means for the site and mensurational variables. Given that plots were imposed in a stratified manner, one would expect plot differences to be detected using this analysis. Future attempts to use regression analysis will be enhanced if this test is significant.

Table 3.-*Species present in the analysis*

Species Code	Common name and scientific name
JUNVIR	Eastern red cedar, *Juniperus virginiana* L.
PINECH	Shortleaf pine, *Pinus cchinata* Mill.
AMEARB	Serviceberry, *Amelanchier arborea* (Michx. f.) Fem.
ACERUB	Red maple, *Acer rubrum* L.
CARCAR	American hornbeam, *Carpinus caroliniana* Walt.
CARCOR	Bittemut hickory, *Carya cordiformis* (Wangenh.) K.Koch
CARTOM	Mockemut hickory, *Carya tomentosa* (Poir.) Nutt.
CARTEX	Black hickory, Carya *texana* Buckl.
CORFLO	Flowering dogwood, *Cornus florida* L.
FRAAME	White ash, *Fraxinus americana* L.
LIQSTY	Sweetgum, *Liquidambar styraciflua* L.
NYSSYL	Black gum, *Nyssa sylvatica* Marsh.
OSTVIR	Eastern hophornbeam, *Ostrya virginiana* (Mill.) K. Koch
PRUSER	Black cherry, *Prunus serotina* Ehrh.
QUEALB	White oak, Quercus *alba* L.
QUEFAL	Southern red oak, Quercus *falcata* Michx. var. *falcata*
QUEMAR	Blackjack oak, *Quercus marilandica* Muenchh.
QUERUB	Northern red oak, Quercus *rubra* L.
QUESTE	Post oak, Quercus *stellata* Wangenh.
QUEVEL	Black oak, Quercus velutina Lam.
ULMALA	Winged elm, *Ulmus alata* Michx.
ULMAME	American elm, *Ulmus americana* L.
ULMRUB	Slippery elm, *Ulmus rubra* Muhl.
GGGSSS	Other species (grouped for this analysis)
TOTAL	All species

Table 4.— *Size classes and inclusive size class endpoints used in this analysis*

Diameter class (inches)	Specific size (inches in d.b.h.)
04-06	3.6 - 6.5
07-09	6.6 - 9.5
10-12	9.6 - 12.5
13-15	12.6 - 15.5
16-18	15.6 - 18.5
19-21	18.6 - 21.5
22-24	21.6 - 24.5
25-27	24.6 - 27.5
28+	27.6 and larger
TOTAL	3.6 and larger

RESULTS

The Average Mature Pine/Hardwood Stand On South-Facing Slopes of the Ouachita/Ozark National Forests

Descriptive summary statistics for all 52 stands in the Phase II study (including mean, standard deviation, and minimum/maximum) are presented in table 5. The "average stand" in the study is a south-facing stand with 11 percent slope, occupies a midslope position on the hillside, and has 91 percent cover. Based on UTM coordinates, the geographic center of the 52-plot data base is located about 5 miles north of the Big Brushy campground in the Oden Ranger District-not unexpected, since that district contains the largest number of stands (11 of 52) in the study. Average site quality was judged to be halfway between medium and good, and average site index for shortleaf pine (base 50) is 62.2 ft. Microsite topography was judged more level than convex, and moderately so; microtopographic relief was judged more smooth than pit-and-mound, though only from mild to moderate.

Statistics for the "average stand" mensurational summary variables, also based on all 52 stands in the study, are presented in table 5. The average stand has 323.2 trees per acre in trees $\geq$ 3.6 inches in d.b.h., of which 51.1 percent is conifer and 48.9 percent hardwood. However, of the 129.5 ft^2/acre of basal area in the average stand, 73.5 percent is conifer and 26.5 percent hardwood. It follows that the average conifer is larger than the average hardwood; the quadratic mean diameter (the diameter of the tree of average basal area) for conifers is 10.45 inches, whereas that for hardwoods is 6.28 inches.

Examination of variable statistics for the 72%plot data base, rather than as summarized stand data, gives a better indication of plot variability. Although statistics for variables based on the plot-based observations result in the same sample means as those for the 52-stand data base, the sample standard deviations, maxima and minima are larger, larger and smaller, respectively, for the 728-plot data base. Histograms of site variables across all plots reveal that in most cases, sample means and modes are similar, but that in all cases a wide spectrum of variation is included in the data base (Appendix, figs. A1-A10).

Table 5.— ***Sample** minimum, maximum, mean, and standard deviation for site and mensurational summary variables based on stand averages **in the 52-stand data base. Stand averages for all except UTM (Universal Transverse Mercator) variables based on 14-plot summaries. TPA - trees per acre; BA - basal area,** ft^2 **per acre ; QD - quadratic mean diameter (diameter** of **the tree of average basal area), inches***

Variable	Minimum	Maximum	Mean	Standard Deviation
I. Site variables				
UTM - North (m)	31803700.00	3936200.00	3844196.15	25115.13
UTM - East (m)	335100.00	463400.00	426144.23	33664.42
Azimuth Orientation (deg)	115.14	280.64	180.31	38.86
Slope percent	4.21	25.36	11.62	4.83
Slope position *	2.36	3.71	3.12	0.31
Percent Cover	82.37	95.57	91.01	3.17
Microtopography †	1.36	2.57	1.88	0.28
Microtopographic severity ‡	1.00	1.93	1.41	0.22
Microrelief §	1.36	2.00	1.84	0.17
Microrelief severity ‡	1.00	2.00	1.50	0.24
Tree Height	57.75	80.07	70.38	5.20
Tree Age	51.64	85.75	64.49	5.92
Site Index	49.59	70.73	62.23	4.35
Site Quality ¶	1.79	3.14	2.51	0.30
II. Mensurational variables				
TPA, conifer midstory	8.57	181.43	81.50	38.72
TPA, conifer overstory	44.13	108.31	83.55	13.31
TPA, all conifers	56.27	283.00	165.05	44.80
TPA, hardwood midstory	24.29	217.86	145.76	38.91
TPA, hardwood overstory	1.38	38.36	12.40	8.55
TPA, all hardwoods	27.76	243.29	158.16	41.92
TPA, all midstory	136.43	355.00	227.25	45.14
TPA, all overstory	71.67	126.52	95.95	12.29
TPA, all trees	203.52	455.19	323.21	48.25
BA, conifer midstory	2.11	46.89	18.20	9.00
BA, conifer overstory	45.71	97.14	77.02	10.65
BA, all conifers	50.12	121.17	95.22	14.31
BA, hardwood midstory	5.00	35.52	23.43	6.45
BA, hardwood overstory	1.07	41.07	10.86	7.86
BA, all hardwoods	8.21	67.13	34.29	11.92
BA, all midstory	24.77	74.90	41.63	9.38
BA, all overstory	62.50	111.07	87.88	10.15
BA, all trees	98.36	155.26	129.51	13.76
QD, conifer midstory	4.35	7.36	6.10	0.61
QD, conifer overstory	11.39	14.65	13.07	0.72
QD, all conifers	9.06	13.97	10.74	0.97
QD, hardwood midstory	4.25	5.86	5.31	0.31
QD, hardwood overstory	2.62	13.85	9.35	2.94
QD, all hardwoods	5.25	8.32	6.22	0.63
QD, all midstory	5.03	6.71	5.77	0.27
QD, all overstory	11.34	14.31	13.05	0.62
QD, all trees	7.74	9.68	8.69	0.47

* Index: 1 - ridgetop; 2 - upper slope; 3 - midslope; 4 - lower slope; 5 - floodplain
† Index: 1 - convex; 2 - level; 3 - concave.
‡ Index: 1 - mild; 2 - moderate; 3 - severe.
§ Index: 1 - pit-and-mound; 2 - smooth.
¶ Index: 1 - poor; 2 - medium; 3 - good; 4 - excellent.

Tree density

The average stand shows a bimodal distribution of trees per acre in the coniferous component, with peaks in the **4-** to **6-inch** class and the **10-** to **12-inch class** (fig. 2). Hardwoods as a group show a continuous exponential decline in density with increasing diameter. Shortleaf pine is the most numerous tree in the average stand, followed by post oak, white oak, black hickory, mockemut hickory, and winged elm (fig. 3).

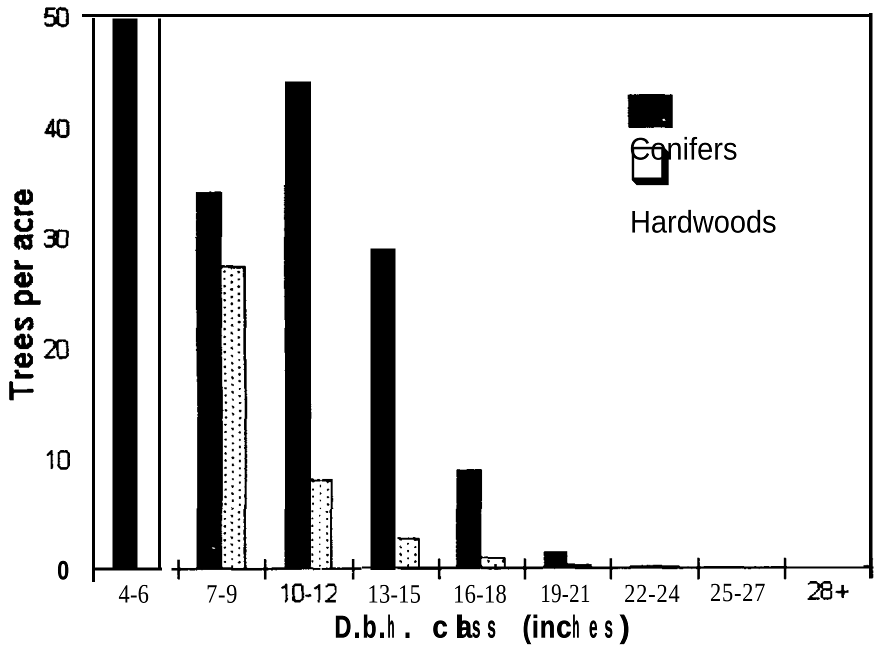

Figure *2.-Trees per acre in the average stand, by conifers and hardwoods.*

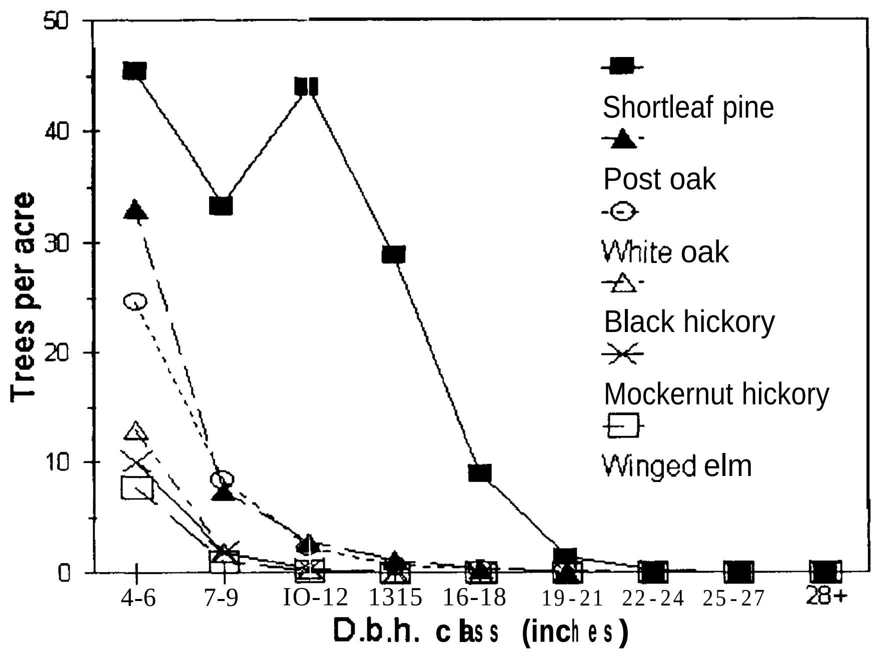

Figure *3.-Trees per acre in the average stand--six most numerous species.*

The most numerous species in the overstory are shortleaf pine, post oak, and white oak; no other species in the average stand exceeds one overstory tree per acre (table 6). Shortleaf pine dominates the overstory with 51.4 percent of its stems in the overstory layer; no other species has more than 20 percent of its stems in the overstory, although southern red oak, slippery elm, sweetgum, northern red oak, post oak, and black cherry all exceed 10 percent (table 6).

Shortleaf pine is also the most numerous species in the midstory (78.8 stems/acre), followed by post oak, white oak, black hickory, and mockernut hickory (table 6), all of which exceed 10 stems per acre. However, when considering the percentage of overstory occupancy by species, a handful of species exists only as midstory trees in the average stand-namely serviceberry, hophornbeam, bitternut hickory, flowering dogwood, white ash, and American hornbeam (table 6).

Basal area

The conifers in the average stand have a normal or "bell-shaped" distribution of basal area per acre, with peaks in the 10- to 15-inch classes (fig. 4). Hardwoods show a continuous exponential decline in basal area as size class increases. Shortleaf pine accounts for 94.7 ft^2/acre in the average stand, or 73 percent of total basal area (table 7). Post oak and white oak account for 10.5 ft^2/acre (8.1 percent) and 8.9 ft^2/acre (6.8 percent), respectively; no other species exceeds 3.0 ft^2/acre.

Basal area data also reveal the degree of overstory dominance by shortleaf pine. Of the 87.9 ft^2/acre in overstory basal area, shortleaf pine accounts for 76.9 ft^2/acre or 87.5 percent (table 7). Post oak and white oak comprise 4.0 ft^2/acre (4.6 percent) and 3.0 ft^2/acre (3.4 percent) of overstory basal area, respectively; no other species in the average stand exceeds 1.0 ft^2/acre of basal area in the overstory (table 7).

Though it does not dominate the midstory as it does the overstory, shortleaf pine nonetheless accounts for the largest percentage of midstory basal area per acre in the average stand, having 17.8 ft^2/acre (table 7) or 42.6 percent. It is followed by post oak, white oak, and black hickory, which have 6.4 ft^2/acre (15.4 percent), 5.9 ft^2/acre (14.2 percent), and 2.1 ft^2/acre (5.1 percent), respectively, in midstory basal area. No other species exceeds 2.0 ft^2/acre in the midstory (table 7).

Table 6.— *Trees per acre in the average stand, by species and 3-inch diameter classes. The midstory includes all trees with 3.6 inches to 9.5 inches in d. b. h.; the overstory includes all trees 9.6 inches in d. b. h. and larger*

Species *	--- Midstory --- 4-6	7-9	Overstory 10-12	13-15	16-18	19-21	22-24	25-27	28+	Midstory Subtotal	Overstory Subtotal	Total	Percent Overstory
	Trees per acre												--Percent--
JUNVIR	2.267	0.714	0.188	0.000	0.004	0.000	0.000	0.000	0.000	2.981	0.192	3.173	6.05
PINECH	45.398	33.380	43.927	28.861	8.938	1.421	0.179	0.007	0.000	78.778	83.334	162.112	51.41
AMEARB	0.275	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.302	0.000	0.302	0.00
ACERUB	2.843	0.288	0.036	0.000	0.000	0.003	0.000	0.000	0.000	3.132	0.038	3.170	1.21
CARCAR	0.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.041	0.000	0.041	0.00
CARCOR	0.055	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.055	0.000	0.055	0.00
CARTOM	10.014	1.758	0.405	0.042	0.014	0.000	0.000	0.000	0.000	11.772	0.461	12.233	3.76
CARTEX	13.008	1.827	0.325	0.065	0.032	0.006	0.000	0.000	0.000	14.835	0.429	15.265	2.81
CORFLO	2.912	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	2.940	0.000	2.940	0.00
FRAAME	0.316	0.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.426	0.000	0.426	0.00
LIQSTY	2.006	0.742	0.358	0.122	0.032	0.012	0.005	0.000	0.000	2.747	0.529	3.276	16.13
NYSSYL	4.080	0.440	0.068	0.048	0.039	0.023	0.017	0.002	0.000	4.519	0.196	4.715	4.16
OSTVIR	0.412	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.412	0.000	0.412	0.00
PRUSER	0.288	0.096	0.039	0.000	0.004	0.000	0.000	0.000	0.000	0.385	0.043	0.428	10.10
QUEALB	24.561	8.393	2.240	0.640	0.305	0.132	0.039	0.004	0.003	32.953	3.363	36.316	9.26
QUEFAL	2.472	1.223	0.567	0.240	0.091	0.018	0.005	0.000	0.000	3.695	0.921	4.616	19.95
QUEMAR	6.030	0.852	0.214	0.068	0.005	0.000	0.000	0.000	0.000	6.882	0.286	7.168	3.99
QUERUB	2.651	1.360	0.333	0.143	0.071	0.006	0.000	0.002	0.003	4.011	0.557	4.568	12.20
QUESTE	33.187	7.349	2.838	1.220	0.355	0.105	0.037	0.004	0.002	40.536	4.561	45.097	10.11
QUENIG	4.643	1.841	0.382	0.177	0.081	0.031	0.002	0.000	0.003	6.483	0.675	7.159	9.44
ULMALA	7.720	0.934	0.152	0.042	0.000	0.000	0.000	0.000	0.000	8.654	0.194	8.848	2.19
ULMAME	0.151	0.055	0.011	0.000	0.000	0.000	0.000	0.000	0.000	0.206	0.011	0.217	5.16
ULMRUB	0.069	0.027	0.022	0.000	0.000	0.000	0.000	0.000	0.000	0.096	0.022	0.118	18.71
GGGSSS	0.591	0.069	0.061	0.039	0.009	0.000	0.003	0.000	0.001	0.659	0.114	0.773	14.71
TOT	165.989	61.511	52.168	31.706	9.979	1.757	0.287	0.019	0.011	227.500	95.928	323.428	29.66
Conifers	47.665	34.094	44.115	28.861	8.942	I.421	0.179	0.007	0.000	81.759	83.526	165.285	50.53
Hardwoods	118.324	27.418	8.053	2.845	1.037	0.336	0.107	0.011	0.011	145.742	12.402	158.143	7.84

* Species codes are defined in Table 3.

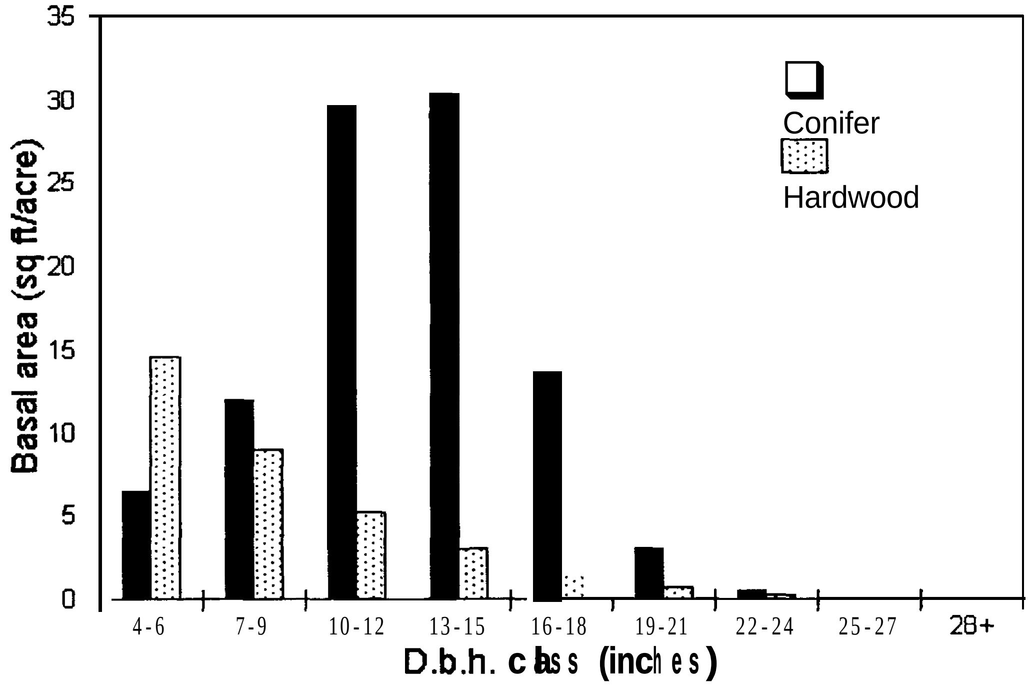

Figure 4.—*Basal area per acre in the average stand, by conifers and hardwoods.*

Table 7.— ***Basal area per acre in the average stand, by species code and 3-inch diameter classes. The midstory includes all trees 3.6 inches to 9.5 inches in d. b.h.; the overstory includes all trees 9.6 inches in d.b.h. and larger***

	--- Midstory ---		Overstory							Midstory	Overstory		Percent
Species *	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28+	Subtotal	Subtotal	Total	Overstory
	Trees per acre												--Percent--
JUNVIR	0.283	0.239	0.110	0.000	0.007	0.000	0.000	0.000	0.000	0.522	0.117	0.639	18.27
PINECH	6.088	11.678	29.512	30.268	13.599	2.981	0.501	0.027	0.000	17.765	76.889	94.654	81.23
ACERUB	0.342	0.090	0.021	0.000	0.000	0.007	0.000	0.000	0.000	0.431	0.027	0.459	5.99
AMEARB	0.028	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036	0.000	0.036	0.00
CARCAR	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.000	0.004	0.00
CARCOR	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.006	0.000	0.006	0.00
CARTEX	1.518	0.596	0.206	0.069	0.048	0.014	0.000	0.000	0.000	2.114	0.336	2.451	13.73
CARTOM	1.242	0.560	0.254	0.041	0.021	0.000	0.000	0.000	0.000	1.802	0.316	2.118	14.91
CORFLO	0.292	0.010	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.301	0.000	0.301	0.00
FRAAME	0.036	0.032	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.068	0.000	0.068	0.00
LIQSTY	0.255	0.235	0.240	0.124	0.048	0.027	0.014	0.000	0.000	0.491	0.453	0.944	48.02
NYSSYL	0.488	0.137	0.041	0.048	0.062	0.048	0.048	0.007	0.000	0.625	0.254	0.879	28.89
OSTVIR	0.042	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.042	0.000	0.042	0.00
PRUSER	0.033	0.033	0.027	0.000	0.007	0.000	0.000	0.000	0.000	0.066	0.034	0.100	34.29
QUEALB	3.155	2.753	1.408	0.666	0.467	0.282	0.110	0.014	0.014	5.908	2.960	8.869	33.37
QUEFAL	0.329	0.404	0.371	0.254	0.144	0.041	0.014	0.000	0.000	0.733	0.824	1.557	52.93
QUEMAR	0.743	0.269	0.130	0.069	0.007	0.000	0.000	0.000	0.000	1.012	0.206	1.218	16.90
QUERUB	0.342	0.436	0.220	0.151	0.110	0.014	0.000	0.007	0.014	0.778	0.515	1.293	39.83
QUESTE	4.063	2.383	1.834	1.284	0.542	0.227	0.103	0.014	0.007	6.446	4.011	10.457	38.36
QUEVEL	0.598	0.612	0.254	0.185	0.124	0.069	0.007	0.000	0.014	1.210	0.652	1.862	35.03
ULMALA	0.907	0.303	0.096	0.041	0.000	0.000	0.000	0.000	0.000	1.210	0.137	1.347	10.19
ULMAME	0.015	0.023	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.038	0.007	0.045	15.18
ULMRUB	0.010	0.011	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.021	0.014	0.035	39.15
GGGSSS	0.067	0.023	0.041	0.041	0.014	0.000	0.007	0.000	0.007	0.090	0.110	0.200	54.93
TOTALS	20.887	20.835	34.787	33.242	15.199	3.709	0.803	0.069	0.055	41.722	87.864	129.586	67.80
Conifers	6.3708	11.917	29.622	30.268	13.606	2.9808	0.5013	0.0275	0	18.288	77.005	95.293	80.81
Hardwoods	14.516	8.9184	5.1642	2.9735	1.593	0.7278	0.3021	0.0412	0.0549	23.434	10.857	34.293	31.66

* Species codes are defined in Table 3.

Importance Values

Considering all size classes in the average stand, the importance value of conifers is greater than that of hardwoods (table 8). This is primarily due to conifer dominance in the overstory, where their importance value is roughly seven times greater than that of the hardwoods. In the midstory, the hardwood importance value exceeds that of conifers, due to high hardwood densities in the midstory.

Table 8.— *Importance values in the average stand, by species and 3" diameter classes. The midstory includes all trees 3.4 inches to 9.5 inches in d. b. h., the overstory includes all trees 9.6 inches in d. b. h. and larger*

	Midstory		Overstory							Midstory	Overstory	
Species *	4-6	7-9	10-12	13-15	16-18	19-21	22-24	25-27	28+	Subtotal	Subtotal	Total
	Trees per acre											
JUNVIR	1.36	1.15	0.34	0.00	0.04	0.00	0.00	0.00	0.00	1.28	0.17	0.74
PINECH	28.25	55.16	84.52	91.04	89.52	80.62	62.46	39.74	0.02	38.60	87.19	6158
ACERUB	0.90	0.24	0.03	0.00	0.00	0.09	0.00	0.00	0.00	0.58	0.02	0.22
AMEARB	0.92	0.25	0.03	0.00	0.00	0.08	0.00	0.00	0.00	0.73	0.02	0.50
CARCAR	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.01
CARCOR	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01
CARTEX	6.65	2.86	0.68	0.17	0.23	0.19	0.00	0.00	0.00	5.12	0.43	2.84
CARTOM	6.89	2.83	0.68	0.16	0.23	0.18	0.00	0.00	0.00	5.42	0.40	3.18
CORFLO	1.58	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.01	0.00	0.57
FRAAME	0.18	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.17	0.00	0.09
LIQSTY	1.22	1.17	0.69	0.38	0.32	0.71	1.69	0.00	0.00	1.19	0.53	0.87
NYSSYL	2.40	0.69	0.12	0.15	0.40	1.29	5.89	10.49	0.00	1.74	0.25	1.07
OSTVIR	0.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.08
PRUSER	0.17	0.16	0.08	0.00	0.04	0.00	0.00	0.00	0.00	0.16	0.04	0.10
QUEALB	14.95	13.43	4.17	2.01	3.06	7.55	13.72	19.54	25.19	14.32	3.44	9.04
QUEFAL	1.53	1.96	1.08	0.76	0.93	1.07	1.71	0.00	0.00	1.69	0.95	1.31
QUEMAR	3.60	1.34	0.39	0.21	0.05	0.00	0.00	0.00	0.00	2.73	0.27	1.58
QUERUB	1.62	2.15	0.64	0.45	0.72	0.35	0.00	9.67	24.68	1.81	0.58	1.21
QUESTE	19.72	11.69	5.36	3.86	3.56	6.05	12.85	20.56	13.47	16.63	4.66	11.01
QUEVEL	2.83	2.91	0.73	0.56	0.81	1.81	0.80	0.00	23.92	2.87	0.72	1.83
ULMALA	4.50	1.49	0.28	0.13	0.00	0.00	0.00	0.00	0.00	3.35	0.18	1.89
ULMAME	0.08	0.10	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.01	0.05
ULMRUB	0.05	0.05	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.02	0.03
GGGSSS	0.34	0.11	0.12	0.12	0.09	0.00	0.87	0.00	12.72	0.25	0.12	0.20
TOTALS	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	bo.0
Conifers	29.61	56.31	84.86	91.04	89.56	80.62	62.46	39.74	0.02	39.88	87.357	6232
Hardwoods	70.39	43.69	15.14	8.96	10.44	19.38	37.54	60.26	99.98	60.12	12.642	37.68

* Species codes are defined in Table 3.

When considering the importance value of conifers and hardwoods in 3-inch size classes, an interesting pattern emerges (fig. 5). In the 4- to 6-inch class, the hardwood group has a larger importance value than the conifers, again because of the many hardwood stems in the 4- to 6-inch class. From the 7- to 9-inch class through the 22- to 24-inch class, the conifer group has greater importance values than the hardwoods; this difference is especially prominent from the 10- to 12-inch class to the 19- to 21-inch class. However, in the two largest classes, hardwood importance values again exceed those of the coniferous group.

Analysis of Variance

Nonparametric analysis of variance using plot averages resulted in significant differences among site and mensurational data. The assumption of equality among means by future treatment was rejected (at $P > 0.05$) for nearly all site and mensurational summary variables (table 9), using the Kruskal-Wallis test statistic. Only three variables did not show significant difference among means by future treatment—trees per acre in the conifer midstory, quadratic mean diameter of the conifer midstory, and quadratic mean diameter of the hardwood overstory. The reason these variables should exhibit a lack of mean difference is not readily apparent. Despite the statistical significance of these tests of mean difference by

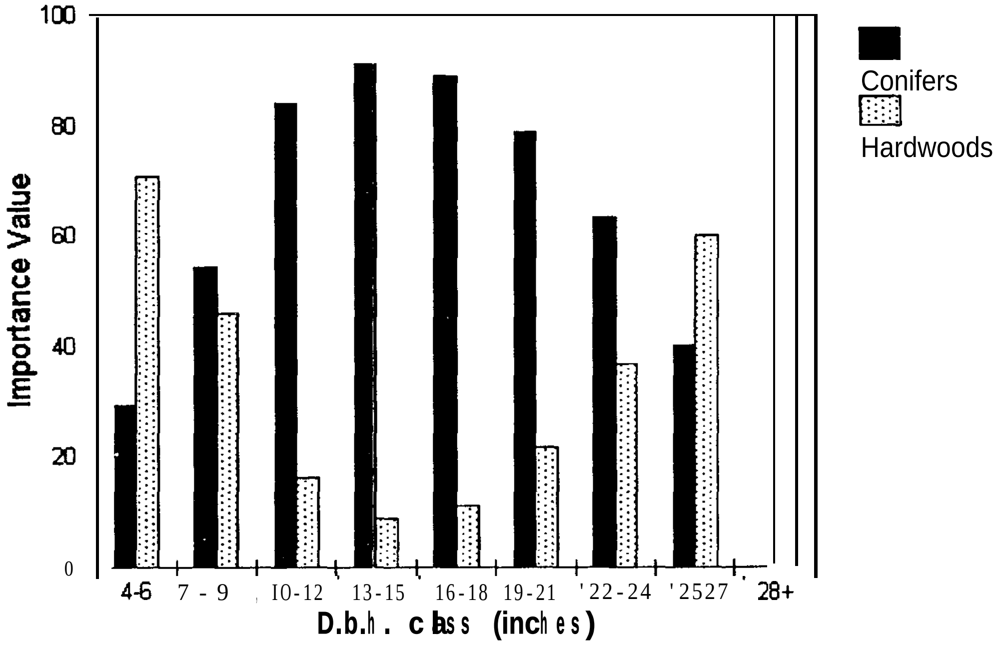

Figure 5.—*Importance values in the average stand, by conifers and hardwoods.*

future treatment for most variables, the values of the means do not show great variation. For example, consider the total trees per acre and basal area per acre for all trees 3.6 inches and larger. Means by future treatment vary from 286 to 377 trees per acre, and from 122 to 147 ft^2 per acre, respectively. Similarly, means by future treatment for site index vary from 58.8 to 65.1 ft, and means for percent cover vary from 89.2 to 93.5 percent.

The assumption of equality among means by physiographic block was also rejected for most site and mensuration variables (table 10). The only site variables in which one fails to reject the hypothesis of mean equality by future treatment are microtopography and microrelief, indications that within-plot surface variation is minimal. Several of the mensuration summary variables-trees per acre of the conifer overstory and all overstory, basal area per acre of the conifer overstory and all overstory, and several of the quadratic mean diameter measurements-exhibit no statistically significant difference among ecoregional blocks means when evaluated at $P > 0.05$.

DISCUSSION AND CONCLUSIONS

The average stand in this study had residual basal areas slightly higher than anticipated, with hardwood midstory basal areas also higher than anticipated. The stand was slightly younger than anticipated, as well. These observations are consistent with the impression in the woods that the dominant and codominant pines in these stands have rather small crowns and a relative absence of cones. It follows that relying on these trees to produce seed following reproduction cutting in the summer of 1993, while not quite a leap of faith, is nonetheless a rather large step. Future work might focus productively on securing mixed-species advance growth several years prior to reproduction cutting, perhaps through late-rotation preparatory cutting coupled with pre-cut site preparation such as prescribed fire. The silvicultural hoops through which the forester must jump are fewer, larger, and less flammable if advance growth of the desired mixture of species existed prior to reproduction cutting.

The reverse J-shaped diameter distribution of the average stand, especially in the hardwood component, might lead some to label these stands as uneven-aged. However, this is discounted on multiple grounds. First, the curve is a mixture of all species; such interpretations are best made for individual species. Second, such interpretations are dubious at best without examining the submerchantable component; the 1- to 3-inch hardwood component has a large number of stems per acre, but that the conifer component does not (Foti and Devall, this volume). Third, a pilot study of age distributions suggests that there are very few trees of any species 3.6 inches and larger that are less than 50 years old; this suggests that the smaller hardwoods are a long-suppressed element similar in age to the overstory, rather than a vigorous younger component. This reverse J-shaped diameter distribution is better explained based on varying growth rates both within and between these hardwood species, related to both shade tolerance and to the exclusion of fire for the past 6 decades.

Table 9.— *Means by future treatment for site and mensuration summary variables, based on plot averages (n =56). The null hypothesis of equality among means is rejected at indicated levels of Kruskal-Wallis(KW) X^2 test statistic. Codes for silvicultural system are defined in Table 1; TPA - trees per acre; BA - basal area, ft^2 per acre ; QD - quadratic mean diameter (diameter of the tree of average basal area), inches*

	-- Controls --		-----Even-aged partial cutting methods-----					--Uneven-aged partial cutting methods-----						KW
Variable	UC	CCNS	STP	STPH	SWP	SWPH	SWW	GSP	GSPH	STSP	STSH	STSW	STSL	$P>X^2$
I. Site variables														
Azimuth (deg)	179.30	161.98	169.25	176.05	181.84	184.61	180.21	184.87	209.29	153.00	154.45	196.48	212.75	0.0001
Slope percent	8.50	14.82	10.66	9.00	12.86	18.55	12.04	11.61	12.45	12.46	10.93	7.09	10.13	0.0001
Slope position *	3.29	2.63	3.13	3.29	3.14	2.89	3.25	3.27	3.20	2.96	3.05	3.34	3.13	0.0001
Percent Cover	90.07	90.94	91.31	92.33	90.70	89.23	90.14	92.74	89.53	91.71	90.18	90.69	93.51	0.0001
Microtopography †	1.77	1.71	2.11	1.86	1.89	1.95	1.68	2.07	1.66	1.93	2.04	1.77	1.95	0.0483
Microtopographic severity ‡	1.21	1.61	1.30	1.30	1.45	1.38	1.57	1.38	1.55	1.29	1.38	1.43	1.43	0.0034
Microrelief §	1.82	1.80	1.91	1.80	1.73	1.96	1.93	1.93	1.68	1.88	1.84	1.84	1.86	0.0009
Microrelief severity ‡	1.41	1.64	1.29	1.63	1.54	1.61	1.55	1.50	1.48	1.45	1.34	1.55	1.55	0.0024
Tree Height	76.13	67.82	71.26	70.96	72.76	64.65	73.32	72.88	69.67	71.12	66.89	68.74	68.79	0.0001
Tree Age	69.32	67.46	65.18	62.17	63.73	59.63	69.28	65.79	65.03	61.89	62.39	64.67	61.80	0.0001
Site Index	65.06	58.84	62.33	63.98	64.57	59.22	62.88	64.01	61.56	63.93	60.04	60.50	62.07	0.0001
Site Quality ¶	2.73	2.11	2.55	2.54	2.55	2.50	2.50	2.70	2.27	2.80	2.48	2.50	2.38	0.0001
II. Mensurational variables														
TPA, conifer midstory	79.64	70.71	86.25	101.96	77.32	96.43	53.39	83.57	70.54	86.61	83.57	68.21	101.25	0.0828
TPA, conifer overstory	78.69	83.07	79.58	96.91	81.09	86.43	90.65	85.83	70.088	86.84	83.23	76.40	87.40	0.0124
TPA, all conifers	158.33	153.78	165.83	198.88	158.41	182.86	144.04	169.40	140.62	173.45	166.80	144.61	188.65	0.0248
TPA, hardwood midstory	138.75	127.86	161.43	165.18	154.46	97.32	132.68	153.39	161.61	146.96	152.32	149.82	153.04	0.0001
TPA, hardwood overstory	9.83	13.16	11.08	13.38	9.62	12.14	9.72	14.06	14.71	18.77	8.45	15.38	10.92	0.0187
TPA, all hardwoods	148.58	141.02	172.51	178.55	164.09	109.46	142.40	167.46	176.32	165.73	160.77	165.20	163.95	0.0001
TPA, all midstory	218.39	198.57	247.68	267.14	231.79	193.75	186.07	236.96	232.14	233.57	235.89	218.04	254.29	0.0001
TPA, all overstory	88.51	96.23	90.66	110.29	90.71	98.57	100.37	99.89	84.80	105.61	91.68	91.78	98.31	0.0009
TPA, all trees	306.90	294.80	338.34	377.43	322.50	292.32	286.44	336.86	316.94	339.18	327.57	309.82	352.60	0.0001
BA, conifer midstory	18.00	16.00	20.96	24.35	16.59	22.01	11.30	20.00	16.04	18.88	17.33	15.29	19.89	0.0165
BA, conifer overstory	81.52	75.36	75.09	84.64	75.54	69.02	89.82	77.95	67.05	77.50	74.73	71.88	81.16	0.0013
BA, all conifers	99.52	91.36	96.05	108.99	92.13	91.03	101.13	97.94	83.09	96.38	92.06	87.16	101.05	0.0086
BA, hardwood midstory	22.74	22.35	24.91	26.30	24.42	15.91	20.93	25.48	26.14	22.78	22.62	24.48	25.54	0.0011
BA, hardwood overstory	8.04	10.98	9.73	11.79	8.57	10.89	8.84	11.52	14.64	16.34	7.32	13.21	9.29	0.0122
BA, all hardwoods	30.77	33.34	34.64	38.09	33.00	26.80	29.77	37.00	40.79	39.12	29.95	37.69	34.83	0.0018
BA, all midstory	40.74	38.36	45.87	50.65	41.01	37.92	32.24	45.48	42.18	41.66	39.95	39.76	45.43	0.0001
BA, all overstory	89.55	86.34	84.82	96.43	84.11	79.91	98.66	89.46	81.70	93.84	82.05	85.09	90.45	0.0010
BA, all trees	130.29	124.70	130.69	147.08	125.12	117.83	130.90	134.94	123.88	135.50	122.00	124.85	135.88	0.0001
QD, conifer midstory	5.86	6.32	5.90	6.48	5.96	6.16	5.96	6.18	5.96	6.22	6.11	6.01	6.18	0.4838
QD, conifer overstory	13.92	13.10	13.09	12.51	13.29	12.20	13.37	12.89	13.51	12.70	13.09	12.89	13.19	0.0001
QD, all conifers	11.30	10.70	10.93	10.51	10.84	10.06	11.54	10.77	11.19	10.39	10.32	0.54	10.59	0.0001
QD, hardwood midstory	5.42	5.59	5.26	5.35	5.34	4.91	5.27	5.32	5.42	5.29	5.17	5.24	5.50	0.0109
QD, hardwood overstory	8.19	10.87	9.88	12.03	9.18	8.16	8.02	10.00	8.67	9.71	7.42	9.76	9.64	0.0563
QD, all hardwoods	6.02	6.58	5.95	6.34	6.06	6.42	6.10	6.35	6.41	6.48	5.68	6.16	6.37	0.0003
QD, all midstory	5.79	5.90	5.72	5.87	5.66	6.06	5.57	5.90	5.79	5.71	5.54	5.72	5.76	0.0001
QD, all overstory	13.70	12.94	12.96	12.69	13.22	12.24	13.48	12.92	13.37	12.87	12.99	13.15	13.12	0.0001
QD, all trees	8.92	8.87	8.51	8.53	8.56	8.76	9.23	8.62	8.65	8.63	8.38	8.72	8.53	0.0014

* Index: 1 - ridge top; 2 - upper slope; 3 - midslope; 4 - lower slope; 5 - floodplain.

† Index: 1 - convex; 2 - level; 3 - concave.

‡ Index: 1 - mild; 2 moderate; 3 - severe.

§ Index: 1 - pit-and-mound; 2 - smooth.

¶ Index: 1 - poor; 2 - medium; 3 - good; 4 - excellent.

Table 10.— ***Means by block for site and mensuration summary variables, based on plot averages (n=182). The null hypothesis of equality among means is rejected at indicated levels of Kruskal-Wallis (KW) X^2 test statistic. Codes for silvicultural system are defined in Table 1; TPA - trees per acre; BA - basal area, ft^2 per acre ; QD - quadratic mean diameter (diameter of the tree of average basal area), inches***

Variable	East Block	North Block	south Block	west Block	KW $P > X^2$
I. Site variables					
Azimuth (deg)	198.64	170.88	166.79	184.95	0.0001
Slope percent	9.74	15.06	12.32	9.37	0.0001
Slope position *	3.19	2.93	3.20	3.15	0.0005
Percent Cover	90.43	91.93	91.00	90.67	0.0456
Microtopography †	1.85	1.93	1.75	1.97	0.0556
Microtopographic severity ‡	1.32	1.52	1.45	1.33	0.0041
Microrelief §	1.86	1.84	1.81	1.87	0.4110
Microrelief severity ‡	1.52	1.64	1.41	1.45	0.0003
Tree Height	70.82	70.04	73.60	67.07	0.0001
Tree Age	65.31	65.42	62.70	64.51	0.0110
Site Index	62.23	61.50	65.82	59.36	0.0001
Site Quality ¶	2.52	2.37	2.70	2.44	0.0001
II. Mensurational variables					
TPA, conifer midstory	79.73	75.06	68.79	102.42	0.0015
TPA, conifer overstory	87.66	81.64	79.04	85.86	0.0688
TPA, all conifers	167.39	156.70	147.83	188.28	0.0008
TPA, hardwood midstory	145.88	134.29	159.73	143.13	0.0064
TPA, hardwood overstory	10.87	12.31	15.73	10.70	0.0442
TPA, all hardwoods	156.75	146.60	175.45	153.83	0.0011
TPA, all midstory	225.60	209.34	228.52	245.55	0.0005
TPA, all overstory	98.53	93.95	94.77	96.56	0.4810
TPA, all trees	324.14	303.29	323.29	342.11	0.0005
BA, conifer midstory	19.14	15.64	15.80	22.22	0.0006
BA, conifer overstory	77.31	76.73	74.42	79.62	0.4863
BA, all conifers	96.45	92.37	90.23	101.84	0.0102
BA, hardwood midstory	23.60	21.10	26.15	22.88	0.0011
BA, hardwood overstory	9.01	11.18	13.63	9.62	0.0246
BA, all hardwoods	32.61	32.28	39.78	32.49	0.0001
BA, all midstory	42.54	36.74	41.95	45.10	0.0001
BA, all overstory	86.32	87.91	88.05	89.23	0.8162
BA, all trees	129.06	124.65	130.00	134.33	0.0043
QD, conifer midstory	6.41	5.74	6.04	6.21	0.0025
QD, conifer overstory	12.i 1	13.20	13.15	13.23	0.0002
QD, all conifers	10.59	10.90	10.91	10.57	0.0407
QD, hardwood midstory	5.28	5.26	5.45	5.26	0.0622
QD, hardwood overstory	8.56	8.97	9.73	9.93	0.0605
QD, all hardwoods	6.C2	6.28	6.37	6.23	0.0847
QD, all midstory	5.84	5.64	5.78	5.81	0.0058
QD, all overstory	12.66	13.23	13.16	13.15	0.0001
QD, all trees	8.67	8.82	8.68	8.59	0.2758

* Index: 1 - ridgetop; 2 - slope; 3 - upper midslope; 4 - lower slope; 5 - floodplain

† Index: 1 - convex; 2 - level; 3 - concave.

‡ Index: 1 - mild; 2 - moderate; 3 - severe.

§ Index: 1 - pit-and-mound; 2 smooth.

¶ Index: 1 - poor; 2 - medium; 3 - good; 4 - excellent.

The importance value graphs depict unexpected trends as well. The high importance values for very small and very large hardwoods, coupled with the very prominent difference in importance value between conifers and hardwoods in the 10- to 24-inch overstory classes, are interesting. The prominence of the hardwood midstory can be attributed to the ongoing successional development of shade-tolerant hardwoods, which is made possible by the alteration of disturbance through fire prevention. The prominence of the 25- to 27-inch and ≥ 28-inch hardwoods may be due to a long-standing philosophy for their retention for wildlife and other non-timber benefits. Conversely, the nontimber benefits of large pines have been less appreciated, especially when considered relative to their timber value. Finally, in the 10- to 24-inch size classes, the prominent difference in importance values between pines and the hardwood species might reflect the relative rates of growth, but could also be explained by the long history of midstory hardwood control efforts conducted by the Ouachita NF over the past decades, especially on sites such as these south-facing slopes that have been traditionally managed for pine. These data suggest a three-step hypothesis toward restoration of natural ecological processes. These steps would include restoration of light surface disturbances, cessation of efforts to eliminate smaller overstory hardwoods, and allowing some proportion of overstory pines and hardwoods to grow beyond 24 inches in diameter.

The analysis of variance indicates that for most of the mensuration and site variables, differences exist among means by both ecophysiographic block and future treatment. This is somewhat unexpected, since stands were selected according to preestablished criteria, treatments were assigned randomly, and plot stratification was conducted systematically. But in a larger sense this is surprising. The results illustrate that even fairly narrowly-defined pine-hardwood stands on south-facing slopes in the Ouachita Mountains are, in fact, inherently variable. It lends credence to the assumption that the plots encompass a full range of conditions likely to be encountered on these south- and southwest-facing mixed-species stands.

However, the observation that statistically significant differences may exist should be interpreted in light of the ecological meaning behind the magnitude of the differences. For example, some variables, such as trees per acre for all trees 3.6 inches and larger, show rather large variation, which might be expected to be of significance ecologically and silviculturally. Others, such as site index or percent cover, show little variation despite the statistical significance of the difference among mean values by future treatment; the ecological importance of these significant differences is likely to be minimal.

The presence of significant differences before treatment indicates that some adjustments in the analysis will be required as comparisons are drawn between pre-treatment and posttreatment conditions. Analysis of variance is not likely to be the best method of data analysis in light of preexisting differences, unless transformation of the data can reduce that variation. On the other hand, the variation inherent in the data, especially at the level of the individual plot, is evident. Regression analysis of stand development under block and future treatment effects at the plot level should be fruitful, in that models will be applicable over a wide range of conditions.

LITERATURE CITED

Baker, James B. 1994. Stand-level ecosystem management research-an overview. In: Baker, J.B., comp. Symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Cooper, A.W. 1989. Ecology of the pine-hardwood type. In: Waldrop, Thomas A., ed. Proceedings of pine-hardwood mixture: a symposium on management and ecology of the type; 1989 April 18-19; Atlanta, GA. Gen. Tech. Rep. SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 3-8.

Farrar, R.M., Jr.; Murphy, P.A.; Leduc, D.J. 1989. Volume growth of pine and hardwood in uneven-aged loblolly pine-upland hardwood mixtures. In: Waldrop, Thomas A., ed. Proceedings of pine-hardwood mixture: a symposium on management and ecology of the type; 1989 April 18-19; Atlanta, GA. Gen. Tech. Rep. SE-58. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 173-179.

Foti, T.L.; Devall, M. 1994. Pretreatment conditions in mature pine/hardwood stands on south-facing slopes of the Ouachita/Ozark National Forests: ground layer and shrub layer. In: Baker, J.B., comp. Symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Foti, T.L., and J.M. Guldin. 1993. Pretreatment conditions in mature pine/hardwood stands on south-facing slopes of the Ouachita/Ozark National Forests: multivariate analysis of ground layer, shrub layer, midstory, and overstory. In: Baker, J.B., comp. Symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; New Orleans, LA: U.S. Department of Agriculture, Forest Service, Graney, D.; Burkhart, H.L. 1973. An equation to predict shortleaf pine site index in the Interior Highlands. Res. Paper SO-85. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 12 p.

Pickett, S.T.A.; White, P.S. 1985. The ecology of natural disturbance and patch dynamics. New York: Academic Press.

SAS Institute Inc. 1990. SAS Language: Reference, Version 6, First Edition. Cary, NC: SAS Instutite Inc. 1,042 p.

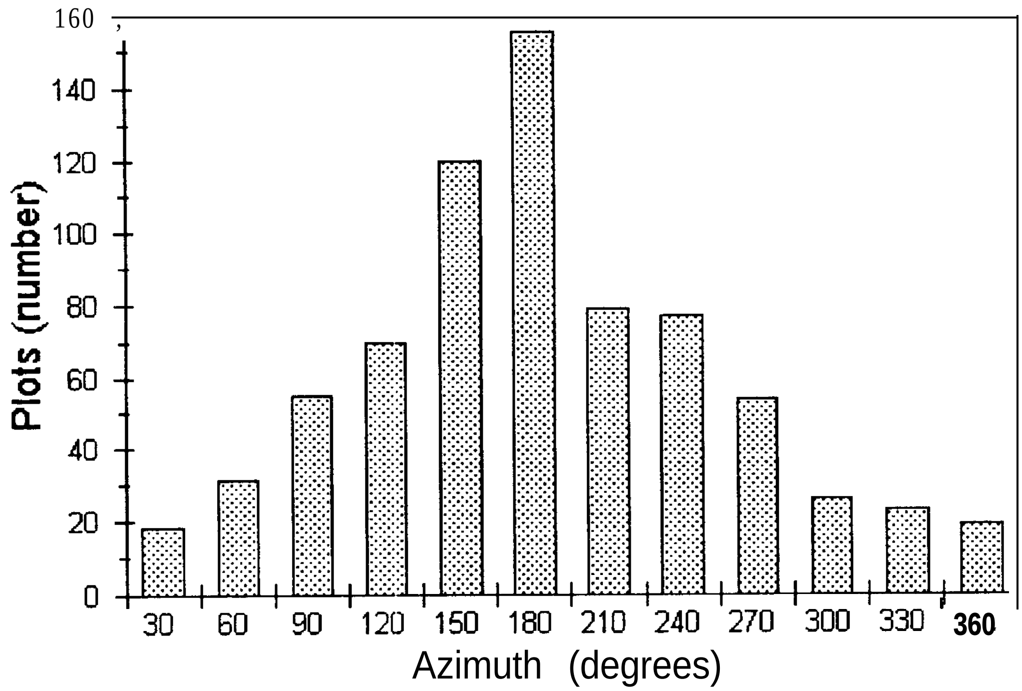

Figure A 1.-*Distribution of azimuth orientation by plot.*

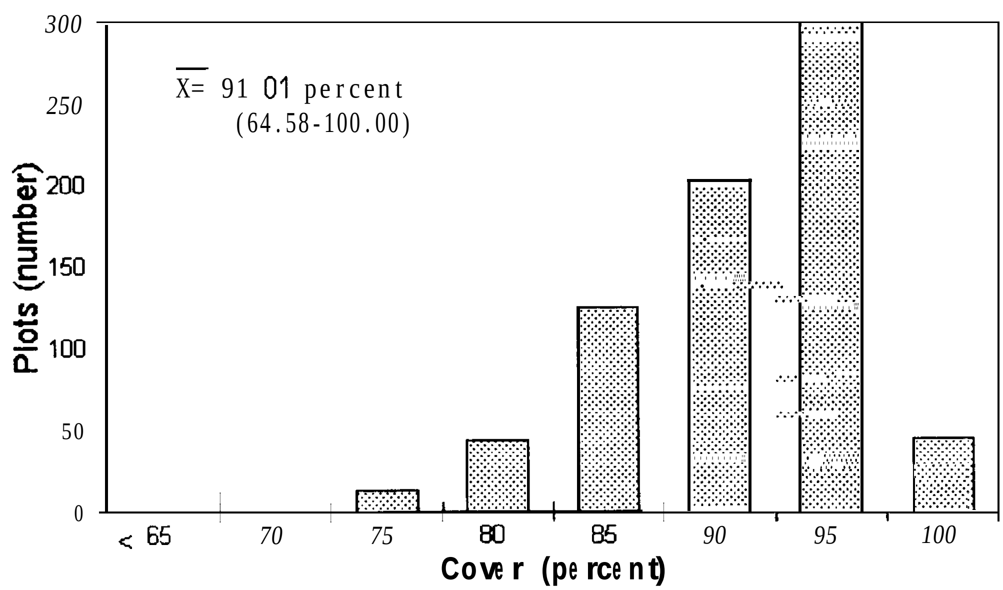

Figure A2.—*Distribution of percentage cover by plot.*

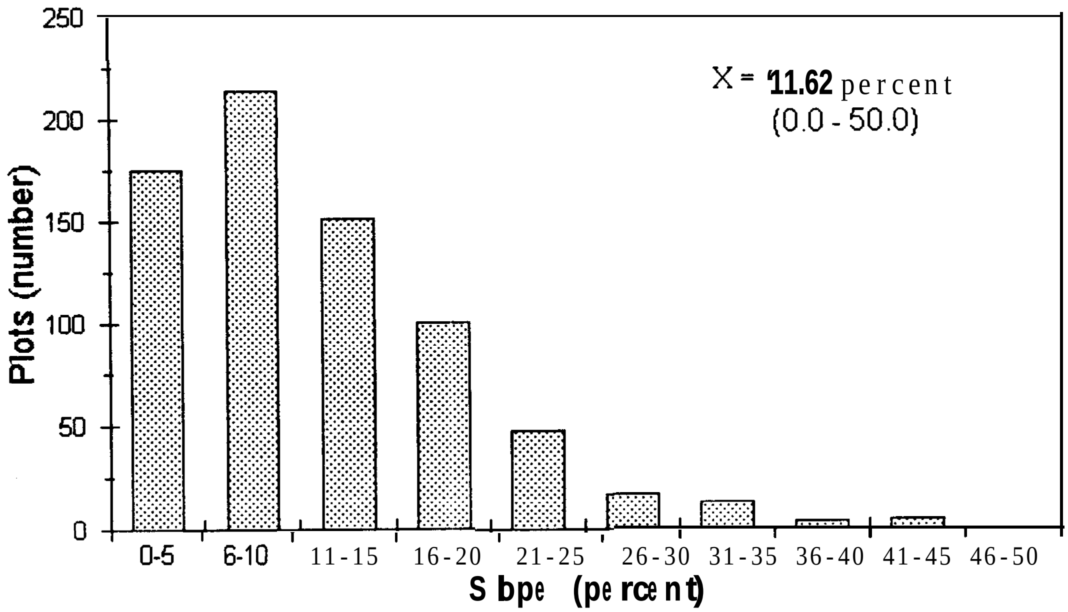

Figure A3.—Distribution of slope percentage by plot.

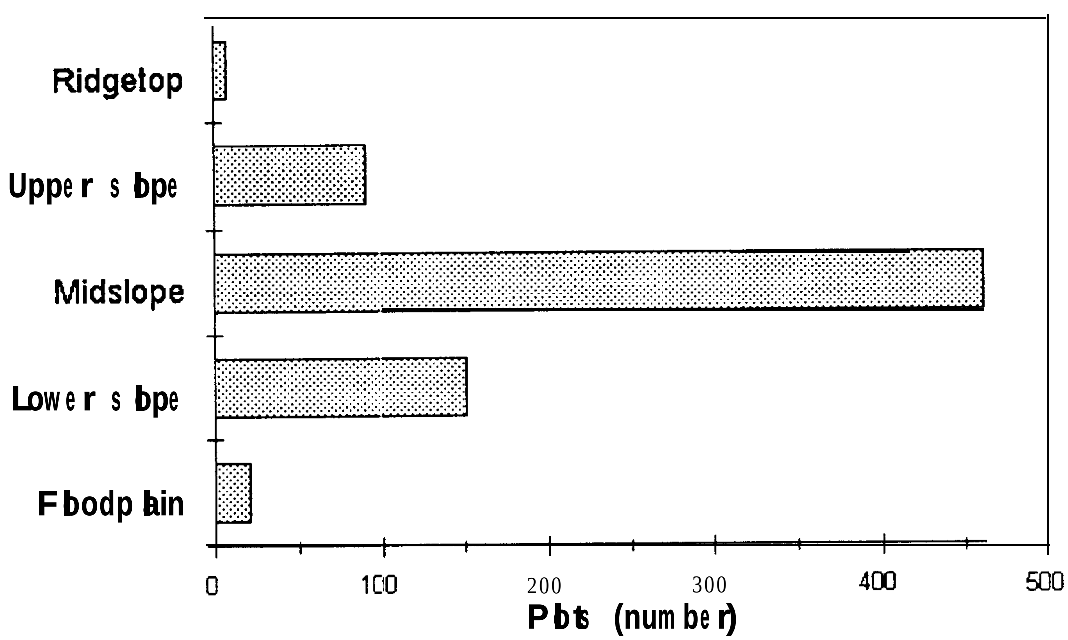

Figure A4.—*Distribution of slope position by plot.*

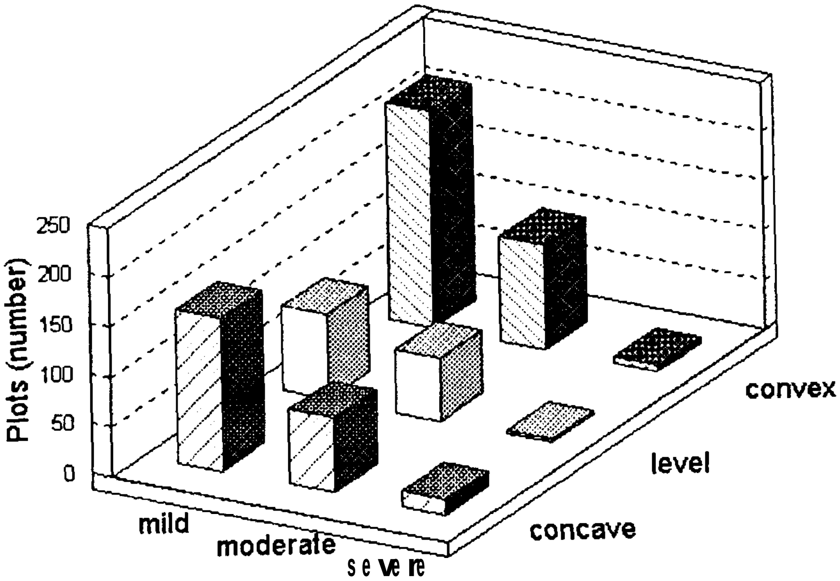

Figure AS.-Distribution of microtopography by plot.

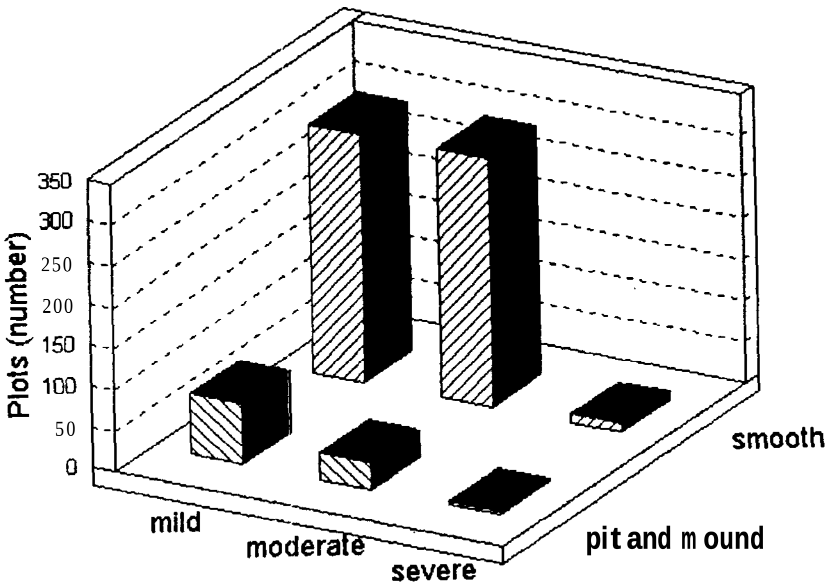

Figure A6.—*Distribution of microrelief by plot.*

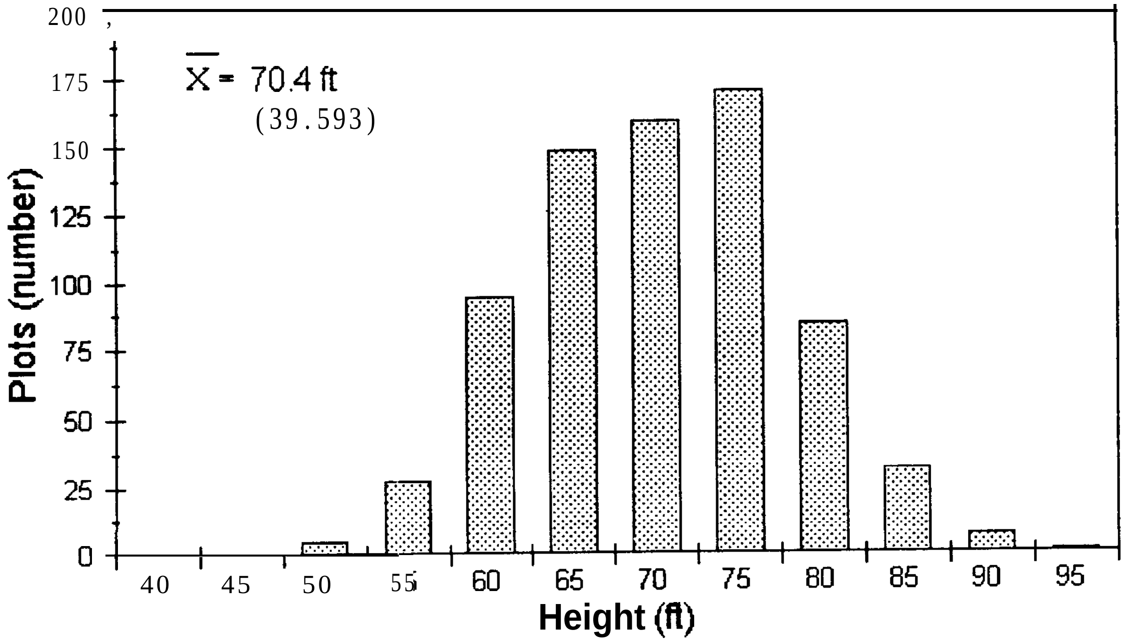

Figure Al.-*Distribution of tree height by plot.*

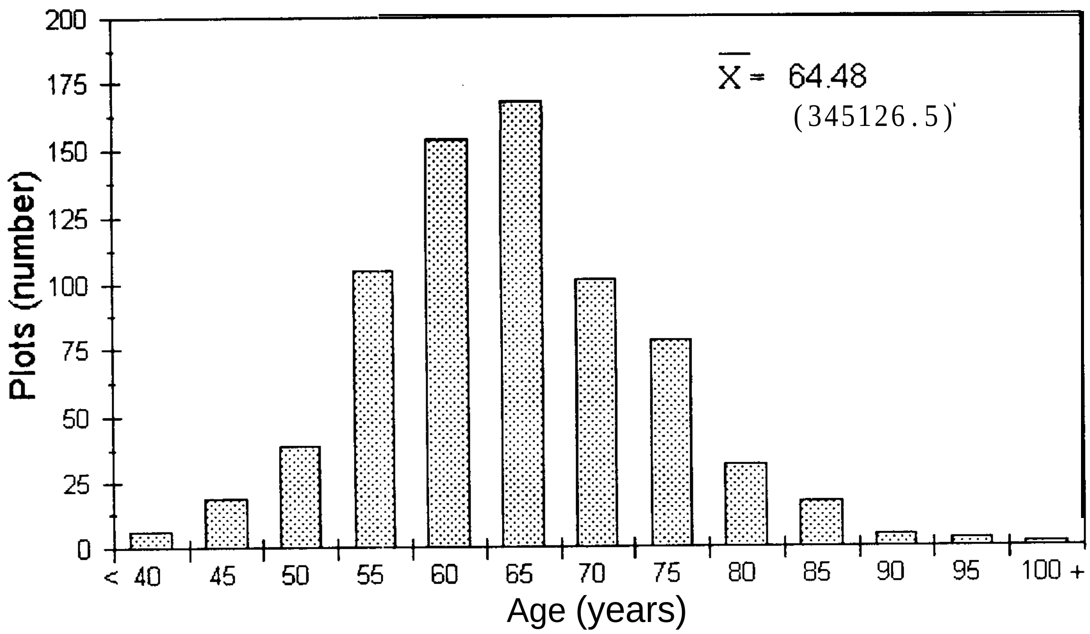

Figure A8.—*Distribution of tree age by plot.*

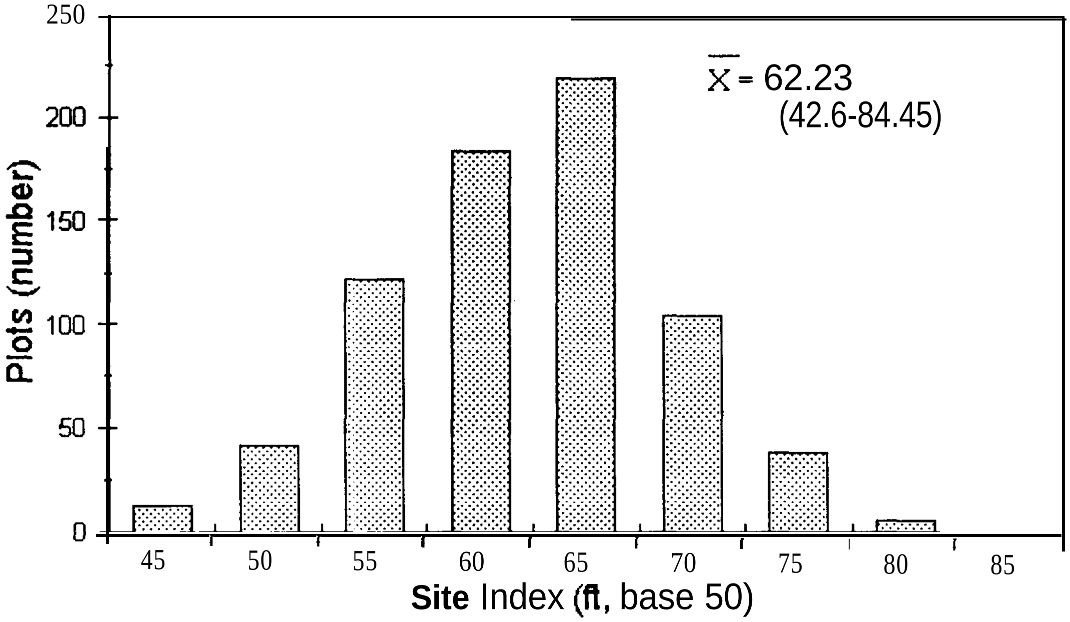

Figure **A9.—*Distribution*** *of site index by plot.*

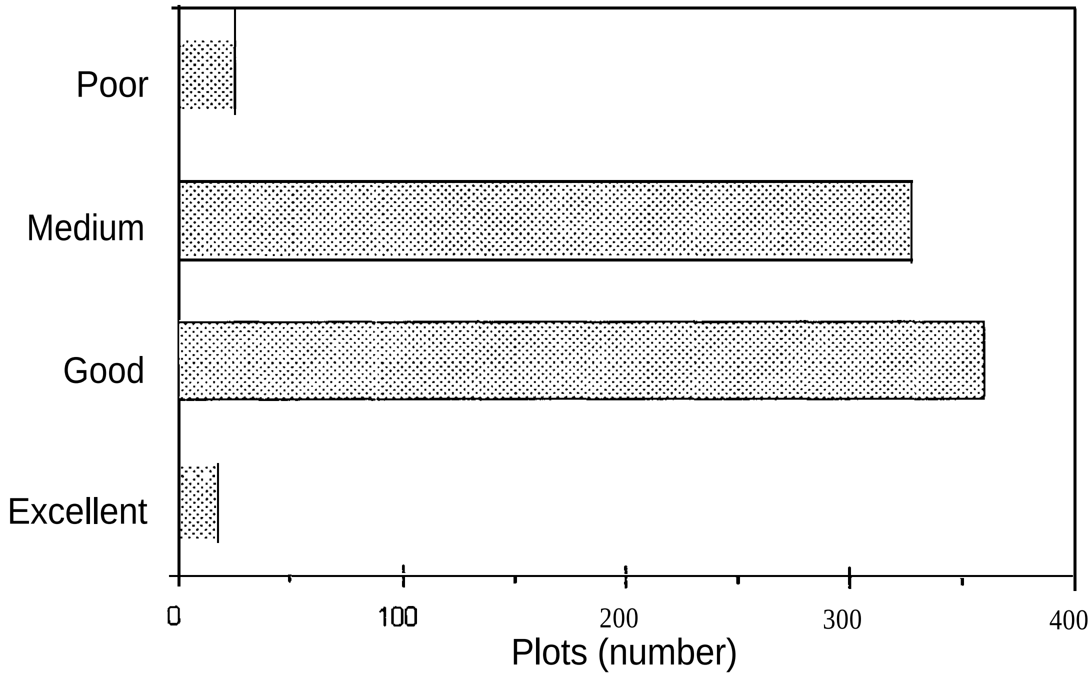

Figure **A10.—*Distribution*** *of site* ***quality*** *by plot.*

Herbaceous Plant Biodiversity of Stands in the Ouachita and Ozark National Forests[1]

Thomas Foti and Margaret S. Devall[2]

ABSTRACT

Pretreatment data on herb and shrub communities of 20 shortleaf pine-dominated stands in the Ouachita and Ozark-St. Francis National forests are presented. These data will become the baseline used to determine the impact of various silvicultural systems on plant diversity as a part of a larger Ecosystem Management research effort. This effort will compare an array of traditional and nontraditional even-aged and uneven-aged natural reproduction cutting methods as alternatives to clearcutting and planting. In this pretreatment study, 582 species were recorded in the stands during three sample periods in 1992 with 76 percent of the total occurring during the summer and 21 percent only occurring during that sampling period. Fall and spring sample periods had fewer total species and fewer unique species. Half the species occurred in three or fewer stands whereas more than half the cover is provided by species that occurred in all stands. These stands, within a narrow range of site, composition and structure conditions, were relatively diverse and contained 40 percent of the species found in the region but had few regionally rare species.

INTRODUCTION

Conservation of biological diversity has become an issue of public concern regarding the changes in biodiversity and their effects on human life. Since adoption of the National Forest Management Act of 1976, the USDA Forest Service has been mandated to consider impacts of its actions on diversity. Increasing awareness of this issue has augmented USDA Forest Service emphasis on preserving biodiversity and on devising acceptable management techniques to maintain and promote biodiversity in national forests. Because traditional management activities in national forests have become controversial in recent years, and because an increase and change in demands are being placed on the forests, new approaches to forest management are being evaluated - most recently under the defining concept "Ecosystem Management." Ecosystem Management provides a unique challenge and opportunity in managing complex values and issues such as biodiversity as well as traditional products such as timber, water, game and nongame wildlife, and fish, recreation, and minerals.

Ecosystem Management research in the Ouachita and Ozark National Forests attempts to objectively begin determining the impacts of alternative management techniques in order to facilitate informed decisionmaking. This study of understory vegetation and flora as a part of the overall research program will characterize and compare herbaceous plant diversity of stands before and after a variety of traditional and nontraditional even-aged and uneven-aged reproduction cutting methods in order to determine the impact of the cutting methods and silvicultural systems on plant biodiversity.

Diversity can be used as an indicator of the "health" of ecosystems (Magurran 1988). But biodiversity is a complicated and challenging issue comprised of, and influenced by, many factors. Herbaceous plants appear to be good indicators of forest diversity and the effect of silvicultural treatment on the environmental quality of the forest. One reason for this is that, in temperate forests, there are typically many more species in the forest understory than in the overstory. They are distributed in relationship to both intrinsic physical site conditions and conditions modified by the overstory (Causten 1988). With individualistic species response (Whittaker 1956), understory communities comprise a broad suite of indicators of site and overstory/understory relationships. In addition, it is possible to characterize the understory flora (at least the vascular species component) in its entirety because these species are persistent, detectable and identifiable by field biologists. Persistence throughout a season allows relatively few samples taken within a year to be used to characterize the flora, while persistence or stability from year to year allows one year's sampling to serve as an adequate characterization of the site's flora. Detectability is important in allowing species to be located in one site visit regardless of time of day or length of time spent sampling. Identifiability results from distinct field characteristics and training of botanists to identify many vascular plant taxa. These characteristics of the vascular flora of temperate forests contrast with those of the fauna of these forests in that the fauna may be ephemeral (migratory species may change population levels on an hourly or

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daily basis), undetectable (many are nocturnal or spend much of their life cycle below ground), or unidentifiable (most zoologists are specialized on fairly narrow taxa).

For these reasons, the flora was addressed in this study not only as a taxonomic unit of importance in these stands, but also as a unit that is especially useful for addressing questions of stand diversity. The objective here is to describe pretreatment conditions on herb and shrub communities within 20 stands in the Ouachita and Ozark-St. Francis National Forests.

METHODS

The research stands used in this study are 14-16 ha, located on slopes of 5 to 20 percent facing south, southeast or southwest, and are more than 70 years old. The stands contain 13.8 to 22.9 m^2/ha basal area (BA) of merchantable pine and 1.15 to 6.9 m^2/ha of merchantable hardwoods ($>$ 9.0 cm d.b.h.). Stands represent the typical sites managed for timber production on the Ouachita and Ozark-St. Francis National Forests. For a detailed description of the study areas, stand selection and treatments, etc., see Baker (1994). Data were collected on all vascular and some nonvascular herbaceous-layer ($<$ 1 m tall) and shrub layer (1 m tall to 9 cm d.b.h.) plants; midstory and overstory data collection was done by the silvicultural team. Understory plant data were collected on stands representing four replications of each of the five projected treatments. Treatments are clearcut, shelterwood, group selection, single tree selection, and control. Data on herbaceous-layer plants were collected during spring (6 weeks from the beginning of March to mid April), summer (10 weeks from the beginning of May to mid July), and fall (10 weeks from the beginning of August to mid October). Data on shrubs and saplings < 8.9 cm d.b.h. and all vines were collected once during the summer period. Although the contract botanists used in this project were skilled at identification of most of the vascular plants of the region, skills were enhanced through a workshop organized by Dr. Lynn Thompson, University of Arkansas at Monticello (4 days), to familiarize scientists with techniques for censusing, collecting and identifying ferns and bryophytes so that ferns could be identified accurately as to species and some mosses and liverworts (as well as some lichens) could be identified to genus or species. The workshop was conducted by Dr. James Peck of the University of Arkansas at Little Rock and by Dr. Paul Redfearn, Emeritus Professor of Southwest Missouri State University at Springfield.

Because funding was limited, full pretreatment biodiversity data were collected on only 20 of the 52 stands. More funding became available, and summer season data were collected on the other 32 stands. Spring, summer, and fall pretreatment data for the original 20 stands are presented and analyzed here.

On entry to each stand by the botany team, a general reconnaissance was made, and a species list was composed for the stand. A directed search was made for rare plant species. Two specimens of each species encountered in the study were collected and will be deposited in a regional herbarium.

The team then sampled flora along transects to assess overall composition of herbaceous-layer flora. A botanist walked along one side of the transect, noting all species within a strip 2 m wide. These 5 to 7 transects in each of the 20 stands were established by the wildlife group (see Thill, Tappe and Koerth 1994 for a more detailed description of transects). The transects exclude a 50-m buffer along the outer boundary of each stand, but otherwise cross all microsites on the stand, including greenbelts. The minimum distance between transects is 30 m, and the maximum distance is 100 m. Measurements made on transects were cover class by species.

The most intensive sampling was done within fourteen macroplots which were installed in each stand by the silviculture group. These macroplots were each 8 m x 16 m (see Guldin and others [1994] for a more detailed description of macroplots. At the ends of each macroplot are two rectangular plots 8 m X 4m = 32 m^2. These plots are used for sampling shrub-layer vegetation. There are four 2 m x 2 m "milacre" microplots per macroplot, two in each of the shrub plots (see Guldin and others [19941 for plot layout). Stem counts by species and diameter class were made on all woody plants taller than 1 m and smaller in d.b.h. than 9 cm in the shrub plots. Size-class d.b.h's were $<$ 2.5 cm; 2.5 to 6.25 cm; and 6.26 to 8.9 cm. The percentage of cover of all plants $<$ 1 m tall and all herbaceous species regardless of size were estimated by species on the milacre plots (Mueller-Dombois and Ellenberg 1974). Whereas the dimensions of the plots in this study were set to meet specific needs, the overall layout and sampling strategy were similar to others previously described (The Nature Conservancy 1988; Ahnendinger 1988). Two macroplots are located in greenbelt areas (unharvested streamside zones) within each stand, whereas the others were placed within the portion of the stand where management was to take place.

The cover values from the four microplots within each macroplot were averaged to give a macroplot percent-cover value for each species. Each species recorded within a macroplot but not measured in a microplot, was arbitrarily given a cover value of 0.01 percent on the plot. Species values for each of the 14 macroplots within each stand were averaged to give a stand mean value for stand-based analysis, and individual macroplot data were recorded for plot-based analysis. Any species recorded on a transect or general walk-through of the stand was arbitrarily given a cover value of 0.001 percent in the stand analysis. These values for species not encountered on the microplots were included in order to ensure that all species encountered in the stands could be included in all diversity analyses.

Data from the two shrub plots in each macroplot were averaged to provide a macroplot density by species and size class. Relative frequency of occurrence in macroplots within a stand and relative density and basal area across size classes were averaged to produce a single importance value for each species in each stand.

Only stand-based analyses are presented here. Plot-based analysis will be undertaken after all data are entered and audited.

For this preliminary analysis, species number and mean percent cover were determined for each stand by season and over three seasons for each stand. Several measures of diversity were computed for each stand, and lists of species from the stands were compared with those from the region. Also, the influence of season on species recorded was examined. The latter was done in order to determine seasonal sampling needs for future years; if three-season sampling is not required, personnel time and expense could be reduced.

Nomenclature follows Smith (1988).

RESULTS AND DISCUSSION

Total Species

A total of 582 species were recorded in the 20 stands (table 1). This compares with approximately 1,450 species listed for the western Ouachita Mountain counties of Arkansas by Smith (1988).

Of the 90 species tracked as being rare or otherwise of special concern by the Arkansas Natural Heritage Commission in the Ouacbita region, one was recorded in the stands, Tradescantia ozarkana. In addition, Penstemon cobaea and Antennaria neglecta were recorded but appear to be misidentifications. Several additional records could be range extensions or new state records if verified; specimens are being checked.

Table 1. - *Species and cover categories used in understory/shrub data collection; nearest occurrence of out-of-range species shown in parentheses*

Acalypha sp.
Acalypha gracilens
Acer rubrum
Acer saccharum
Aesculus sp
Aesculus glabra
Agave virginica
Agrimonia parviflora
Agrimonia sp
Agrimonia pubescens
Agrimonia rostellata
Agrostis sp.
Agrostis alba = A. gigantea
Allium sp.
Allium canadense
Allium stellatum
Amaryllis family
Ambrosia sp.
Ambrosia artimisiifolia
Ambrosia bidentata
Amelanchier arborea
Andropogon sp.
Andropogon elliottii = A. gyrans
Andropogon gerardii
Andropogon virginicus
Anemone sp.
Anemonella thalictroides = Thalictrum thalictroides
Antennaria sp.
Antennaria neglecta (mis id?)
Antennaria plataginifolia
Apiaceae
Aplectrum hyemale
Arabis sp.
Aralia spinosa
Aristida sp.
Aristida dichotoma
Aristida purpurascens
Aristolochia reticulata
Aristolochia serpentaria
Asclepias sp.
Asclepias quadrifolia
Asclepias tuberosa
Asclepias variegata
Asclepias viridis
Asimina triloba
Asplenium sp.
Asplenium platyneuron
Aster sp.
Aster drummondii = A. cordifolius
Aster linearifolius
Aster novae-angliae
Aster parviceps (mis id? - Ozarks)
Aster patens
Aster subulatus
Asteraceae
Athyrium filix-femina
Aureolaria sp.
Aureolaria grandiflora
Avena sativa
Bacopa acuminata
Baptisia sp.
Baptisia leucophaea = B. bracteata
Baptisia nuttalliana
Baptisia sphaerocarpon
Bare mineral soil
Bare rock
Berchemia scandens
Bidens sp.
Bidens polylepis = B. aristosa
Bignonia capreolata
Boltonia diffusa
Botrichium sp.
Borrychium biternatum
Bortychium dissectum
Brassica family
Bumelia lanuginosa
Cacalia plantaginea
Callicarpa americana
Callirhoe sp.
Calopogon tuberosus
Campsis radicans
Cardamine concatenata = Dentaria laciniata
Cardamine pensylvanica
Carex sp.
Carex caroliniana
Carex cephaiophora

Table 1.- Species and cover categories used in *understory/shrub* data collection; nearest occurrence of out-of-range species shown in parentheses (continued)

Carex complanata
Carex flaccosperma
Carex frankii
Carex hirsutella = *C. complanata* var. *hirsuta*
Carex muhlenbergii
Carex retroflexa
Carex umbellata
Carpinus caroliana
Carya sp.
Carya illinoensis
Carya laciniosa
Carya ovata
Carya tomentosa
Cassia fasciculata = *Chamaecrista fasciculata*
Cassia nictitans = *Chaemicrista nictitans*
Castanea ozarkensis = *C. pumila* var. *ozarkensi*
Ceanothus americanus
Ceanothus herbaceus
Celtis laevigata
Celtis occidentalis
Centrosema virginianum
Cephalanthus occidentalis
Cercis canadensis
Chantrel (mushroom)
Chasmanthium sp.
Chasmanthium latifolium
Chasmanthium laxum
Chasmanthium sessiliflorum
Cicuta maculata
Cirsium sp.
Cirsium altissimum
Cirsium carolinianum
Cirsium horridulum
Cladastrus lutea = *C. kentuckea*
Cladonia sp. (lichen)
Cladonia cristatella (lichen)
Cladonia subtenuis (lichen)
Claytonia virginiana
Clitoria mariana
Cocculus carolinus
Convovulvus sp.
Conyza canadensis
Corallorhiza odontorhiza
Coreopsis sp
Coreopsis grandiflora
Coreopsis palmata
Coreopsis pubescens
Coreopsis tinctoria
Coreosis tripteris
Cornus drummondii
Cornus florida
Cornus foemina
Crataegus sp.
Crataegus crus-galli
Crataegus marshallii
Crataegus pruinosa
Crataegus spathulata
Crataegus viridis
Croton sp.
Croton capitatus
Crotonopsis elliptica
Cunila origanoides
Cynoglossum sp.
Cynoglossum virginianum
Cyperus sp.
Cyperus erythrorhizos
Dactylis glomerata
Danthonia spicata
Daucus sp.
Daucus carota
Delphinium carolinianum
Desmodium sp.
Desmodium glutinosum
Desmodium humifusum (Missouri)
Desmodium marilandicum
Desmodium nudiflorum
Desmodium ochroleucum (Missouri)
Desmodium paniculatum
Desmodium pauciflorum
Desmodium rigidum = *D. obtusum*
Desmodium rotundifolium
Desmodium viridiflorum
Dicentra cucullaria
Dichondra repens var. *carolinensis*
Dicliptera brachiata
Dioscorea sp.
Dioscorea villosa
Diospyrus virginiana
Dodecatheon meadia
Echinacea sp.
Echinacea pallida
Erhinacea purpurea
Eleocharis sp.
Elephantopus tomentosa
Elymus sp.
Elymus canadensis
Elymus glaucus
Elymus riparius
Elymus villosus
Elymus virginicus
Equisetum sp.
Erechtites hieraciifolia
Erianthus conformis
Erigeron annuus
Erigeron strigosus
Erigonum sp.
Eryngium yuccifolium
Euonymous sp.
Euonymus americanus
Euonymus atropurpureus
Eupatorium sp.
Euparorium album
Eupatorium coelestinum
Eupatorium perfoliatum
Eupatorium rotundifloium var. *pubescens*
Eupatorium serotinum
Euphorbia sp.
Euphorbia corollata
Fernmoss
Festuca elatior = *F. arundinacea*
Foliose lichen
Fragaria virginiana
Fraxinus sp.
Fraxinus americana
Fraxinus pennsylvanica
Galactica volubilis = *G. regularis*
Galium sp.
Galium arkansanum
Galium circaezans
Galium obtussum
Galium pilosum
Galium tinctorium

Table 1. - Species and cover categories used in understory/shrub data collection; nearest occurrence of out-of-range species shown in parentheses (continued)

Galium triflorum
Geranium maculatum
Gerardia sp. = Agalinis sp.
Geum sp.
Geum canadense
Gillenia sp. = Porteranthus sp.
Gillenia stipulata = Porteranthus stipulatus
Gnaphalium sp.
Gnaphalium obtusifolium
Gnaphalium purpureum
Hedyotis sp.
Hedyotis crassifolia
Hedyotis longifolia
Hedyotis minima (Missouri)
Hedyotis nigricans
Hedyotis purpurea
Helenium flexuosum
Helenium nudiflorum = H. flexuosum?
Helianthus sp.
Helianthus angustifolius
Helianthus divaricatus
Helianthus hirsutus
Helianthus microcephalus
Heterotheca graminifolia
Heterotheca pilosa = Chrysopsis pilosa
Heuchera americana
Heuchera americana
Hieracium sp.
Hieracium gronovii
Hydrocotyle sp.
Hypericum sp.
Hypericum hypericoides
Hypericum mutilum
Hypericum perforatum
Hypericum spathulatum = H. prolificum
Hypericum stans
Hypoxis hirsuta
Ilex decidua
Ilex opaca
Ilex vomitoria
Impatiens sp.
Impatiens capensis
Indigofera miniata
Ipomea sp.
Iris sp.
Iris cristata
Juncus sp.
Juncus balticus
Juncus effusus
Juncus secundus
Juncus tenuis
Juniperus virginiana
Kicksia elatine
Krigia sp.
Krigia dandelion
Kuhnia eupatorioides = Brickellia eupatorioides
Labiatae
Lactuca sp.
Lactuca floridana
Lactuca floridana var. villosa
Lactuca hirsuta
Lamium sp.
Lechea tenuifolia
Lemna sp.
Lespedeza sp.
Lespedeza cuneata
Lespedeza hirta
Lespedeza intermedia
Lespedeza procumbens
Lespedeza repens
Lespedeza striata
Lespedeza stuevei
Lespedeza violacea
Lespedeza virginica
Leurobryum sp. (moss)
Liatris sp.
Liatris aspera
Liatris elegans
Liatris pycnostachya
Liatris squarrosa
Lichen
Ligustrum sinense
Ligustrum vulgare
Lindera benzoin
Linum medium
Linum virginianum (Louisiana)
Liquidambar styraciflua
Litter
Lobelia sp.
Lobelia puberula
Lobelia spicata
Lonicera sp.
Lonicera alba (Oklahoma)
Lonicera japonica
Lorinseria (Woodwardia) areolata
Ludwigia alternifolia
Luzula bulbosa
Lycopodium sp.
Lysimachia sp.
Lysimachia ciliata
Lysimachia quadrifolia
Matelea sp.
Melica mutica
Mimulus alatus
Mitchella repens
Monarda sp.
Monarda fistulosa
Monarda russeliana
Monarda stipitatoglandulosa
Monotropa hypopithys
Monotropa uniflora
Morus rubra
Moss
Muhlenbergia sp.
Muhlenbergia capillaris
Muhlenbergia sobolifera
Mushrooms
Myrica cerifera
Nyssa aquatica
Nyssa sylvatica
Oenothera fruiticosa
Onoclea sensibilis
Open water
Ophioglossum petiolatum
Opuntia compressa = O. humifusa
Osmunda sp.
Ostrya virginiana
Oxalis stricta
Oxalis violacea
Panicum sp.
Panicum aciculare = P. angustifolium
Panicum anceps

Table 1. - ***Species and cover categories used in*** *understory/shrub* ***data collection; nearest occurrence of out-of-range species shown in parentheses*** (continued)

Panicum bicknellii = P. linearifolium
Panicum boscii
Panicum commutatum
Panicum dichotomiflorum
Panicum dichotomum
Panicum hians
Panicum latifolium
Panicum laxiflorum
Panicum linearifolium
Panicum obtusum
Panicum philadelphicum
Panicum polyanthes
Panicum sphaerocarpon
Panicum villosissimum
Parthenium hispidum = P. integrifolium v. hispidum
Parthenium integrifolium
Parthenium sp.
Parthenocissus quinquefolia
Parthenocissus vitaceae
Paspalum floridanum
Passiflora lutea
Pedicularis canadensis
Penstemon sp.
Penstemon arkansanus
Penstemon cobea (mis id?)
Penstemon digitalis
Penstemon pallidus
Petalostemon sp.
Phlox sp.
Phlox pilosa
Phoradendron serotinum
Phyllanthus sp.
Phyllanthus polygonoides
Physalis sp.
Physostegia virginiana
Phytolacca americana
Pinus echinata
Platanthera ciliaris
Platanthera lacera
Platanus occidentalis
Pluchea camphorata
Poa sp.
Podophyllum peltatum
Polygala sp.
Polygala verticillata
Polygonum sp.
Polygonum hydropiperoides
Polygonum punctatum
Polypodium sp.
Polypodium polypodioides
Polystichum sp.
Polystichum acrostichoides
Polytrichum sp.
Potentilla sp.
Potentilla recta
Prenanthes altissima
Prunella vulgaris
Prunus sp.
Prunus americana
Prunus mexicana
Prunus serotina
Psoralea sp.
Psoralea psoralioides
Pteridium sp.
Pteridium aquilinum
Pycnanthemum sp
Pycnanthemum albescens
Pycnanthemum tenuifolium
Pycnanthemum virginianum
Quercus sp.
Quercus alba
Quercus falcata
Quercus imbricaria
Quercus marilandica
Quercus nigra
Quercus phellos
Quercus prinoides
Quercus rubra
Quercus shumardii
Quercus stellata
Quercus velutina
Ratibida pinnata
Rhamnus caroliniana
Rhododendron prinophyllum
Rhus aromatica
Rhus copallina
Rhus glabra
Rhynchosia latifolia
Rhyncospora sp.
Robinia pseudo-acacia
Rosa sp.
Rosa Carolina
Rosa setigera
Rubus sp.
Rubus trivialis
Rudbeckia sp.
Rudbeckia fulgida
Rudbeckia grandiflora
Rudbeckia hirta
Rudbeckia triloba
Ruellia humilis
Ruellia sp.
Ruellia pedunculata
Ruellia strepens
Sabatia angularis
Salix sp.
Salvia azurae
Salvia lyrata
Sambucus canadensis
Sanicula canadensis
Sanicula gregaria = S. odorata
Sassafras albidum
Satureja sp.
Schizachyrium scoparium = Andropogon scoparius
Schrankia nuttallii
Scirpus atrovirens
Scleria sp.
Scleria ciliata
Scleria oligantha
Scleria triglomerata
Scutellaria sp.
Scutellaria elliptica
Scutellaria ovata
Senecio sp.
Senecio obovatus
Senecio tomentosus
Silene virginica
Silphium sp.
Silphium laciniatum
Sisyrinchium sp.
Sisirinchium angustifolium
Sisyrinchium campestre

Table 1. - *Species and cover categories used in understory/shrub data collection; nearest occurrence of out-of-range species shown in parentheses* (continued)

Smilacina racemosa = Maianthemum paniculatum
Smilax sp.
Smilax auriculata
Smilax bona-nox
Smilax glauca
Smilax herbacea
Smilax pumila
Smilax rotundifolia
Solanum sp.
Solanum carolinense
Solidago sp.
Solidago canadensis
Solidago leptocephala = Euthamia leptocephala
Solidago odora
Solidago rugosa
Solidago ulmifolia
Sorghum halepense
Sphagnum sp. (moss)
Spilanthes americana = Acmella oppositifolia
Spiranthes sp.
Spiranthes cemua
Spiranthes ovalis
Spiranthes tuberosa
Sporobolus sp.
Sporobolus asper
Stachys sp.
Stipa sp.
Stipa avenacea
Stipa spartea (Missouri)
Scrophostyles sp.
Strophostyles leiospenna
Stylosanthes sp.
Stylosanches biflora
Symphoricarpos orbiculatus
Taraxacum officinale
Tephrosia virginiana
Thelesperma filifolium
Tilia amen'cana
Tipularia discolor
Toxicodendron sp.
Toxicodendron radicans
Tracelospennum difforme
Tradescantia sp.
Tradesrantia ohiensis
Tradescantia ozarkana
Tridens flavus
Trifolium sp.
Trifolium hybridum
Trifolium repens
Triodanis biflora = T. perfoliata var. biflora
Triodanis perfoliata
Ulmus sp.
Ulmus alata
Ulmus rubra
Unidentified
Unidentified Gramineae
Unidentified gymnosperm
Unidentified Laminaceae
Unidentified monocot
Unidified Leguminosae
Urnula sp. (fungus)
Urnula craterium (fungus)
Vaccinium arboreum
Vaccinium pallidum
Vaccinium sp.
Vaccinium stamineum
Verbena canadensis = Glandularia canadensis
Verbena sp.
Verbesina alternifolia
Verbesina helianthoides
Verbesina virginica
Vemonia lettermanii
Vemonia sp.
Veronica sp.
Veronicastrum virginicum
Viburnum sp.
Viburnum rufidulum
Vicia sp.
Vicia caroliniana
Vicia villosa
Viola sp.
Viola palmata
Viola pedata
Viola primulifolia
Viola pubescens
Viola sagittata
Viola sororia
Viola striata
Viola viarum
Vitis sp.
Vitis aestivalis
Vitis rotundifolia
Woodsia sp.
Woodsia obcusa
Yucca sp.
Zizia aptera
Zizia aurea

Seasonal Influence

Data were collected in three seasons to capture ephemeral species. The periods were March-April, June-July, and September-October. There is a seasonal influence; in no single season was as much as 80 percent of the total flora recorded (table **2).** The summer sample was most comprehensive, with 76 percent of the total flora. At the other extreme, the spring sample included only 44 percent. Each season contributed species not found in any other season, with 21 percent of the total occurring only in the summer; each of the other seasons contributed only about half as many (table 2). When considered as season pairs, summer/fall and summer/spring each produced approximately 90 percent of the total, whereas spring/fall produced about 10 percent fewer species (table 2).

Table 2. - ***Total species per season, total species encountered in each pair of seasons, and species occurring uniquely in only one season.***

	Single Season Totals (Percent)		
	Spring	Summer	Fall
Total Spp.	256 (44)	443 (76)	368 (63)
Unique Spp.	60 (10)	123 (21)	72 (13)
Season Pairs	**Num. Spp. (Percent)**		
Spring/Summer	510 (88)		
Summer/Fall	522 (90)		
Spring/Fall	459 (79)		

From this analysis it appears that three season sampling is necessary to assess plant biodiversity because at a maximum, only 76 percent of the species recorded in this study occurred in any one sample season, If only one season of sampling were possible, it should be summer, with fall as a second choice and spring as the last choice. With two samples, one in summer and one in either spring or fall will increase the species encountered to about 90 percent.

Stand Analysis Of Ground Cover Species

Species per stand ranged from 123 to 238 with a mean of 176 (table 3). Total area1 ground cover of each stand in percent (sum of individual species values) ranged from 12.78 to 32.37 with a mean of 21.08 percent.

Diversity of the stands was investigated using H', the Shannon Diversity Index. This index is based on information theory, with larger values equal to greater uncertainty about the identity of a species drawn at random from the population. It has a minimum value of zero if only one species is present and a maximum value of

$$H(max) = \ln(S)$$

where: S = number of species. It achieves the maximum value when all species have equal abundance. In the stands in this study H' ranged from 1.94 to 3.78 with a mean of 3.19 (table 3).

Because the maximum value of the Shannon index varies with the number of species per stand and the number of species per stand in our study varies, it is useful to use the ratio

$$J' = H'/H(max).$$

This ratio varies from 0 to 1. It measures the relative evenness or diversity. In our stands it ranged from 0.403 to 0.739 (40 percent to 74 percent of maximum evenness) with a mean of 0.618 (62 percent of maximum) (table 3).

Table 3. - ***Stand summaries of floristic data. SP is number of species per stand, CV is total percent cover (sum of individual species values), H' is the Shannon*** Diver-***sity Index*** and ***J' is H'/H(max).***

STAND	SP	CV	H'	J'
2310	191	20.08	3.09	0.588
2701	199	14.45	3.32	0.628
3551	206	12.78	3.67	0.688
4618	203	15.97	3.44	0.648
6206	143	16.67	3.38	0.680
7010	175	16.51	3.07	0.594
24817	152	32.16	3.35	0.668
28411	178	32.37	3.37	0.650
45712	171	14.55	3.78	0.739
45816	176	18.86	3.67	0.711
60505	206	20.03	2.81	0.529
60909	238	28.26	3.56	0.651
83301	147	25.28	3.20	0.642
89607	140	29.53	2.52	0.509
106715	123	21.77	1.94	0.403
111951	208	23.60	3.23	0.605
112411	195	27.62	2.98	0.565
129202	145	14.56	3.66	0.735
164913	193	19.18	3.35	0.636
165805	138	17.35	2.41	0.488
LOW	123	12.78	1.94	0.403
HIGH	238	32.37	3.78	0.739
MEAN	176	21.08	3.19	0.618
S.D.	29.87	06.04	0.45	0.084

Measures of species abundance are contrasted in figures 1 and 2. Over half the species recorded in this study occur in only 1, 2, or 3 stands (fig. 1). However, over half the area1 cover (13 percent out of the 2lpercent average) is provided by the species that occur in all 20 stands (fig. 2). In contrast to the analysis of seasonal sampling needs, relatively few samples are required to characterize those species that exert community control through cover, biomass, competition, etc., because over half of the total cover measured in this study was produced by species that occurred in all stands.

This preliminary analysis of the understory plant communities of these stands demonstrates that south-facing, pinedominated stands in the Ouachita Mountains are moderately diverse in that they contain 40 percent of the species found in the region as a whole and have a relatively even proportion of the species that occur there. However, they have few regionally rare species.

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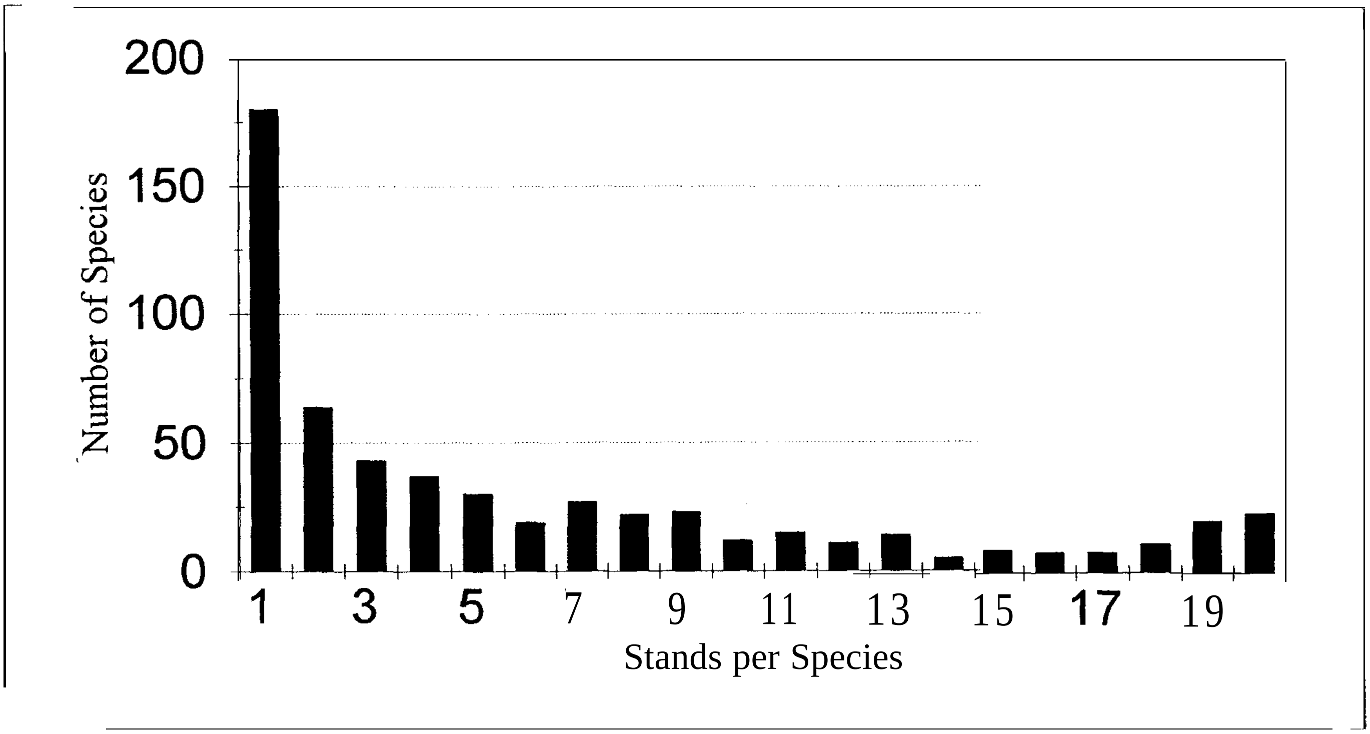

Figure 1. - *Number of species occurring in a specified number of stands.*

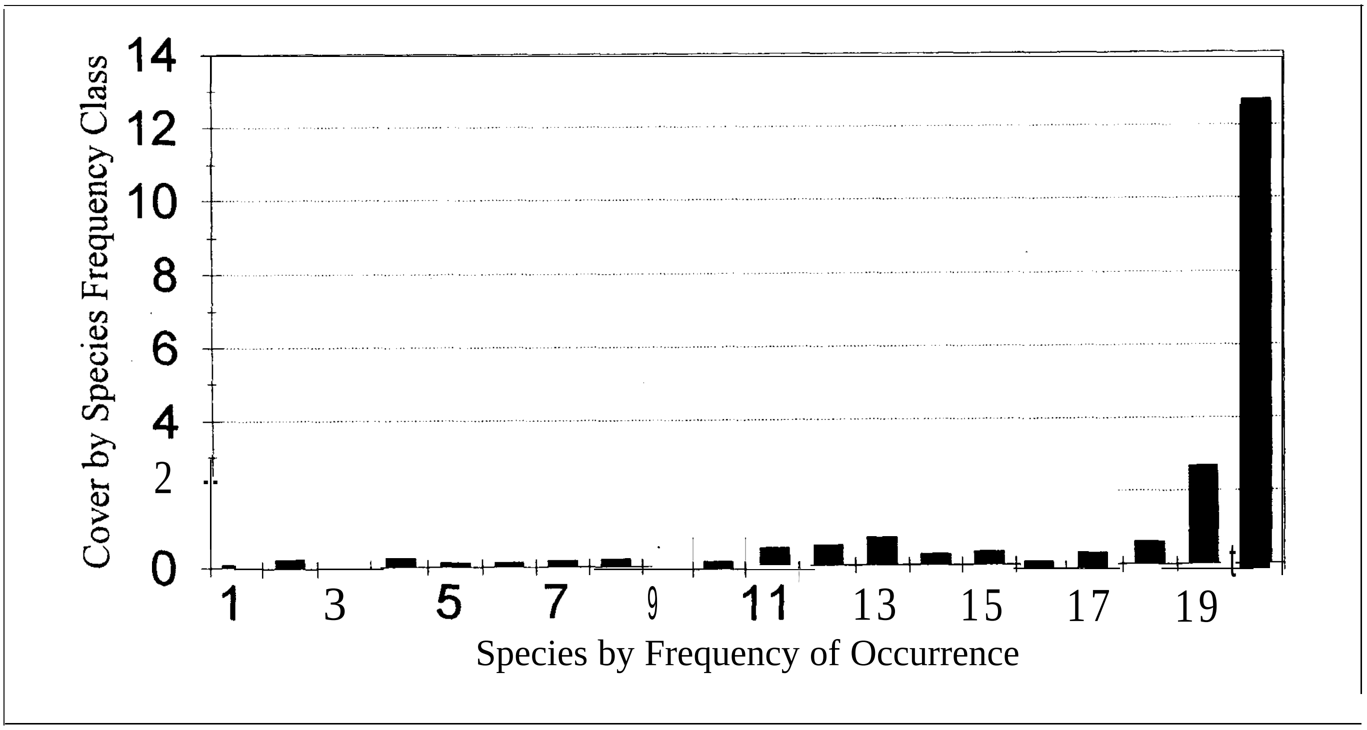

Figure 2. - *Average percent cover of all stands contributed by species that occurred in a specified number of stands. Average percent cover of all stands (sum of individual species values) is 21 percent.*

LITERATURE CITATIONS

Almendinger, John C. 1988. A handbook for collecting relevé data in Minnesota. Minneapolis, MN: Department of Natural Resources, Minnesota Natural Heritage Program.

Baker, James B. 1994. An overview of stand-level ecosystem management in the Ouachita/Ozark National Forests. In: Baker, James B. 1994. Proceedings of a symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Expperiment Station.

Causten, D.R. 1988. Introduction to vegetation analysis. London: Unwin Hyman. 342 p.

Guldin, James. M.; Baker, J.B.; Shelton, M.S.; 1994. Pretreatment conditions in mature pine/hardwood stands on south-facing slopes of the Ouachita National Forests: midstory and overstory plants. In: Baker, James B. 1994. Proceedings of a symposium on ecosystem management research in the Onachita Mountains: pretreatment conditions and preliminary findings. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Expperiment Station.

Magurran, A.E. 1988. Ecological diversity and its measurement. Princeton NJ: Princeton University Press. 67 p.

Mueller-Dombois, D.; Ellenberg, H. 1974. Aims and methods of vegetation ecology. New York: John Wiley and Sons. 547 p.

The Nature Conservancy. 1988. Community Survey Handbook. Arlington, VA: The Nature Conservancy.

Smith E.B. 1988. Atlas and Annotated List of the Vascular Plants of Arkansas. Fayetteville, AR: Privately published. 489 p.

Thill, Ronald E.; Tappe, Philip A.; Koerth, Nancy E. 1994. Wildlife habitat conditions in mature pine-hardwood stands in the Ouachita/Ozark National Forests. In: Baker, James B. 1994. Proceedings of a symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Expperiment Station.

Whittaker, R. H.. 1956. Vegetation of the Great Smoky Mountains. Ecol. Mon. 26(1): l-80.

Multivariate Analysis of the Ground Cover Layer, Shrub Layer, Midstory, and Overstory of the Ouachita/Ozark National Forests[1]

Thomas L. Foti and James M. Guldin[2,3]

ABSTRACT

Data from nested samples of ground cover, shrub, midstory, and overstory vegetation were used to study the floristic composition and structure in stands on south- and southwest-facing slopes in the Ouachita Mountains. Preliminary analyses reduced the data set to 162 species (109 ground cover, 32 shrub, 15 midstory, and 6 overstory species variables) and 20 site variables from 20 stands. Correlation analysis, principal components analysis, and regression analysis were used to identify *major* species associations and site relationships. Three species associations were identified from the correlation analysis-one characterized by shortleaf pine (*Pinus echinata* Mill.), another by mesic oak species such as white oak (*Quercus alba* L.), and a third by xeric oak species such as post oak (Q. *stellata* Wang.). Principal components analysis of the 162-variable data set resulted in a geographic interpretation of the pattern of stand composition. Regression of the first 3 principal component axes resulting from the 162-variable data set versus site variables produced the better geographic explanation, whereas regression of the principal *component axes* from the 21-variable midstory and overstory data set versus the 162-species data set gave the better interpretation of vegetation. Although stand-based comparisons are used in this initial exploration, plot-level studies hold even more promise because the stands are not uniform expanses of a single slope, aspect, and community. These analyses could be made more interesting through addition of data from other groups.

INTRODUCTION

Most of the studies presented in this symposium concentrate on a single taxonomic, structural, or functional component presented at the stand-level scale. Though this approach has been effective at this scale, patterns at wider scales may be missed. Combining data among groups offers the opportunity to address larger landscape scale issues immediately.

One intent of the present paper is to explore patterns that result when stands are considered samples of a set of related communities or site types occurring over a large geographic area. This type of analysis has particular merit in this research, given that the stands included in the study were selected randomly within the following set of narrow constraints: (1) stands were limited to pine and pine-hardwood stands on south- to southwest-facing slopes, (2) stands had to meet preestablished age and basal area criteria, and (3) future treatments were blocked geographically.

This paper also represents the first effort to aggregate *several* of the taxonomic and structural elements being otherwise treated in separate studies by distinct research groups. Because of the physical and computational logistics involved in combining data, and because much of the data from individual studies are not yet in final form, this study has concentrated on merging the ground cover and shrub layer data with the midstory and overstory data. Data were combined for the 20 stands in which 3-season ground cover and shrub estimates were taken (Foti and Devall 1994). This represents the first fruit of efforts between the silviculture group and understory vegetation group that began with the development of a nested sample procedure designed expressly to enable such comparisons (Guldin and others 1994).

The goal of this paper is to explore the interrelationships of the ground cover, shrub, midstory, and overstory vegetation elements, in order to develop a conceptual model of floristic composition and structure of the forest plant community found on south- and southwest-facing slopes in the Ouachita Mountains.

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[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1994.

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[3] The authors extend their thanks to Dr. A.A. Karlin, Department of Biology, University of Arkansas at Little Rock, Little Rock AR, without whose generous and altruistic support this paper would not have been possible.

METHODS

Development of the Data Set

Data were obtained and summarized as described in Foti and Devall (1994) and Guldin and others (1994). Canopy layers included in this analysis are as defined in those papers, and include the ground cover layer, the shrub layer, the midstory layer, and the overstory layer.

The overstory and midstory data were combined with shrub and ground cover data additively by layer, in the following manner. In the ground cover layer, percent cover was determined for each species, based on averaging the spring, summer, and fall measurement percent cover estimates for each species across all stands (Foti and Devall 1994). These estimates were then directly applied as input to the analysis, so that the variables for the ground-cover species are based on percent cover. In the shrub layer, importance values for each species were calculated based on relative density (based on number of stems per acre) ‘and relative dominance (by percent cover) during each sample season; the final importance value was derived as the average of the importance values for all three sample seasons. In the midstory and overstory layers, the importance value for each species was calculated as the average of relative density (based on number of stems per acre) and relative dominance (based on basal area per acre) across all twenty "non-split" stands (Guldin and others 1994). The variables for the shrub, midstory, and overstory layers, then, are the importance values for each species by layer. In this manner, a total of 699 species variables were included in the preliminary analysis-579 in the ground cover layer, 81 in the shrub layer, 24 in the midstory layer, and 15 in the overstory layer.

The size of this data base is at the least ungainly, and leads to an unacceptable ratio between observations and variables for the multivariate analysis. Memory limitations in PC-SAS dictated the need for alternative analytical tools, so the data were installed on a VAX minicomputer at the Biology Department of the University of Arkansas at Little Rock and the analysis was continued there. Despite the shift to the larger computer, the 699-variable data set generated a correlation matrix that exceeded the available memory allocation, locked up the computer, and led to an acquaintance with a graduate student with system privileges. Therefore, for both theoretical and practical reasons, it was decided to edit the data so that only a subset of the 699 species variables were retained for analysis.

Editing the data proceeded as follows. Of the 579 ground cover layer species, over 100 were recorded as having only a trace occurrence; other species had trace values in the other layers as well. While important in a larger analysis, trace occurrences confound attempts to make sense of the larger patterns in the data base because of the inherent lack of ecological distance between species with trace values relative to that between common species.

The number of species in the analysis was arbitrarily reduced based on the summed percent cover or importance value across all 20 stands. Thresholds of percent cover or importance value were subjectively established by layer. In the ground cover layer, species were retained if their average percent cover per stand exceeded 0.02 percent; this resulted in including 109 of the 579 species (19 percent) in this analysis. In the shrub, midstory, and overstory layers, species were retained if their average importance value exceeded 0.5 on a 0 to 100 scale; this resulted in retaining 32 (40 percent) of the shrub species, 15 (62 percent) of the midstory species, and 6 (40 percent) of the overstory species. The final data base upon which this analysis is based thus includes 162 species variables. See appendix table 1 for variable codes, scientific names (including authorities), families, and common names by vegetation layer.

The site variables obtained by the silviculture group and the understory biodiversity group were also merged (Guldin and others 1994, Foti and Devall 1994). These served as input establishing the average condition for the stands in the study, associated with values for the species (appendix table 2). As a result, we were able to explore the relationships of the 162-species data base in relation to the 20-variable site parameter data base.

Statistical Analysis

Relationships between the vegetation data and the site data were studied using correlation analyses, principal components analyses, and regression analyses.

Correlations were developed between the midstory and overstory against all 162 species. Supplemental correlations between species of interest in the shrub and ground cover layers were also conducted. This approach should provide insight into composition of plant communities or species assemblages within them. In order to concentrate attention on patterns rather than the erroneous occasional "statistically significant" relationships that are to be expected in any large correlation analysis, only those significant relationships that occurred consistently among a set of variables were sought.

Determination of patterns among the data was done as follows. First, significant correlations among overstory and midstory variables were identified. Then, the correlations between these correlated overstory and midstory variables and the all-layer list were examined to determine whether two species significantly correlated (either positively or negatively) with each other were also correlated with a third species in the all-layer list. In this way, only those species showing consistent patterns of correlations were identified.

Principal components analysis (PCA) was conducted to analyze patterns of stand association based on vegetation. With this technique, assuming II variables, stands are ordered along a series of *n* axes called principal components (PCs), in which the first axis accounts for the largest proportion of variation in the data, and subsequent axes account for orthogonal relationships from the previous axis (SAS Institute 1990). Two arrangements of the data were analyzed using this method-first, all canopy layers (162 species variables), and second, only the overstory and midstory layers (21 species variables). Results from the PCA are generated as ***scores*** for each stand along each principal component axis.

These scores were used as dependent variables in either stepwise or MAXR regression analysis (SAS Institute 1990) as follows. The first three PC axes resulting from the 162-species data set and the 21-species data set were regressed against 2 sets of independent variables -- the 162-species data set and the 20-variable data set of site parameters. The purpose of these regressions was to elucidate information regarding the relationships of the PC axes with the species and site data.

In combination, these complementary and interrelated analyses were used explore the ecological relationships in the data. The combinations of insights resulting from the analyses presented here provide evidence of community floristics and the arrangement of stands relative to the prevailing patterns in vegetation and site variables.

RESULTS

Correlation Analysis

One set of overstory and midstory species variables showing consistent patterns of correlations are the pines and oaks. Overstory shortleaf pine is positively correlated with midstory shortleaf pine; these form one species association. These two are negatively correlated with overstory white oak, northern red oak, and water oak, and with midstory northern red oak; the oaks form a second association. In order to examine relationships between these species and other species variables from the all-layer list, any species included in the analysis were required to share significant correlations with five of these six midstory and overstory species.

Nine of the 162 species were significantly correlated with at least 5 of these 6 overstory and midstory species (table 1). In each case the ground cover species are positively correlated with the oaks and negatively correlated with pine. The ground cover variables are northern red oak, flowering dogwood, panic grass, tick trefoil, dittany, ***Aristolochia serpentaria, Galium*** sp., total moss cover and total unidentified grass cover.

Table 1. — ***Correlation matrix of overstory and midstory species variables showing consistent significant correlations vs. each other and other species variables. Species codes are defined in appendix table 1. Codes ending in 4 indicate overstory, 3 indicate midstory, 2 indicate shrub layer, and those without a number are ground cover. The direction of the correlation is shown as positive (+) or negative (-)***

Other species variables *	Overstory and midstory species variables *					
	QUEALB4	QUERUB4	QUENIG4	QUERUB3	PINECH4	PINECH3
QUERUB	+	+	+	+		
PANBOS	+	+	+	+		
MOSS	+	+	+	+		
DESNUD	+	+	+	+		
GALSPP	n.s.	+	+	+		
GRASS	n.s.	+	+	+		
CORFLO	+	+	+	+		
CUNORI	+	+	+	+		n.s.
ARISER	+	+	+	+		

• Species variables defined in appendix table 1.

A third set of related species emerged using this analysis. Overstory post oak was not significantly correlated with most of the species presented in table 1, but was positively correlated with midstory post oak. These were found to be positively correlated with five ground-cover species and two shrub-layer species, and negatively correlated with three midstory species (table 2). In each case these species had the same relationship (positive or negative) with both overstory and midstory post oak. The midstory associates were white oak, water oak and blackgum; shrub layer associates are blackjack oak and winged elm, and ground cover species were bird's-foot violet, phlox, ***Coreopsispalmata*** and poverty oatgrass. Unidentified ground cover layer oak species were also positively correlated.

Table 2.— ***Correlation matrix of species variables showing consistent correlations vs. each other and other species variables. Species codes are defined in appendix table 1. Codes ending in 4 indicate overstory, 3 indicate midstory, 2 indicate shrub layer, and those without a number are ground cover. The direction of the correlation is shown as positive (+) or negative (-)***

Other species variables *	Overstory and midstory species variables *	
	QUESTE4	**QUESTE3**
QUENIG3		
QUEALB3		
NYSSYL3		
QUEMAR2	+	+
ULMALA2	+	+
VIOPED	+	+
PHLPIL	+	+
CORPAL	+	+
DANSPI	+	+
QUESPP	+	+

* Species variables defined in appendix table 1.

Principal components analysis

In order to interpret the results of the PCA, it is helpful to have an understanding of the orientation of the 20 stands in the data base. The most easily visualized pattern is the geographic location of the stands. Thus, for purposes of comparison, stands were plotted according to their Universal Transverse Mercator (UTM) coordinates for latitude and longitude (fig. 1).

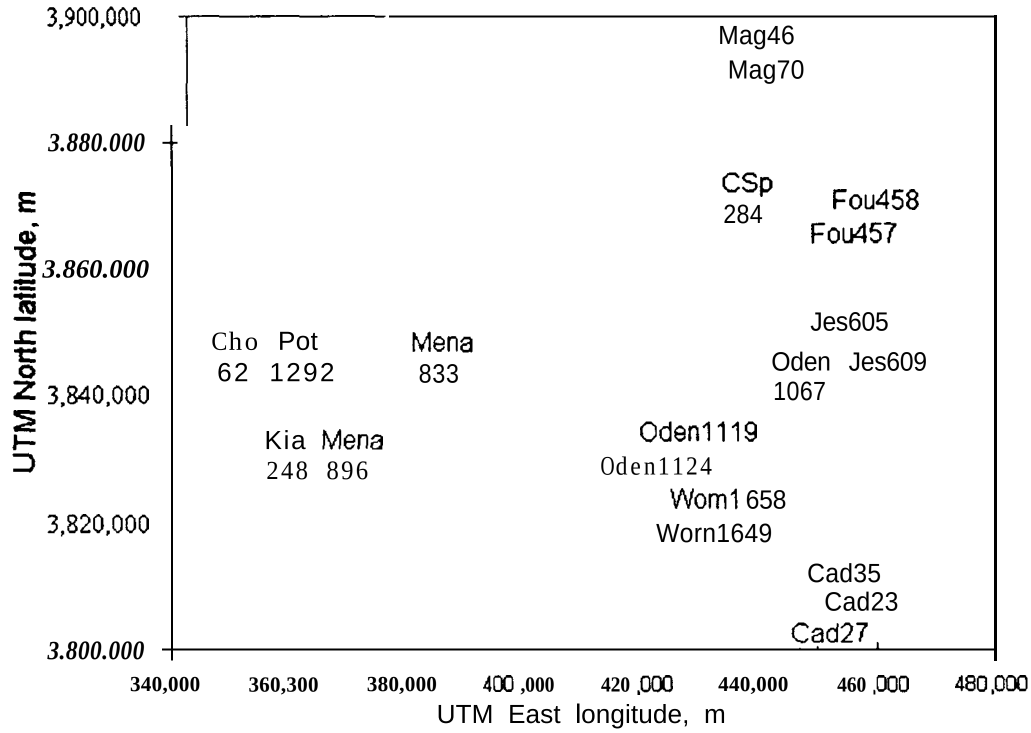
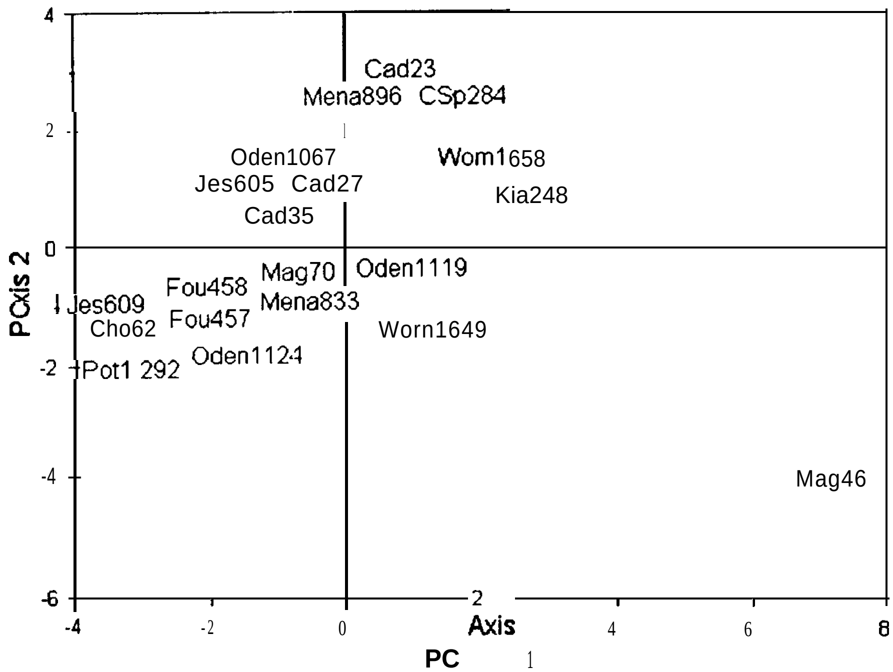


Figure 1.— ***Geographic distribution of 20 stands in the study, based on Cartesian plot of Universal Transverse Mercator coordinates. Stands identified by compartment number and ranger district acronym, as follows: Cad-Caddo RD; Cho-Choctaw RD; CSp—Cold Springs RD; Fou-Fourche RD; Jes-Jessieville RD; Kia-Kiamichi RD; Mag-Mt. Magazine RD; Mena—Mena RD; Oden-Oden RD; Worn-Womble RD.***

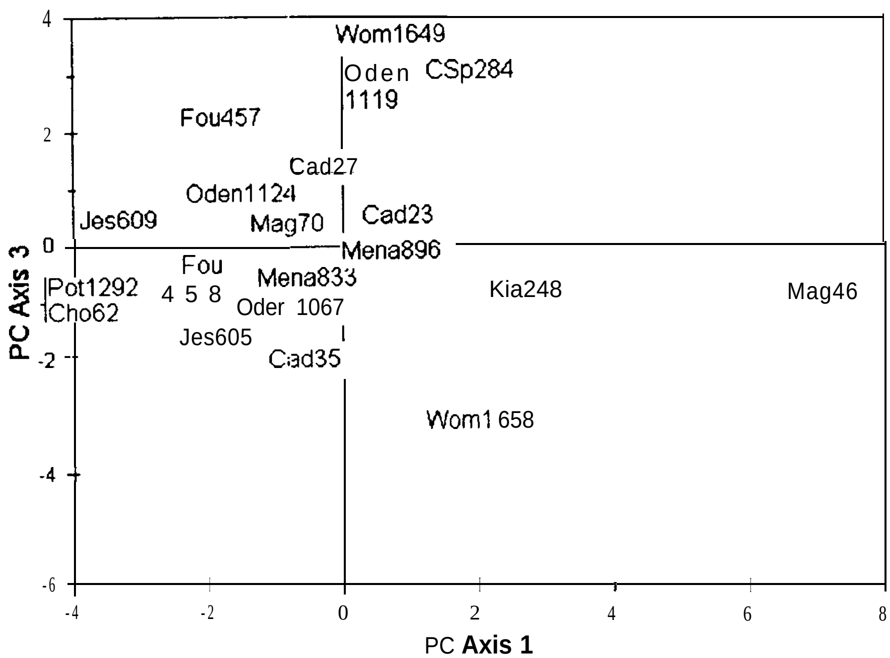
The PCA of the 21-variable overstory and **midstory** layers resulted in the first three PC axes explaining 56.1 percent of the variation in the data set. Graphs of PC axes 1 and 2, and axes 1 and 3, are presented in figures 2a and **2b,** respectively. These graphs reveal no obvious relationship with the geographic location of stands (fig. 1). The Mag46 stand, the northernmost stand in the data set, is found at one end of PC axes 1 and 2, but the arrangements of the other stands on the axes appear to be influenced by factors other than geographic association.

Figure **2.—** ***Principal components (PCs) analysis of 20 stands in the study based on overstory and midstory vegetation layers only. Stands identified as in figure 1.*** a. ***Principal component axis I versus principal component axis 2.*** b. ***Principal component axis 1 versus principal component axis 3.***

a.



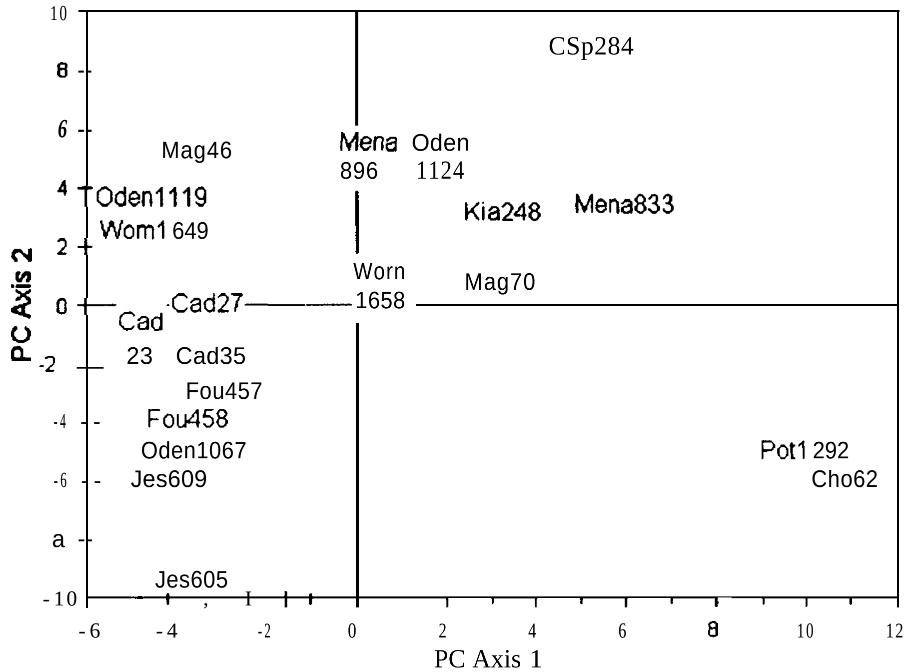
b.



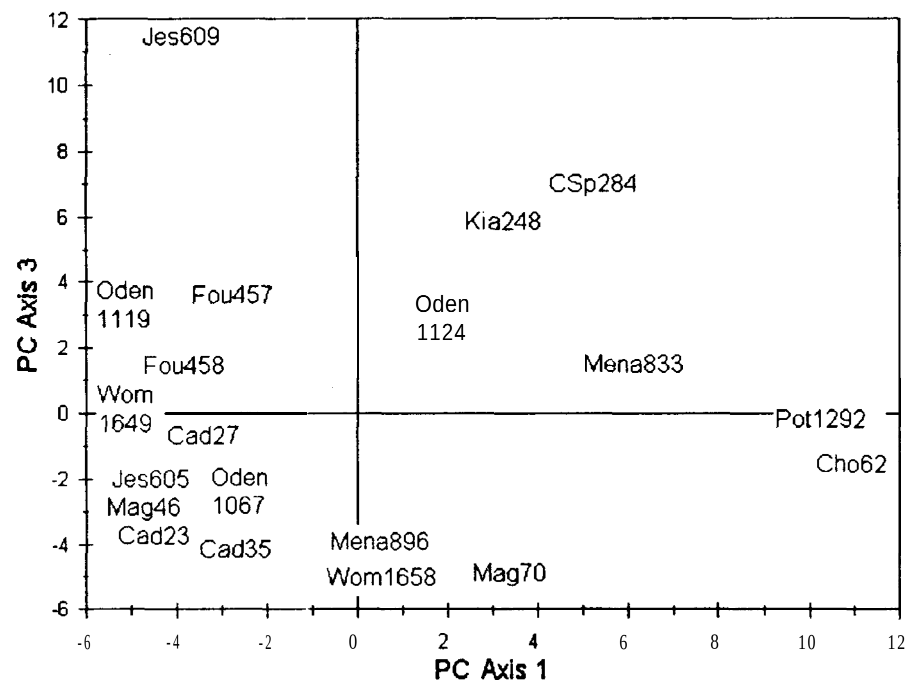
The PCA of all canopy layers resulted in the first three PC axes explaining 39.0 percent of the variation in the data set. Graphs of PC axes 1 and 2, and axes 1 and 3, are presented in figures 3a and **3b,** respectively. These graphs relate more easily to geographic position (fig. 1). For example, the easternmost stands **(Caddo,** Jessieville, and Fourche) lie in the **(-,-)** quadrant of the plot of PC axes 1 and 2, the westernmost stands (Choctaw and Poteau) lie in the (+ ,-) quadrant, and most of the centrally-located stands are found in the positive half of PC axis 2. The third PC axis adds little to the interpretation.

Figure 3. — ***Principal components (PCs) analysis of*** 20 ***stands in the study based on all vegetation layers (162 species). Stands identified as in figure 1.*** a. ***Principal component axis I versus principal component axis 2.*** b. ***Principal component axis 1 versus principal component axis 3.***

a.



b.



Regression Analysis

The first set of regression analyses were conducted to relate the PCA axis scores with the site data, to study underlying site relationships.

For the overstory-midstory PCA, stepwise regression analysis produced a four-variable model for PC axis 1, a three-variable model for PC axis 2, and a two-variable model for PC axis 3 (table 3). In each model, variables related to site quality are significant and carry positive influence. It was previously noted that slope percent, site quality, and site index differ by block in the full 52-stand data set (Guldin and others 1994), with higher slope percent in the north and south blocks, and higher site index and site quality in the south and east block plots. These PC models may therefore reflect a previously-observed block effect.

Table 3.— ***Results from SAS stepwise regression analysis to regress principal components vs. measured site variables. Results indicate the site variables within each layer most related to the principal components. All variables in the model are significant at the 0.05 level***

Dependent variable	Principal components derived from overstory and midstory cover canopy layers only	Principal components derived from overstory, midstory, shrub, and ground cover canopy layers
A. PC Axis 1	Y = -24.13355 + 0.02538 * AZDEG + 0.23268 * SLPCT + 0.27543 * COVER + 2.41958 * SQ R2 = 80.9 percent P(>F) = 0.0005	Y = -23.88073 - 3.36549 * SQ + 6.01906 * MRT - 0.0000876 * UTMET + 0.52080 * LITTER R2 = 80.0 percent P(>F) = 0.0001
B. PC Axis 2	Y = -4.50040 + 0.18096 * SLPCT + 0.17256 * SX - 5.51607 * MSS R2 = 55.7 percent P(>F) = 0.0039	Y = -89.97034 + 3.86398 * SLOPOS + 0.59229 * COVER + 0.32468 * HGT + 0.45057 * ROCK R2 = 85.0 percent P(>F) = 0.0001
C. PC Axis 3	Y = -6.39313 + 2.70794 * SQ - 22.00791 * WATER R2 = 46.3 percent P(>F) = 0.0051	Y = -15.74287 + 11.49851 * MRT - 3.79540 * SOIL - 0.70772 * ROCK R2 = 62.2 percent P(>F) = 0.0011

For the all-layer PCA, stepwise regression analysis produced a four-variable model for PC axis 1, a four-variable model for PC axis 2, and a three-variable model for PC axis 3 (table 4). The prominence of UTMET in axis 1 of the overstory-midstory PCA is consistent with the geographic relationships for the all-layer PCA presented in figure 2. The second PC axis presents a positive relationship with variables that relate to high site productivity (more protected slope position, higher percent cover, and greater height), but these are at odds with an increasing percentage of rock.

In the second set of regression analyses, the search for community relationships centered on models of the PC axes with species variables. In the all-layer PCA, regression of the first two axes against the 162-species all-layer data set resulted in models that contained no midstory or overstory species (table 4). The first axis model includes positive association for both shrub and ground cover layers of oaks, tick trefoil species, and negative association for greenbrier. The second includes mockemut hickory (+) and birds-foot violet (-) in the ground cover layer, and winged elm and red maple (both +) in the shrub layer. The only midstory and overstory species that appear in the regression occur in PC axis 3, with the inclusion of midstory water oak.

Table 4.— *Results from SAS MAXR regression analysis to regress overstory-midstory principal component axes and all-layer principal component axes versus all-layer (162) species variables. Results indicate the species within each layer most related to the principal components. All variables in the model are significant at the 0.05 level*

Dependent variable	Principal components derived from overstory and midstory canopy layers.	Principal components derived from overstory, midstory, shrub, and ground cover canopy layers.
A. PC Axis 1	Y = -3.68050 + 3.09191 * DESSPP + 7.19833 * QUESPP - 1.56719 * SMIBON + 0.34208 * QUESPP2 R2 = 90.0 percent P(>F) = 0.0001	Y = -2.91119 + 0.22715 * LIQSTY3 + 0.04172 * QUEALB3 + 0.28522 * QUEALB4 + 0.48832 * QUENIG4 R2 = 96.0 percent P(>F) = 0.0001
B. PC Axis	Y = -4.03727 + 9.10940 * CARYTOM - 34.48905 * VIOPED + 0.61293 • ACERUB2 + 0.28104 * ULMALA2 R2 = 95.6 percent P(>F) = 0.0001	Y = -9.21345 + 3.37593 * EUOAME + 9.01782 * NYSSYL - 4.68207 * ULMALA + 0.09783 * PINECH4 R2 = 92.0 percent P(>F) = 0.0001
C. PC Axis 3	Y = -2.12705 + 78.97042 * LACSPP + 18.30949* PRUSER - 3.44123 * VACARB - 0.32088 * QUENIG3 R2 = 96.9 percent P(>F) = 0.0001	Y = -0.32304 + 18.81324 * VIOSAG + 16.41026 • VITAES - 0.09227 * QUEMAR3 - 0.23826 * QUERUB3 R2 = 89.1 percent P(>F) = 0.0001

Conversely, in the overstory-midstory PCA, regression of the three PC axes against the 162-species all-layer data set resulted in midstory and overstory species included in each axis model. Regression against PC axis 1 resulted in positive association with midstory sweetgum, midstory and overstory white oak, and overstory water oak. This suggests a gradient in relation to site quality, in that these species are typically associated with lower slopes and protected topographic settings. Regression against PC axis 2 resulted in a model having positive association with overstory shortleaf pine, in addition to three ground cover species. Regression against PC axis 3 led to a model in which two ground cover species have positive association and two midstory oaks-southern red and blackjack-have negative association.

DISCUSSION AND CONCLUSIONS

It appears that three sets of associated species have been defined through the correlation analysis-one characterized by shortleaf pine, another by mesic oak species, and a third by xeric oaks.

In the mesic oak association, the overstory and midstory oak species discussed here are typical of dry-mesic to mesic sites in the Ouachitas, although water oak has not received much attention in the literature on Ouachita Mountain plant communities. Most of the associated ground cover species present are typical of dry-mesic to mesic communities as well. High moss cover is consistent with this community, whereas the appropriateness of high total unidentified grass cover and high cover of *Galium* sp. is unclear.

In the pine association, the consistent negative correlations between shortleaf pine and other species may be a characteristic of pine-dominated communities, or it may be an artifact of the stand-selection criteria. This may be an association in which the pines reflect disturbance, with the species that then become established in conjunction with the pines reflecting the shift toward later successional stages.

The third species association is consistent with communities in the Ouachita Mountains characteristic of dry to xeric sites: an open forest or woodland dominated by post oak in the overstory. In this analysis, post oak is typical in the midstory with shrub layer associates blackjack oak and winged elm, and a ground cover layer with bird's-foot violet, phlox, ***Coreopsis palmata*** and poverty oatgrass. Midstory white oak, water oak, and blackgum are characteristic of dry-mesic to mesic communities, so their negative association with post oak in this species association is ecologically consistent.

From the PCA graphs, it appears that a more geographically lucid interpretation of the stand pattern results from adding the shrub and ground ***cover*** layers to the principal component analysis. ***One*** explanation for this is that the lower canopy layers add valuable ecological information, even on these south- and southwest-facing pine and pine-hardwood stands, that aid in stand classification. This might also be influenced by past species-specific manipulations in the overstory and midstory, such as hardwood control or selective harvest of pines, which could alter the relative proportions of these species in a stand for decades after the treatment was imposed.

Overall, the regression models most easily explained are the all-layer PCA versus site variables, which gave the better geographic explanation, and the midstory-overstory PCA versus the full-canopy species data set, which gave the better interpretation in light of the correlation analysis. Both of these analyses have as their core a relationship to site quality, either expressed as site variables or species variables in the regression models. However, the assumption that geographic pattern represents ecological pattern is not necessarily valid, especially in light of the varying disturbance history that one would expect in these stands.

In regard to subsequent analyses, it will be interesting to stratify the data base in ecologically meaningful ways. For example, analysis of each vegetation layer or specific combinations may allow us to better understand interlayer and intralayer relationships. Grouping plots by strata of similar attributes may also elucidate meaningful relationships. Effective groupings could be made using the ecological classification schemes under development in the National Forest System or by use of LANDSAT imagery or digitized aerial photo imagery.

Although stand-based comparisons are used in this initial exploration, plot-level studies potentially hold even more promise because variance between plots is greater than that between stands (Guldin and others 1994). The stands are not uniform expanses of a single slope, aspect, and community. Indeed, plot-based analysis may allow the development of a plant community/ecological site classification which describes the community variation on south-facing slopes in the Ouachitas and extrapolates to other site types as well.

Finally, we would like to extend an invitation to other groups to join us in the multivariate compilation. We especially would solicit the involvement of other groups that have characterized variables across either the 20-stand data base, the 52-stand data base, or the 728-plot data base. For example, we suspect it would be easy to append forest floor and soil disturbance variables, small mammals, birds, and wildlife habitat data. But there may also be opportunities for others with a more limited plot- or stand-based data set as well, depending on the nature of the data and the scope of the analysis that would result.

LITERATURE CITED

Foti, T.L.; Devall, M. 1994. Pretreatment conditions in mature pine-hardwood stands on south-facing slopes of the Ouachita/Ozark National Forests: ground layer and shrub layer. In: Baker, J.B., comp. Proceedings of the symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen.Tech. Rep. SO-xx. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station..

Guldin, James M.; Baker, James B.; Shelton, Michael G. 1994. Midstory and overstory plants in mature pine-hardwood stands of the Ouachita/Ozark National Forests. In: Baker, J.B., comp. Proceedings of the symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen.Tech. Rep. SO-xx. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station..

SAS Institute, Inc. 1990. SAS/STAT user's guide, version 6, fourth edition, vol. 2. Cary, NC: SAS Institute, Inc.

Smith, Edwin B. 1988. An atlas and annotated list of the vascular plants of Arkansas. 2d ed. Fayetteville, AR: Bound xerographic text. 489 p.

Appendix Table 1.— *Species included in the analysis presented in this paper. Scientific and common names follow Smith (1988)*

Variable Code	Scientific names	Family	Common name
A. Ground cover layer			
ACERUB	*Acer rubrum* L.	Aceraceae	Red maple
AMEARB	*Amelanchier arborea* (Michx. f.) Fem.	Rosaceae	Serviceberry
ANDSPP	*Andropogon* spp.	Gramineae	Bluestem grasses
ANTPLA	*Antennaria plantaginifolia* (L.) Richards	Compositae	Pussy's toes
ARIDIC	*Aristida dichotoma* Michx.	Gramineae	Church-mouse three-awn
ARIPUR	*Aristida putpurascens* Poir.	Gramineae	Arrowfeather three-awn
ARISPP	*Aristida* spp.	Gramineae	Three-awn spp.
ASPPLA	*Asplenium platyneuron* (L.) Oakes ex D.C. Eat.	Polypodiaceae	Ebony spleenwort
ASTNOV	*Aster novae-angliae* L.	Compositae	Aster
ASTSPP	*Aster* spp.	Compositae	Asters
BAPLEU	*Baptisia leucantha* T. & G.	Leguminosae	White wild indigo
BERSCA	*Berchemia scandens* (Hill) K. Koch	Rhamnaceae	Rattan vine
CARCAR	*Carpinus caroliniana* Walt.	Betulaceae	American hornbeam
CARXCOM	*Carex complanata* Torr. and Hook.	Cyperaceae	Sedge
CARXFLA	*Carex flaccosperma* Dewey	Cyperaceae	Sedge
CARXSPP	*Carex* spp.	Cyperaceae	Sedge
CARYSPP	*Carya* spp.	Juglandaceae	Hickories
CARYTOM	*Carya tomentosa* (Poir.) Nutt.	Juglandaceae	Mockemut hickory
CHALAT	*Chasmanthium latifolium* (Michx.) Yates	Gramineae	Inland sea oats
CHALAX	*Chasmanthium laxum* (L.) Yates	Gramineae	
CHASES	*Chusmanthium sessiliflorum* (Poir.) Yates	Gramineae	
CLIMAR	*Clitoria mariana* L.	Leguminosae	Butterfly pea
CORFLO	*Cornus florida* L.	Cornaceae	Flowering dogwood
CUNORI	*Cunila origanoides* (L.) Britt.	Labiatae	Dittany
DANSPI	*Danthonia spicata* (L.) Beauv. ex Roem.& Schult.	Gramineae	Poverty oatgrass
DESNUD	*Desmodium nudiflorum* (L.) DC.	Leguminosae	Tick trefoil
DESROT	*Desmodium rotundifolium* DC.	Leguminosae	Tick trefoil
DESSPP	*Desmodium* spp.	Leguminosae	Tick trefoil
ELETOM	*Elephantopus tomentosus* L.	Compositae	Tobacco-weed
EUOAME	*Euonymus americanus* L.	Celastraceae	Strawberry bush
EUPCOR	*Euphorbin corollata* L.	Euphorbiaceae	Flowering spurge
FERNMOSS	Various fern and moss spp.		
FUNGI	Various fungi		
GALCIR	*Galium circaezans* Michx.	Rubiaceae	Wild licorice
HELDIV	*Helianthus divaricatus* L.	Compositae	Sunflower
HELHIR	*Helianthus hirsutus* Raf.	Compositae	Sunflower
HIEGRO	*Hieracium gronovii* L.	Compositae	Hawkweed
IRICRI	Iris *cristata* Ait.	Iridaceae	Crested iris
JUNVIR	*Juniperus virginiana* L.	Cupressaceae	Eastern red cedar
LACSPP	*Lactuca* spp.	Compositae	Wild lettuce
LESPRO	*Lespedeza procumbens* Michx.	Leguminosae	Trailing bush clover
LESREP	*Lespedeza repens* (L.) Bart.	Leguminosae	Creeping bush clover
LESSPP	*Lespedeza* spp	Leguminosae	Clovers
LESVIO	*Lespedeza violacea* (L.) Pers.	Leguminosae	Prairie clover
LEUSPP	*Leucobryum* spp.		Mosses
LIAASP	*Liatris aspera* Michx.	Compositae	Blazing star
LICHEN	Various lichen spp.		
LIQSTY	*Liquidambar styraciflua* L.	Hamamelidaceae	Sweetgum
LONJAP	*Lonicera japonica* Thunb.	Caprifoliaceae	Japanese honeysuckle
MITREP	*Mitchella repens* L.	Rubiaceae	Partridge beny
MONFIS	*Monarda fistulosa* L.	Labiatae	Wild bergamot
MONRUS	*Monarda russeliana* Nutt. ex Sims	Labiatae	Horsemint
MONSPP	*Monarda* spp.	Labiatae	Mints
MOSS	Various moss spp.		
NYSSYL	*Nyssa sylvatica* Marsh.	Nyssaceae	Blackgum
OSTVIR	*Ostrya virginiana* (P. Mill.) K. Koch	Betulaceae	Hophombeam
OXASTR	*Oxalis stn'cta* L.	Oxalidaceae	Yellow wood sorrel

Appendix Tab le 1:— ***Species included in the analysis presented in this paper. Scientific and common names follow Smith (1988) (continued)***

Variable Code	Scientific name	Family	Common name
A. Ground cover layer, cont'd.			
OXAVIO	*Oxalis violacea* L.	Oxalidaceae	Violet wood sorrel
PANBOS	*Panicum boscii* Poir.	Gramineae	Panicum grass
PANDIC	*Panicum dichotomum* L.	Gramineae	Panicum grass
PANDICF	*Panicum dichotomiflorum* Michx.	Gramineae	Fall panic grass
PANSPP	*Panicum* spp.	Gramineae	Panic grasses
PARINT	*Parthenium integrifolium* L.	Compoaitae	Wild quinine
PARQUI	*Parthenocissus quinquefolia* (L.) Planchon	Vitaceae	Virginia creeper
PHLPIL	*Phlox pilosa* L.	Polemoniaceae	Phlox
PHLSPP	*Phlox* spp.	Polemoniaceae	Phloxes
PINECH	*Pinus cchinata* Mill.	Pinaceae	Shortleaf pine
POLSPP	*Polygala* spp.		
POLYMOSS	*Polystichum* spp.		
PRUAME	*Prunus americana* Marsh.	Rosaceae	Wild plum
PRUSER	*Prunus serotina* Ehrh.	Roaaceae	Black cherry
PTEAQU	*Pteridium aquilinum* (L.) Kuhn in Decken	Polypodiaceae	Bracken fern
QUEALB	Quercus *alba* L.	Fagaceae	White oak
QUEFAL	*Quercus falcata* Michx.	Fagaceae	Southern ted oak
QUEMAR	Quercus *marilandica* Muench.	Fagaceae	Blackjack oak
QUENIG	*Quercus nigra* L.	Fagaceae	Water oak
QUEPHE	*Quercus phellos* L.	Fagaceae	Willow oak
QUERUB	*Quercus rubra* L.	Fagaceae	Northern red oak
QUESPP	*Quercus* app.	Fagaceae	Oaks
QUESTE	*Quercus stellata* Wang.	Fagaceae	Post oak
QUEVEL	*Quercus velutina Lam.*	Fagaceae	Black oak
RUBSPP	*Rubus* spp.	Roaaceae	Blackberries
SANCAN	*Sanicula* canadensis L.	Umbelliferae	Black snakeroot
SCHSCO	*Schizachyrium scoparium* (Michx.) Nash var. *divergens* Gould	Gramineae	Blueatem grass
SCLCIL	*Scleria ciliata* Michx.	Cyperaceae	Nut rush
SCLOLI	*Scleria oligantha* Michx.	Cyperaceae	Nut rush
SCLSPP	*Scleria* app.	Cyperaceae	Nut rushes
SCLTRI	*Scleria triglomerata* Michx.	Cyperacee	Tall nut grass
SMIBON	*Smilax bona-nox* L.	Liliaceae	Greenbrier
SMIGLA	*Smilax glauca* Walt.	Liliiceae	Greenbrier
SMIROT	*Smilax rotundifolia* L.	Liliaceae	Greenbrier
SOLISP	*Solidago* app.	Compoaitae	Goldenrod
SOLULM	*Solidago ulmifolia* Muhl.	Compoaitae	Elm-leaf goldenrod
SPHSPP	*Sphenopholis* app.	Gramineae	Wedgeacales
TEPVIR	*Tephrosia virginiana* (L.) Pers.	Leguminosae	Goat's Rue
TOXRAD	*Toxicodendron radicans* (L.) Kuntze	Anacacdiaceae	Poison ivy
TOXSPP	*Toxicodendron* spp.	Anacardiaceae	Poison ivy-oak
TRACDIF	*Trachelospennum difforme* (Walt.) Gray	Apocynaceae	Climbing dogbane
ULMALA	*Ulmus alata* Michx.	Ulmaceae	Winged elm
UNKNOWN	Unknown app.		
VACARB	*Vaccinium arboreum* Marsh.	Ericaceae	Tree huckleberry
VACPAL	*Vaccinium pallidum* Ait.	Ericaceae	Low-bush huckleberry
VACSTA	*Vaccinium stamineum* L.	Ericaceae	Gooseberry
VIBRUF	*Viburnum rufidulum* Raf.	Caprifoliaceae	Ruaty blackhaw
VIOPED	*Viola pedata* L.	Violaceae	Bird's-foot violet
VIOSAG	*Viola sagittata* Ait.	Violaceae	Arrow-leaved violet
VITAES	*Vitis aestivalis* Michx.	Vitaceae	Summer grape
VITROT	*Vitis rotundifolia* Michx.	Vitaceae	Muacadine grape
ZIZAUR	*Zizia aurea* (L.) Koch	Umbelliferae	Golden Alexanders

Appendix Table 1:— *Species included in the analysis presented in this paper. Scientific and common names follow Smith (1988) (continued)*

Variable Code	Scientific name	Family	Common name
B. Shrub layer			
ACERUB2	*Acer rubrum* L.	Aceraceae	Red maple
AMEARB2	*Amelanchier arborea* (Michx. f.) Fem.	Rosaceae	Serviceberry
BERSCA2	*Berchemia scandens* (Hill) K. Koch	Rhamnaceae	Rattan vine
CARCAR2	*Carpinus caroliniana* Walt.	Betulaceae	American hornbeam
CARYOVA2	Carya *ovata* (P.Mill.) K.Koch	Juglandaceae	Shagbark hickory
CARYTOM2	*Carya tomentosa* (Poir.) Nutt.	Juglandaceae	Mockemut hickory
CORFLO2	*Cornus florida* L.	Comaceae	Flowering dogwood
CRASPP2	*Crataegus* spp.	Rosaceae	Hawthorn
FRAPEN2	*Fraxinus pennsylvanica* Marsh.	Oleaceae	Green ash
JUNVIR2	*Juniperus virginiana* L.	Cupressaceae	Eastern redcedar
LIQSTY2	*Liquidambar styraciflua* L.	Hamamelidaceae	Sweetgum
NYSSYL2	*Nyssa sylvatica* Marsh.	Nyssaceae	Blackgum
OSTVIR2	Osrrya *virginiana* (P. Mill.) K. Koch	Betulaceae	Hophombeam
PARQU12	*Parthenocissus quinquefolia* (L.) Planchon	Vitaceae	Virginia creeper
PINECH2	*Pinus echinata* Mill.	Pinaceae	Shortleaf pine
PRUAME2	*Prunus americana* Marsh.	Rosaceae	Wild plum
PRUSER2	*Prunus serotina* Ehrh.	Rosaceae	Black cherry
QUEALB2	*Quercus alba* L.	Fagaceae	White oak
QUEFAL2	*Quercus falcata* Michx.	Fagaceae	Southern red oak
QUEMAR2	Quercus *man'landica* Muench.	Fagaceae	Blackjack oak
QUERUB2	Quercus *rubra* L.	Fagaceae	Northern red oak
QUESPP2	Quercus spp.	Fagaceae	Oaks
QUESTE2	*Quercus stellata* Wang.	Fagaceae	Post oak
QUEVEL2	*Quercus velutina* Lam.	Fagaceae	Black oak
SMIBON2	*Smilax bona-nox* L.	Liliaceae	Greenbrier
SMIGLA2	*Smilax glauca* Walt.	Liliaceae	Greenbrier
SMIROT2	*Smilax rotundifolia* L.	Liliaceae	Greenbrier
TOXRAD2	*Toxicodendron radicans* (L.) Kuntze	Anacardiaceae	Poison ivy
ULMALA2	*Ulmus alata* Michx.	Ulmaceae	Winged elm
VACARB2	*Vaccinium arboreum* Marsh.	Ericaceae	Tree huckleberry
VIBRUF2	*Viburnum rufidulum* Raf.	Caprifoliaceae	Rusty blackhaw
VITROT2	*Vitis rotundifolia* Michx.	Vitaceae	Muscadine grape
C. Midstory layer			
ACERUB3	*Acer rubrum* L.	Aceraceae	Red maple
CARYTOM3	Carya tomentosa (Poir.) Nutt.	Juglandaceae	Mockemut hickory
cARYTEx3	*Carya texana* Buckl.	Juglandaceae	Black hickory
CORFL03	*Cornus florida* L.	Comaceae	Flowering dogwood
JUNVIR3	*Juniperus virginiana* L.	Cupresaaceae	Eastern redcedar
LIQSTY3	*Liquidambar styraciflua* L.	Hamamelidaceae	Sweetgum
NYSSYL3	*Nyssa sylvan'ca* Marsh.	Nyssaceae	Blac kgum
PINECH3	*Pinus echinata* Mill.	Pinaceae	Shortleaf pine
QUEALB3	Quercus *alba* L.	Fagaceae	White oak
QUEFAL3	*Quercus falcata* Michx.	Fagaceae	Southern red oak
QUEMAR3	Quercus *man'landica* Muench.	Fagaceae	Blackjack oak
QUENIG3	Quercus *nigra* L.	Fagaceae	Water oak
QUERUB3	*Quercus rubra* L.	Fagaceae	Northern red oak
QUESTE3	*Quercus stellata* Wang.	Fagaceae	Post oak
ULMALA3	*Ulmus alata* Michx.	Ulmaceae	Winged elm
D. Overstory layer			
LIQSTY4	*Liquidambar styraciflua* L.	Hamamelidaceae	Sweetgum
PINECH4	*Pinus echinata* Mill.	Pinaceae	Shortleaf pine
QUEALB4	Quercus *alba* L.	Fagaceae	White oak
QUESTE4	*Quercus stellata* Wang.	Fagaceae	Post oak
QUENIG4	Quercus *nigra L.*	Fagaceae	Water oak
QUERUB4	*Quercus rubra* L.	Fagaceae	Northern red oak

Appendix Table 2.— ***Site variables included in the analysispresented in thispaper (Guldin and others 1994, Foti and Devall 1994)***

Variable code	Variable
BKNO	Block number
TRTNO	Treatment number
AZDEG	Azimuth, degrees
SLPCT	Slope percent
SLOPOS	Slope position
COVER	Percent cover
HGT	Height, ft
AGE	Age, years
s x	Site index, A (base 50)
SQ	Site quality
MST	Microsite topography
MSS	Microsite severity
MRT	Microrelief topography
MRS	Microrelief severity
UTMN	Universal Transverse Mercator - North, m
UTMNT	UTMN Transformed (3,800,000 - UTMN), m
UTME	Universal Transverse Mercator - East, m
UTMET	UTME Transformed (340,000 - UTME), m
LITTER	Percent coverage of litter
SOIL	Percent of exposed mineral soil
WATER	Percent coverage by water
ROCK	Percent coverage of rock

Small Mammal Communities of Mature Pine-Hardwood Stands in the Ouachita Mountains[1]

Philip A. Tappe, Ronald E. Thill, Joseph J. Krystofik, and Gary A. Heidt[2]

ABSTRACT

A study was conducted on the Ouachita and Ozark National Forests in Arkansas to evaluate the effects of alternative pine-hardwood reproduction cutting methods on small mammal abundance and diversity. Pretreatment characteristics of small mammal communities on 20 late-rotation mixed pine-hardwood stands in four physiographic zones of the Ouachita Mountain region of Arkansas are presented. Each physiographic zone (block) contained one replication of five treatments (four future treatments and an untreated control). The most commonly captured small mammal species were *Peromyscus* spp., *Blarina carolinensis*, and *Ochrotomys nuttalli.* Capture success varied between years but most likely reflected changes in probabilities of capture of individual animals and not fluctuations in community composition. Small mammal species richness, diversity, evenness, and relative abundance did not differ between physiographic zones or future treatments.

INTRODUCTION

There is currently a paucity of information concerning the implications of even- and uneven-aged mixed pine-hardwood management for small mammals. In extensive literature searches on the topic of silvicultural effects on wildlife habitat (covering the years 1953 through 1990), Harlow and Van Lear (1981, 1987) and NCASI (1993) did not cite a single paper specifically addressing the effects of reproduction cutting methods in mixed pine-hardwood stands on small mammal communities. Coupled with increasing concerns over the impacts of silvicultural practices on wildlife, research on the effects of alternative silvicultural practices is particularly warranted for small mammal communities. Small mammals are the primary prey base for many mammalian and avian predators. Mycophagous species facilitate dispersal of fungal spores that form root-inhabiting ecotomycorrhizae required by most higher plants for adequate nutrient procurement, enhanced water absorption, and protection from root pathogens (Maser and others 1978). Consumption of pine seeds by some species may adversely affect regeneration success (Pank 1974, Smith and Aldous 1947). In addition, fossorial species may significantly influence hydrological processes on forested watersheds (Ursic and Esher 1988).

The objective of this study is to evaluate the effects of alternative pine-hardwood reproduction cutting methods on small mammal abundance and diversity. Pretreatment characteristics of small mammal communities in late-rotation stands in the Ouachita Mountain region of Arkansas are presented in this paper.

METHODS

Study Areas and Treatments

Twenty late-rotation mixed pine-hardwood stands in four physiographic zones of the Ouachita Mountain region were selected for study. These stands are located in the Ouachita National Forest and Ozark-St. Francis National Forest and are characterized by: size ranges from 14.2 to 16.2 ha; predominantly south, southeast, or southwest aspects; and slopes of 5 to 20 percent. Locations and habitat characteristics of the stands are described by Thill and others (1994).

Four replications of five treatments, blocked by physiographic zone, were randomly assigned to 20 stands. These treatments consist of an untreated control and four reproduction cutting methods: clearcut, shelterwood, group selection, and single-tree

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selection. All silvicultural treatments, except for the clearcut, provide for the retention of overstory hardwoods. These treatments were implemented in the summer of 1993. For a detailed description of treatments and physiographic zones, see Baker (1994).

Small Mammal Surveys

Small mammals were trapped prior to treatment installation during December of 1991 and 1992 using Sherman livetraps (7.62 cm by 8.89 cm by 22.86 cm). These traps are of sufficient size to capture eastern woodrats (*Neotoma floridana*), flying squirrels (*Glaucomys volans*), and smaller mammals. Eighty trap stations per stand were located at 15-m intervals along permanent transects established for small mammal trapping, habitat sampling, and biodiversity surveys. To ensure adequate coverage of each study area, each stand was subdivided into 50-m wide, parallel bands. One randomly selected transect was located within each band so that no transect was closer than 30 m from another transect. The number of transects and their lengths varied by stand size and shape. To minimize potential edge influences, no traps were placed closer than 50 m from the stand boundaries. A more detailed description of transect establishment is given by Thill and others (1994). In 199 1, one trap was placed at each station. Sampling effort was increased to two traps per station in 1992 to ensure ample opportunities for multiple captures per trap station.

Traps were baited with commercial horse and mule feed and checked for 10 consecutive days. A wad of cotton was placed in each trap for nesting material to minimize trap mortality. Captured mammals were marked and released at the site of capture after recording species, sex (when possible), and location (station number) of capture. A tally was also kept on the number of empty/sprung traps so that total available trap nights could be computed. Because of insufficient discriminating physical characteristics available from field observations, animals of the genus *Peromyscus* (including *P. leucopus, P. gossypinus, P. maniculatus, and P. uttwuteri)* were not identified to the species level.

Data Analyses

A number of diversity measures were computed for each stand. These included species richness (i.e., the number of species encountered), Shannon's diversity index (Shannon and Weaver 1963), and species evenness (i.e., the distribution of individuals among species). In addition, an index of relative species abundance was obtained by computing small mammal captures per 100 trap nights, excluding recaptures and after correcting for sprung/empty traps. Though sampling intensity was doubled in 1992, very few multiple captures occurred. Thus, to ensure that data were comparable between years, 1992 trap nights were based on the number of trap stations as opposed to the number of individual traps. Diversity, evenness, richness, and relative abundance of small mammals were compared by year using Wilcoxon matched-pairs signed-ranks tests and by physiographic zone and future treatment using one-way analysis of variance (ANOVA) and Tukey's HSD. In addition, small mammal community composition was evaluated among physiographic zones and among future treatments using Sorensen's Similarity Index (Mueller-Dombois and Ellenberg 1974). This index is computed as: SI = $200C/(A + B)$, where A = the number of species in zone or treatment A, B = the number of species in zone or treatment B, and C = the number of species that areas A and B have in common. Similarity can range from 0 percent (no species in common) to 100 percent (identical species composition). So that community composition could be readily compared between any two blocks or treatments, an index value was computed for each combination of both physiographic zones (6 combinations) and future treatments (10 combinations).

RESULTS

After correcting for sprung traps and differential sampling intensity, 2 1,165 trap nights were accumulated over 2 years across all stands. A total of 502 small mammals of 10 species were captured (table 1). Trapping success across years was 2.37 new captures per 100 trap nights. The most commonly captured species were *Peromyscus* spp., *Blurinu carolinensis*, and *Ochrotomys nuttulli,* comprising 94 percent of all animals captured (table 1).

Differences by Year

Capture success was different between 1991 and 1992. Total captures varied significantly between years ($Z = -3.6773$, $P < 0.001$), and numbers of individuals within the species were different for the three most commonly caught species (table 1). New captures per 100 trap nights also differed between years for the three most commonly captured species (table 1): *Peromyscus* spp. ($Z = -2.6880$, $P = 0.007$) *Blurinu curolinensis* ($Z = -2.7253$, $P = 0.006$), and *Ochrotomys nuttalli* ($Z = -3.0\ 102$, $P = 0.003$).

Because of these differences in capture success, measures of diversity also differed between years. Species richness among stands differed by year ($Z= -2.1993$, $P = 0.028$), averaging 3.35 (SE = 0.24) for 1991 and 2.55 (SE = 0.20) for 1992. Species diversity also differed by year ($Z = -2.3\ 146$, $P = 0.021$), averaging 0.90 (SE = 0.08) for 1991 and 0.71 (SE = 0.07) for 1992. However, species evenness did not differ between years ($Z = -0.8213$, $P = 0.412$), averaging 0.73 (SE = 0.06) for 1991 and 0.75 (SE = 0.06) for 1992.

Table 1- *Species, numbers of captured individuals, and relative abundance (new captures per 100 trap nights) of small mammals captured by year in Ecosystem Management research stands in the Ouachita Mountains of Arkansas*

	1991		*1992*			
Species	Captures	Captures/l 00 trap nights	Captures	Captures/l00 trap nights	Total captures	Total captures/100 trap nights
Peromyscus **spp.***	170	1.62	84	0.79	254	1.20
Blarina carolinensis	*127*	*1.21*	*31*	*0.29*	*158*	*0.75*
Ochrotomys nuttalli	*51*	*0.49*	*9*	*0.08*	*60*	*0.28*
Neotomajloridana	*8*	*0.08*	*5*	*0.05*	*13*	*0.06*
Reithrodontomys fulvescens	*5*	*0.05*	1	0.01	6	0.03
Glaucomys volans	3	0.03	2	0.02	5	0.02
Microtuspinetorum	*2*	*0.02*	1	0.01	3	0.01
Orzomys palustris	1	0.01	0	0.00	1	co.01
Sigmodon hispidus	1	0.01	0	0.00	1	co.01
Mus musculus	0	0.00	1	0.01	1	co.01
Total	368	3.51	134	1.26	502	2.37

*Includes *P.* ***leucopus****, P. gossypinus, P. maniculatus, and P. attwateri.*

Because habitat characteristics did not change appreciably between years, differences in relative abundance and diversity were probably related to differences in the inherent probabilities of capture of individual animals and not to yearly fluctuations in the actual abundance and/or composition of small mammal species. Species that were captured only 1 year were likely present both years, but their populations may have been so low that capture was unlikely given our sampling intensity. When richness, diversity, and evenness values were computed for pooled 1991 and 1992 data, mean values across all stands were 3.70 (SE = 0.21) for species richness, 0.98 (SE = 0.07) for species diversity, and 0.75 for species evenness.

Differences by Physiographic Zones

Physiographic zones were compared for each year and for pooled data across years. In 199 1, 1992, and 199 l-92 combined, no differences between zones were found for relative abundance, richness, diversity, or evenness (tables 2, 3). Likewise, few habitat parameters were significantly different by physiographic zone (Thill and others 1994). Small mammal community similarity between physiographic zones ranged from 6 1.5 percent to 87.5 percent (table 4), and averaged 74.1 percent. However, *Peromyscus* spp., *Blarina carolinensis,* and *Ochrotomys* ***nuttalli*** were present in all zones. Because all other species comprised only 6 percent of the animals captured, these areas may be more similar than indicated by Sorensen's index.

Differences by Future Treatments

Groups of stands targeted for future treatments were also compared for each year and for pooled data across years. In 199 1 and 1991-92, no differences between future treatments were found for relative abundance, richness, diversity, or evenness (Tables 5 and 6). In 1992, there were no differences between future treatments for relative abundance, richness, or diversity; however, the mean evenness value for the group of stands to receive the shelterwood treatment differed from all other groups of stands except the control group (tables 5, 6). Likewise, only one of 69 habitat parameters (volume of down pine logs, decay class 3) differed significantly among future treatments (Thill and others 1994). Small mammal community similarity between future treatments ranged from 57.1 percent to 92.3 percent (table 4) and averaged 78.5 percent. Similar to physiographic zones, *Peromyscus* spp., *Blarina carolinensis,* and *Ochrotomys nuttalli were* present in all treatment areas. In addition, the next most abundant species, *Neotomajloridana* (table 1), was also present in all treatment areas. Thus, these areas may also be more similar in small mammal composition than indicated by Sorensen's index.

Table 2– *Relative abundance (new **captures per** 100 trap nights) of small mammals and the three most **commonly** captured species (x± SE) in Ecosystem Management research **stands** in the Ouachita Mountains of Arkansas byphysiographic zone, 1991-92*

Species	Year	Zone: North	South	East	West	F	P†
All species	1991	3.21 ± 1.13	3.21 ● 1.23	4.88 ± 0.91	2.15 ± 1.35	0.637	0.60
	1992	1.29 ± 0.44	1.11 ± 0.22	1.46 ± 0.47	1.15 ± 0.36	0.173	0.91
	Pooled	2.25 ● 0.66	2.19 ± 0.69	3.17 ± 0.75	1.95 ± 0.71	0.584	0.63
***Peromyscus* spp.‡**	1991	2.01 ± 0.80	1.99 ± 1.32	1.46 ± 0.37	0.98 ± 0.47	0.351	0.79
	1992	0.88 ± 0.33	0.63 ● 0.15	0.93 ± 0.39	0.69 ± 0.24	0.245	0.86
	Pooled	1.45 ± 0.45	1.31 ± 0.67	1.19 ± 0.27	0.84 ± 0.26	0.346	0.79
Blarina carolinensis	*1991*	*0.30 ● 0.09*	*0.75 ± 0.27*	*2.53 ● 1.03*	*1.35 ± 1.68*	*2.193*	*0.13*
	1992	*0.22 ± 0.09*	*0.29 ± 0.09*	*0.34 ± 0.21*	*0.30 ±* 0.10	0.306	0.82
	Pooled	0.26 ± 0.06	0.52 ± 0.15	1.44 ± 0.61	0.83 ± 0.40	1.847	0.16
Ochrotomys nuttalli	*1991*	*0.72 ± 0.29*	*0.34 ± 0.17*	*0.81 ± 0.33*	*0.08 ± 0.05*	*2.022*	*0.15*
	1992	*0.07 ± 0.07*	*0.04 ± 0.04*	*0.15 ± 0.09*	*0.08 ± 0.05*	*0.514*	*0.68*
	Pooled	0.40 ± 0.18	0.19 ± 0.10	0.48 ± 0.20	0.08 ± 0.11	1.695	0.19

*One-way ANOVA F-value.
'Probability associated with one-way ANOVA F-value.
*Includes *P. leucopus, P. gossypinus, P. maniculatus, and P. attwateri.*

Table 3– *Species richness, diversity, and evenness (xi SE) in Ecosystem Management research stands in the Ouachita Mountains of Arkansas by physiographic zone, 1991-92*

Variable	Year	Zone: North	south	East	West	F*	P†
Richness	1991	3.20 ± 0.20	3.40 ● 0.51	3.20 ± 0.21	3.60 ± 0.87	0.133	0.94
	1992	2.20 ± 0.37	2.80 ± 0.37	2.60 ± 0.40	2.60 ± 0.5 1	0.362	0.78
	Pooled	3.60 ± 0.24	3.83 ± 0.48	3.40 ± 0.25	4.00 ± 0.63	0.346	0.79
Diversity*	1991	0.88 ± 0.10	0.94 ● 0.20	0.88 ± 0.12	0.89 ± 0.23	0.028	0.99
	1992	0.55 ± 0.17	0.84 ± 0.13	0.76 ● 0.09	0.70 ● 0.19	0.694	0.57
	Pooled	0.96 ● 0.14	1.02 ± 0.21	0.89 ± 0.13	1.06 ± 0.05	0.214	0.89
Evenness	1991	0.77 ± 0.09	0.76 ± 0.12	0.76 ± 0.09	0.65 ± 0.17	0.210	0.89
	1992	0.61 ± 0.17	0.84 ± 0.04	0.87 ± 0.07	0.67 ± 0.17	0.936	0.45
	Pooled	0.74 ± 0.09	0.72 ± 0.13	0.73 ± 0.08	0.81 ± 0.05	0.173	0.91

*One-way ANOVA F-value.
'Probability associated with one-way ANOVA F-value.
*Shannon's diversity index (Shannon and Weaver 1963)

Table 4– *Sorensen's similarity indices (Mueller-Dombois and Ellenberg 1974) for small mammal communities in Ecosystem Management research stands in the Ouachita Mountains of Arkansas by future treatments and physiographic zones. 1991-92*

Analysis	Comparison	Similarity index (percent)
Future treatments	Clearcut-single tree selection	92.3
	Clearcut-shelterwood	90.9
	Control-single tree selection	85.7
	Control-shelterwood	83.3
	Single tree selection-shelterwood	83.3
	Control-clearcut	76.9
	Group selection-clearcut	76.9
	Group selection-single tree selection	71.4
	Group selection-shelterwood	66.7
	Group selection-control	57.1
Physiographic zones	South-West	87.5
	North-East	80.0
	North-South	76.9
	North-West	76.9
	South-East	61.5
	East-West'	61.5

DISCUSSION

Small mammals play an important role in several ecological processes of forested communities and can be greatly influenced by forest management activities. To effectively evaluate the impacts of imposing specific treatments on forest stands, pretreatment conditions relative to small mammal abundance and community composition should be as similar as possible. In this study, no differences were found in small mammal relative abundance, richness, diversity, or evenness by physiographic region, and with only one exception, no differences were found in these same parameters by future treatment. Thus, future analyses of posttreatment data should not be confounded by pretreatment differences in respect to small mammal community composition and stand location (physiographic zone).

Though differences in trap types and trapping methodologies prevent direct comparisons with other studies, all stands sampled in this study appeared to be characterized by a relatively low density and diversity of small mammals. Several studies have shown that small mammal abundance and diversity is influenced by successional vegetation patterns and structural habitat characteristics (Goodwin and Hungerford 1979; Kirkland 1977, 1990; McComb and Noble 1980; Mengak and others 1989a, 1989b). In general, early successional seres are characterized by higher small mammal abundance and diversity than later seres, as well as differences in species composition.

Small mammal abundance, diversity, and species composition is often positively related to understory cover and down woody material. Stands in this study generally had very little down woody material (averaging 3.3 percent ground coverage), and the percentage of cover was low (averaging 0.3 to 2.3 percent) for woody plants, forbs, and graminoids (Thill and others 1994). Numerical and compositional responses of small mammals following treatments will most likely reflect associated increases in the above habitat parameters. The magnitude and temporal characteristics of these responses will probably vary by treatment, and total numbers of some species may increase substantially. Though increasing sampling intensity during pretreatment trapping did not increase trapping success, retaining two traps per station will probably be necessary to sample increased small mammal populations following certain treatments.

The three most commonly captured species in this study represented three different trophic groups: insectivores (*Blarina carolinensis*), granivores (*Ochrotomys nuttalli*), and omnivores (*Peromyscus* spp.). If sufficient numbers of additional species

Table 5– *Relative abundance (captures per 100 trap nights) of small mammals and the three most commonly captured species ($\bar{x}$ ± SE) in Ecosystem Management research stands in the Ouachita Mountains of Arkansas* ***by future*** *treatment, 1991-92*

Species	Year	Treatment					F	P†
		Clearcut	Shelterwood	Single-tree selection	Group selection	Control		
All species	1991	1.06 ± 0.23	3.90 ± 1.62	4.77 ± 1.22	3.54 ± 1.54	*4.36 ± 0.88*	1.437	0.27
	1992	0.60 ± 0.11	1.30 ± 0.67	1.65 ± 0.31	1.39 ± 0.35	*1.31 ± 0.35*	0.95 1	0.46
	Pooled	0.83 ± 0.15	2.60 ± 0.95	3.21 ± 0.83	2.47 ± 0.84	*2.83 ± 0.73*	1.475	0.23
Peromyscus spp.‡	1991	0.55 ± 0.16	2.57 ± 1.61	1.45 ± 0.62	2.06 ± 1.00	1.41 ± 0.32	0.704	0.60
	1992	0.37 ● 0.13	0.88 ± 0.50	1.04 ± 0.29	0.78 ± 0.29	0.84 ± 0.28	0.614	0.66
	Pooled	0.46 ± 0.10	1.73 ± 0.84	1.25 ± 0.32	1.42 ± 0.54	1.13 ± 0.23	0.942	0.45
Blarina carolinensis	1991	0.46 ± 0.12	0.74 ± 0.37	2.16 ± 1.08	0.47 ± 0.18	2.32 ± 1.22	1.508	0.25
	1992	0.18 ± 0.07	0.19 ± 0.08	0.28 ± 0.12	0.42 ± 0.09	0.38 ± 0.11	1.280	0.32
	Pooled	0.32 ± 0.08	0.46 ● 0.21	1.22 ● 0.62	0.45 ± 0.10	1.35 ± 0.68	1.298	0.29
Ochrotomys nuttalli	1991	0.23 ± 0.18	0.48 ± 0.36	0.67 ± 0.3 1	0.72 ± 0.42	0.33 ● 0.15	0.486	0.75
	1992	0.00 ± 0.00	0.14 ± 0.09	0.14 ± 0.09	0.10 ● 0.10	0.05 ± 0.05	0.676	0.62
	Pooled	0.12 ± 0.09	0.31 ± 0.18	0.41 ± 0.18	0.41 ± 0.23	0.19 ± 0.09	0.629	0.65

*One-way ANOVA F-value.
†Probability associated with one-way ANOVA F-value.
‡Includes *P. leucopus, P. gossypinus, P. maniculatus,* and *P. attwateri.*

Table 6– *Species richness, diversity, and evenness ($\bar{x}$ ± SE) in Ecosystem Management research* ***stands*** *in the Ouachita Mountains of Arkansas* ***by future*** *treatment, 1991-92*

Variable	Year	Treatment					F*	P†
		Clearcut	Shelterwood	Single-tree selection	Group selection	Control		
Richness	1991	3.25 ● 0.25	2.75 ± 0.25	3.50 ● 0.50	3.00 ± 0.71	4.25 ● 0.75	1.152	0.37
	1992	2.00 ± 0.00	2.50 ± 0.87	3.00 ● 0.41	2.75 ± 0.25	2.50 ± 0.29	0.647	0.64
	Pooled	3.25 ● 0.25	3.40 ± 0.40	4.25 ± 0.48	3.50 ± 0.29	4.25 ± 0.75	1.062	0.41
Diversity’	1991	1.03 ± 0.06	0.82 ± 0.21	0.97 ● 0.06	0.76 ± 0.26	0.93 ± 0.26	0.328	0.89
	1992	0.62 ● 0.04	0.48 ± 0.28	0.88 ± 0.10	0.86 ± 0.12	0.73 ± 0.14	1.167	0.36
	Pooled	1.04 ± 0.11	0.90 ± 0.22	1.13 ± 0.12	0.99 ● 0.07	0.87 ± 0.23	0.360	0.83
Evenness	1991	0.88 ± 0.03	0.77 ± 0.17	0.81 ± 0.08	0.59 ● 0.20	0.62 ± 0.11	0.875	0.50
	1992	0.89 ± 0.06 *A*	0.34 ± 0.20 *B*	0.84 ± 0.05 *A*	0.86 ± 0.06 *A*	0.80 ± 0.10 *AB*	*4.212*	*0.02*
	Pooled	0.88 ± 0.04	0.70 ± 0.16	0.79 ± 0.05	0.80 ± 0.04	0.59 ± 0.10	1.196	0.35

*One-way ANOVA F-value. Means within rows followed by unlike letters are statistically different ($P < 0.05$).
‘Probability associated with one-way ANOVA F-value.
*Shannon’s diversity index (Shannon and Weaver 1963).

are captured during posttreatment sampling, changes in community structure relative to trophic groups will be of interest, particularly in respect to fungi- and seed-consuming species due to their potential effects on natural regeneration.

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LITERATURE CITED

Baker, J.B. 1994. An overview of stand-level ecosystem management research in the Ouachita/Ozark National Forests. In: Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings. 1993. October 26-27: Hot Springs, AR. Gen. Tech. Rep. New Orleans LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Goodwin, John G., Jr.; Hungerford, C. Roger. 1979. Rodent population densities and food habits in Arizona ponderosa pine forests. Res. Pap. RM-214. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p.

Hat-low, Richard F.; Van Lear, David H. 1981. Silvicultural effects on wildlife habitat in the South (an annotated bibliography): 1953-1979. Tech. Pap. 14. Clemson, SC: Clemson University Department of Forestry. 30 p.

Harlow, Richard F.; Van Lear, David H. 1987. Silvicultural effects on wildlife habitat in the South (an annotated bibliography): 1980-1985. Tech. Pap. 17. Clemson, SC: Clemson University Department of Forestry. 42 p.

Kirkland, Gordon L., Jr. 1977. Responses of small mammals to the clearcutting of northern Appalachian forest. Journal of Mammalogy 58: 600-609.

Kirkland, Gordon L., Jr. 1990. Patterns of initial small mammal community change after clearcutting of temperate North American forests. Oikos. 59(3): 3 13-320.

Maser, Chris; Anderson, Ralph G.; Cromack, Kermit, Jr. [and others]. 1979. Dead and down woody material. In: Thomas, Jack Ward, tech ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture: 78-95. Chapter 6. In cooperation with: The Wildlife Management Institute; U.S. Department of the Interior, Bureau of Land Management.

McComb, W.C.; Noble, R.E. 1980. Small mammal and bird use of some unmanaged and managed forest stands in the mid-South. In: Proceedings of the 34th Annual Conference of the Southeastern Association of Fish and Wildlife Agencies. 482-49 1.

Mengak, Michael T.; Guynn, David C., Jr.; Van Lear, David H. 1989a. Ecological implications of loblolly pine regeneration for small mammal communities. Forest Science 35(2): 503-514.

Mengak, Michael T.; Van Lear, David H.; Guynn, David C., Jr. 1989b. Impacts of loblolly pine regeneration on selected wildlife habitat components. In: Miller, J.H., comp. Proceedings of the 5th biennial southern silvicultural research conference. Gen. Tech. Rep. SO-74. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 612-618.

National Council of the Paper Industry for Air and Stream Improvement, Inc. 1993. Forestry, wildlife, and habitat in the East (an annotated bibliography), 1986-1990. In: Sweeny, S.R.; Wigley, T.B., comps. Tech. Bull. 651. 3 17 p.

Pank, L.F. 1974. A bibliography on seed-eating mammals and birds that affect forest regeneration. Spec. 174. U.S. Department of the Interior, Fish and Wildlife Service. 28 p.

Mueller-Dombois, D.; Ellenberg, H. 1974. Aims and methods of vegetation ecology. New York: John Wiley and Sons.

Smith, C.F.; Aldous, S.E. 1947. The influence of mammals and birds in retarding artificial and natural regeneration of coniferous forests of the United States. Journal of Forestry. 45: 361-369.

Shannon, C.E.; Weaver, W. 1963. The mathematical theory of communication. Urbana, IL: University of Illinois Press. 177 p.

Thill, R.E.; Tappe, P.A.; Koerth, N.E. 1994. Wildlife habitat conditions in mature pine-hardwood stands in the Ouachita/Ozark National Forests. In: Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings. 1993. October 26-27: Hot Springs, AR. Gen. Tech. Rep. New Orleans LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Ursic, S.J.; Esher, R.J. 1988. Influence of small mammals on stormflow responses of pine-covered catchments. Water Resources Bulletin. 24: 133-139.

Southern Flying Squirrels in Mature Pine/Hardwood Stands in the Ouachita and Ozark National Forests of Arkansas[1]

James F. Taulman and Ronald E. Thill[2]

ABSTRACT

The southern flying squirrel (*Glaucomys volans*) was chosen as a representative forest-dependent mammal for examination in this study imposing a variety of habitat-altering management techniques. Considering its habitat requirements, the flying squirrel should be very responsive to changes in forest structure, density of cavity trees, and availability of hard mast, Goals of this research on the mature pine-hardwood forest type were to gather baseline data on flying squirrel population demographics, including reproductive success; to identify any habitat features influencing squirrel habitat use; to investigate any differences in groups of stands according to future treatment type or replicated group; and to identify ectoparasites associated with flying squirrels.

During fall 1992,630 nest boxes were constructed and installed on 21 mature stands comprising 3 replications of 6 different proposed cutting treatments plus 3 controls. Boxes were checked once each in January, February, and March 1993. Ninety-one adult and 27 juvenile squirrels were marked on 16 stands; five stands yielded no squirrels. The mean number of marked squirrels per stand was 5.6, and density averaged 0.37 per ha. The mean weight of nomnatemal adult squirrels was 67.45 g, and monthly mean weights did not differ from that value throughout the sampling period. Twenty-three maternity boxes had a mean of 1.96 squirrels per litter. Young were born between February 8 and March 13. Thirty-four non-maternity boxes contained a mean of 2.8 adults per box. Two maternal females shared nest boxes with other adults. A maximum of six squirrels was found in one box. Fifty-four nests (constructed predominately of shredded eastern redcedar [*Juniperus virginiana* L.] bark) were collected and dried, yielding 6 families of ectoparasites after a partial analysis.

Slope was negatively correlated with numbers of marked squirrels across all stands. Numbers of pines in the lower midstory diameter class (8.9 to 16.6 cm in d.b.h.) were negatively correlated with the numbers of marked squirrels and significantly fewer in macroplots containing nests compared with macroplots across all stands. Habitat variables did not differ between stands grouped by future treatment, and only azimuth differed between stands grouped by replicated subset.

INTRODUCTION

Growing public awareness of, and concern over, habitat destruction and species declines and extinctions worldwide has resulted in a shift to a more ecological approach to management of national forests in the United States. The U. S. Department of Agriculture, Forest Service has initiated a large-scale, replicated, interdisciplinary study in Arkansas to compare ecological and financial aspects of several silvicultural treatments as alternatives to clearcutting. While population responses of birds and mammals to even-aged harvesting techniques (primarily clearcutting) have been investigated (Harlow and Van Lear 1987, Smith and Petit 1988), little is known of the effect of uneven-aged silviculture on forest wildlife (Thill and others 1992).

The Ecosystem Management Research Program of the USDA Forest Service includes a research venture in which alternative silvicultural practices are being evaluated under rigorous scientific scrutiny. In Arkansas, researchers with the USDA Forest Service, Southern Forest Experiment Station and the Ouachita and Ozark National Forests are cooperating to meet the Ecosystem Management goals through a three-phase approach. Under Phase II of this project, an array of 12

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partial cutting treatments ranging from pine-hardwood single-tree selection to clearcut, plus an uncut control, were replicated in four forest zones. Stands were selected for the study from a pool that conformed to a range of criteria (see Baker 1994). Seven research groups will monitor various economic and ecological parameters before and after treatment at the stand level to provide data on the relative merits and ecological effects of each cutting method. Pretreatment data were collected on the replicated Phase II stands during 1992 and the spring of 1993. All experimental stands were harvested during the summer of 1993.

This study design affords the opportunity to monitor populations of a forest-dependent mammal in a concurrent comparison of matched groups of control and experimental stands both before and after harvest, as suggested by Eberhardt (1976), thus eliminating the problem of unknown environmental factors, such as weather, causing observed changes in experimental variables (Eberhardt and Thomas 1991). This report presents pretreatment results from the first year of a 3-year study of flying squirrel demographics and habitat features on a subset of 21 mature stands within this larger study.

Flying squirrels are common inhabitants of pine-hardwood forests in the Southern United States (Goertz and others 1975). Because G. *volans* glides as a primary means of escape and travel, habitat needs include trees of considerable height and a relatively open midstory (Bendel and Gates 1987). High-use areas also have been found to be characterized by a fairly dense understory shrub layer (0.5 to 3.0 m in height) in both flying squirrels (Bendel and Gates 1987, Jordan 1948, Sonenshine and Levy 1981) and gray squirrels (*Sciurus carolinensis*) (Fischer and Holler 1991). The shrub layer provides foraging cover and soft mast during summer before acorns and hickory nuts are available (Sonenshine and Levy 1981). Southern flying squirrels are omnivorous (Harlow and Doyle 1990) but rely heavily on hard mast (seeds, hickory nuts, and acorns) throughout the year (Braun 1988, Sawyer and Rose 1985, Sealander and Heidt 1990, Sollberger 1943). Hard mast provides an energy-rich storable food source that minimizes foraging trips during winter (Weigl 1978).

Because flying squirrels move inefficiently in cleared areas within forests, Bendel and Gates (1987) emphasized the importance of forest structure to squirrel escape behavior. They suggested that clearings more than 75 m wide may be the limit of a successful glide and, therefore, may be avoided by flying squirrels. If that is true, clearcuts may be effective barriers to dispersal and movement. Knowledge of the amount of structural alteration that a flying squirrel population will tolerate in a mixed pine-hardwood ecosystem may provide implications for the overall suitability of the stand for other species of mammals, particularly gray squirrels and fox squirrels (*S. niger*), which consume similar foods and are also tree nesters (Fischer and Holler 1991, Kantola and Humphrey 1990, Sealander and Heidt 1990).

Plying squirrels form nesting aggregations during winter that reduce metabolic stresses associated with thermoregulation (Stapp and others 1991). The size of aggregations is inversely correlated with ambient temperatures (Goertz and others 1975; Muul 1968, 1974; Sawyer and Rose 1985). Since flying squirrels do not excavate their own tree cavities, den trees and snags are critical habitat components (Bendel and Gates 1987, Doby 1984, Gilmore and Gates 1985, Loeb 1993, Muul 1974, Sawyer and Rose 1985, Weigl 1978). The scarcity of suitable nest sites has been suggested as a possible cause for increased interspecific aggression between flying squirrels and other cavity-nesting species such as gray squirrels (Doby 1984), red squirrels (*Tamiasciurus hudsonicus*) (Muul 1968), and woodpeckers (Conner and Rudolph 1989, Stabb and others 1989). The conflict between flying squirrels and red-cockaded woodpeckers (*Picoides borealis*, RCW) over available cavities is apparently severe because both species prefer cavities with small entrances (Loeb 1993). Where they occur together, flying squirrel use of RCW cavities has reached levels of 21 percent (Loeb 1993) and 25 percent (Dennis 1971).

Questions addressed in this first year's research were: (1) What are the population dynamics of flying squirrels in the mature habitat type represented by this group of study areas?, (2) In what densities do squirrels occur on these stands?, (3) What is the reproductive rate of local populations of flying squirrels?, (4) Do any forest habitat variables of interest differ with respect to future treatment group or by replicated subset?, (5) Do any of these habitat variables appear to be critical to squirrel nest-site selection?, and (6) What ectoparasites are associated with flying squirrels in this habitat type?

METHODS

Study Area Layout

Three replications of seven treatments (control, pine-hardwood single-tree selection, pine single-tree selection, pine-hardwood shelterwood, pine shelterwood, pine-hardwood seed tree, and pine seed tree) were selected for this study (fig. 1). During September 1992, 630 nest boxes (30 boxes per stand on 21 stands) were installed at a height of 3 to 4 m on trees scheduled to be retained after cutting. Box trees were selected to form a grid with 60-m spacing between trees and rows. A 60-m buffer zone was retained around the outside of the grid to approximate one-half the mean maximum distance moved (MMDM) and to allow for density estimation from grid captures using the stand area without creating an inflationary bias (Wilson and Anderson 1985). Where habitat macroplots (see explanation below) were available, a box was placed on

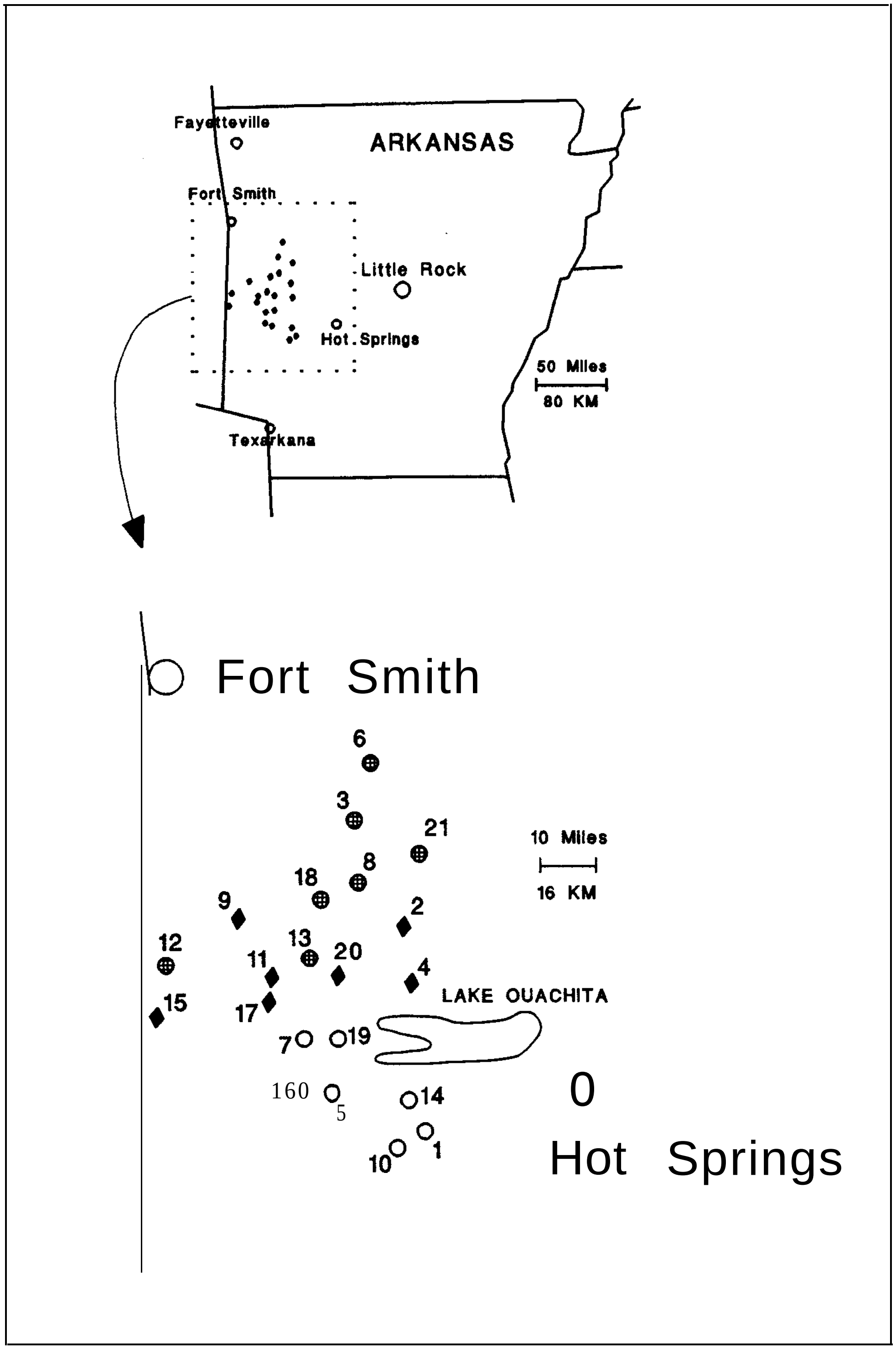

Figure 1.—*Approximate locations of the 21 experimental stands in the Ouachita mountains of western Arkansas. Stand numbers correspond to treatment numbers in Table 1. Stands in the same replicated treatment group denoted by similar icons, i.e. hatched circle, filled diamond, or open circle.*

a tree within the plot. That tree was then substituted for the nearest gridpoint tree. Only habitat plots inside a 60-m buffer zone from the stand boundary were used. Of the 14 macroplots in each stand, a mean of 8.4 plots per stand (SE = 0.40) contain box trees. Figure 2 shows a typical stand layout and distribution of box trees,

Habitat Measurements

Fourteen habitat macroplots were established in each stand, 12 in the treatment area and 2 in greenbelt (uncut strips along ephemeral creek channels). Each macroplot consists of an 11.3-m-radius (0.04 ha) circle containing 2 nested 4 by 8 m (0.006 ha) rectangular subplots. Pretreatment measurements were taken on all woody vegetation within 294 macroplots across 21 stands from July to December 1992 (Guldin and others, 1994). Squirrel boxes were located on trees in 169 of these macroplots. The 14 macroplots per stand (0.6 ha per stand) proved to be an inadequate area to accurately account for snag density. Therefore, additional snag data collected on the 9 stands comprising the future control, PH/STS, and PH/SW treatments were used in the analysis. Snags weretallied along parallel 15-m wide strips averaging 1,328 m through each stand and covering an average 2.0 ha per stand. In additian, estimates of horizontal vegetative density were made on the same 9 stands at 30 random points along the 15-m wide strips. The percentage of horizontal foliage cover on a 0.5-m-square checkerboard was estimated from 15 m away at elevations of 0.25, 1.0, and 2.0 m.

In order to investigate the effect of adjacent habitat condition on squirrel populations in study areas, vegetative types at the four cardinal directions from each study area were characterized as (1) mature pine-hardwood forest, (2) immature plantation (<20 years since harvest), or (3) pasture. Ground reconnaissance and low-level aerial photographs were used to determine adjacent habitat characteristics. Using the combined categories for the four adjacent habitats, each stand was given a rank from 1 to 12 based on the similarity of the surrounding areas to the mature stand type (1 = most similar. 12 = most different).

Nest Box Monitoring

Nest boxes were checked during January, February, and March 1993. All adult squirrels captured were marked with two numbered metal ear tags, weighed, sexed, examined for reproductive condition, and released at the point of capture. Because of their small size, juveniles less than 5 weeks old were returned to the nest untagged. We did not toe clip young for identification because the magnitude of any possible resulting reduction in fitness was unknown. A tissue sample was collected from each squirrel and stored in 95 percent ethanol to permit later genetic evaluation of kinship between nestmates. When possible, fresh fecal samples were collected. After the third survey in March, entrance holes were covered, and any nests present were removed. Mothers with young under 8 weeks of age were returned to the nest; those boxes were closed in April and the remaining nests were collected. Boxes will remain closed for 7 months to minimize the effect of artificial nesting habitat on squirrel use of experimental stands.

Data Analysis

The Kruskal-Wallis one-way ANOVA was used to analyze habitat variables and numbers of marked squirrels on each of the 21 mature stands in subsets grouped by future treatment (3 stands each) and by 7-treatment replicated sets. The Mann-Whitney U test was used to compare means of habitat variables for stands with and without squirrels. The Mann-Whimey U test was also used to test for mean variable differences between macroplots in which squirrels nested and macroplots across all stands. Habitat variables on stands with and without squirrels were subjected to logistic regression. Spearman rank-order correlations were calculated for all variable means across the 21 stands. Adjacent habitat rankings were compared with numbers of marked squirrels on study areas usingSpearman rank-order correlation. All statistical tests were performed using CSS:Statistica (Statsoft c1991).

RESULTS AND DISCUSSION

Abundance and Nest Box Use

One hundred and eighteen squirrels (91 adults, 27 juveniles) were captured and marked on 16 stands; 16 additional juveniles observed when too young to mark, were subsequently moved by their mothers and not seen again. Five stands yielded no squirrels (table 1). Squirrels constructed nests in 56 boxes on 16 stands ($\bar{x}$ = 3.5 nests per stand, SE = 0.89). Excluding maternal nests, thirty-four boxes with nests were occupied by adult squirrels when checked, yielding a total of

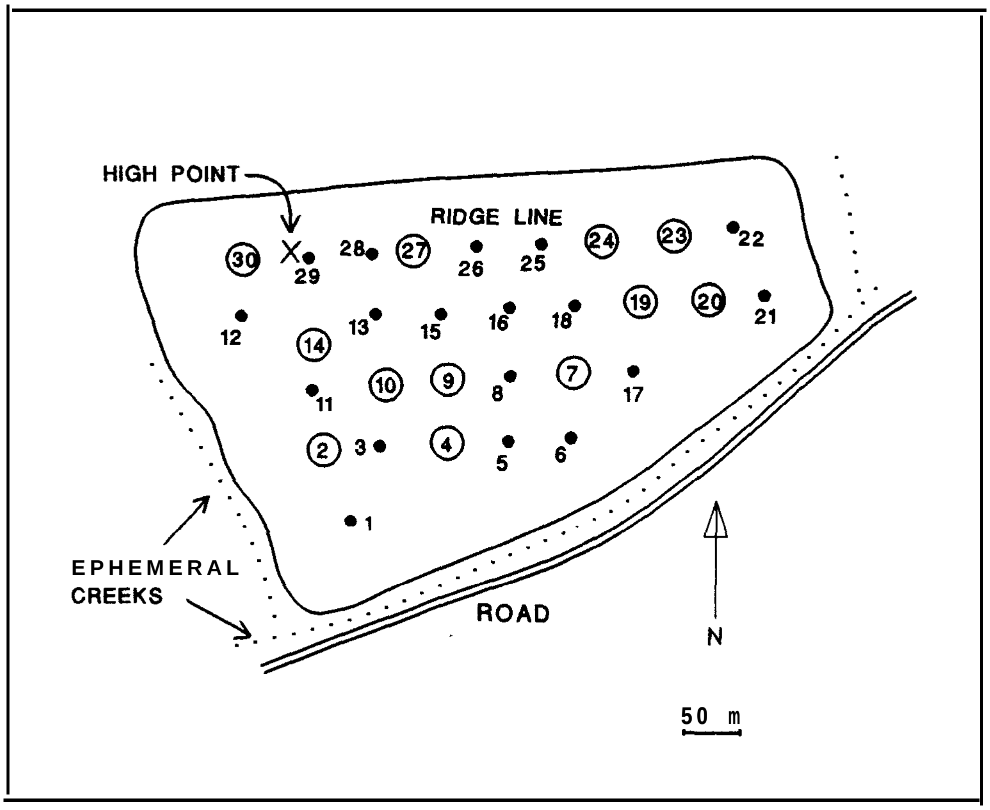

Figure *2.-Typical stand* ***layout*** *showing 60 x 60-m grid with 30 numbered trees containing squirrel nest boxes. Encircled numbers* ***indicate*** *a box tree in an 11.3 m-radius habitat* ***macroplot.***

96 squirrels ($\bar{x}$ = 2.8 adults per box, SE = 0.237). A maximum of six squirrels was found in one box. While no completely formed nests were found on the five stands without squirrels, one to five boxes on four of the stands showed evidence of squirrel presence such as balls of shredded eastern redcedar or acorn and hickory nut hulls. One hundred and forty-three boxes showed signs of squirrel use (1.57 boxes per adult squirrel). Fifty-six contained platform or chamber nests, 22 held incompleted nests, and 65 contained acorn and/or hickory nut hulls and had evidently beeused as feeding stations. Increasing box use on study areas was positively correlated with the numbers of marked adult squirrels (r_s = 0.74, P = 0.0001, N = 21). There were 1.62 adult squirrels marked per observed nest.

Weights of adult males and nonmaternal females averaged 67.45 g (SE = 0.85, N = 86) and monthly mean weights did not vary significantly over the sampling period, whether compared as a combined group (fig. 3) or separately (table 2). Weights of maternal females averaged 86.96 g (SE = 1.14, N = 48) and also did not vary over the sampling period when monthly means were compared to the mean weights of all maternal squirrels (Chi-square = 0.148, P = 0.98, Table 2). The mean weight of maternal females actually increased about 4 g in April over the weight in January, indicating that nursing females were generally able to maintain body mass throughout the nursing period.

Of the flying squirrels captured and marked in 1993, 11 percent were marked in January, 40 percent in February, and 47 percent in March. The 27 young were added to the population during February and March, but 40 and 35 new adults, respectively, were also marked during those months. While only 12 maternity boxes were left open after March, 3 additional new adults (2 percent of the total marked) were observed and marked when those boxes were closed in April, Because substantial numbers of new squirrels appeared during the second and third surveys, the total number of marked squirrels is considered a conservative population estimator, probably underestimating the local population of squirrels using each stand, particularly considering that 18 young squirrels and several adult escapees were observed but not marked. The total number of marked squirrels may, in this case, be the best local population estimate.[3] The "Jolly" open population estimator (Pollock and others 1990) was not applicable to these data because of the small number of sampling occasions.

The number of marked squirrels and stand area were used to calculate squirrel density (Table 1). Nineteen squirrels were recaptured in boxes different from those in which they were originally observed. The mean maximum distance moved (MMDM) was 105 m (SE = 12.55, N = 19). The buffer zone of 60 m around the grid of box trees within the stand boundary very closely approximated one-half the MMDM, a compensator for edge effect suggested by Wilson and Anderson (1985). Though the density of flying squirrels on this set of similar stands ($\bar{x}$ = 0.37 per ha, SE = 0.10, N = 21) might seem low compared to those ranging from 1.1 to 12.0 per ha reported elsewhere (Burt 1940, Jordan 1948, Muul 1968, Sollberger 1943, Stojeba 1978), no studies have investigated flying squirrel population density and abundance in habitats closely matching conditions present in this study. Apparently, the structure of the stands under investigation here (predominately pine with scattered hardwood on upland south slopes) constitutes a minimal level of one or more critical habitat features required by southern flying squirrels. Indeed, this may also be the case for other small mammals as well. In a separate study of small mammals on 9 of these and 11 other similar stands (20 total), Tappe and others (1994) trapped each stand for a mean of 524 adjusted trap nights (TN, subtracting snapped empty traps) in 1991 and 1,068 adjusted TN in 1992. In 1991, only three species of small mammals were captured in mean frequencies higher than one individual per stand (0.06/ha). One of those, ***Peromyscus*** spp., included ***P. leucopus, P. gossypinus, P. maniculatus***, and ***P. attwateri*** lumped together because of the diiculty in field identification. Mean numbers of each species captured per stand across the 20 trapped stands were ***Peromyscus*** spp. 8.5 (SE = 2.15), ***Ochrotomys nuttalli*** 2.6 (SE = 0.67), and ***Blarina carolinensis*** 6.4 (SE = 1.85). In 1992, only two species were captured in greater mean densities than one per stand: ***Peromyscus*** spp. 4.8 (SE = 0.91), and ***B. carolinensis*** 1.6 (SE = 0.23). Considering these results, the mean of 5.6 flying squirrels per stand observed in this study suggests that flying squirrels occur in these stands in frequencies compamble to the most numerous forest-floor small mammals, or at least that nest boxes capture flying squirrels at rates similar to the sampling of forest-floor small mammals using Sherman live traps.

In 8 instances, females moved from boxes that they had occupied alone or shared with other squirrels to establish a maternity box. Mean dispersal distance was 92.5 m (SE = 14.36, N = 8). In one other instance, a female remained in the box she had previously shared with other adults after the other squirrels moved out. In addition to females dispersing to establish a maternity box, 11 other adults were recaptured in boxes other than those in which they were first observed. Mean distance for those movements was 115 m (SE = 19.09). Thirty-one adults were recaptured once, 7 others were captured twice. On two occasions during the survey period, groups of six and five squirrels, respectively, having shared boxes for 1 to 2 months, vacated them. Some were recaptured in other boxes; others were not seen again. The nesting material in both abandoned boxes was wet, muddied, and compacted. Squirrels which were not recaptured in other boxes presumably relocated to natural cavities. Madden (1974), Muul (1968), and Stojeba (1978) concluded that southern flying

[3] Hines, J.E. 1993. U.S. Fish and Wildlife Service. Personal communication with author dated October 1, 1993.

squirrels in New York, Michigan, and Arkansas, respectively, vacated nests that had become dirty and flea infested.

While it might be argued that nest-box-use data reported here could have resulted from immigration of squirrels onto the experimental stands during the survey period, the following evidence suggests that the new squirrels observed during each survey period were probably either residents on experimental stands or were squirrels whose home ranges overlapped the study areas:

(1) The fact that squirrels found boxes indicates that the home ranges of captured squirrels at least overlapped onto experimental stands.

(2) Doby (1984) considered the fact that southern flying squirrels in hardwood forests of North Carolina used nest boxes "almost immediately" after installation as evidence supporting the hypothesis that nesting cavities were in short supply due to intense competition with gray squirrels. Only 11 percent of the total number of squirrels marked in this study were captured during the first survey in January, two months after boxes had been installed. Squirrels first seen during the second and third surveys may have started the winter in established cavities and selected boxes after the first nests became soiled.

(3) A Spearman rank-or&r correlation test of the relationship between the number of marked squirrels on a study area and the increasing dissimilarity of the surrounding habitat to the mature forest type yielded a weak positive correlation (r_s = 0.382, P = 0.088, N = 21). Stands with less suitable surrounding squirrel habitat (pasture or young plantation) seemed to have larger squirrel populations. Just the opposite would presumably be the case were squirrels immigrating onto study areas from surrounding stands.

(4) The dynamics of flying squirrel cavity use apparently include multiple refugia throughout the home range to which squirrels can flee for protection or which can serve as auxiliary nesting sites (Fridell and Litvaitis 1991, Gilmore and Gates 1985, Heidt 1977, Muul 1968, Stone 1993). In this study, released squirrels often glided directly to den trees or snags and entered cavities, corroborating the supposition of preexisting natural refugia which were augmented by nest boxes. Mull (1968) observed individual flying squirrels enter as many as 9 different natural cavities when pursued through their home ranges. The rather low box use frequency of 1.57 boxes per adult squirrel reported here would also suggest that other natural refugia were avaiable to squirrels on these study areas. A similar defensive strategy is employed by hoary marmots (*Marmota caligata*), the largest North American ground squirrel. Hoary marmots maintain many auxiliary burrows throughout their home range which are used as refugia for marmots foraging nearby. Tauhnan (1990) found that one group, ranging from 7 to 12 marmots, defended a territory of 12 ha in Washington on which they maintained 71 burrows, only 4 of which were used for sleeping. Foraging marmots ran to the nearest burrow when alarmed or threatened.

Since flying squirrels often nest on the periphery of their home ranges (Bendel and Gates 1987; Stone 1993), nest boxes may allow squirrels to use part of a harvested study area for nesting, even though they might forage predominantly in uncut greenbelt areas or in adjacent stands. Telemetry data on collared squirrels gathered during the summers of 1994 and 1995, when boxes will be closed, will answer questions about squirrel range and habitat use on control and treated stands without any possible bias from additional artificial nesting habitat.

Reproductive Demographics

Twenty-three boxes were used as maternity nests. A total of 45 young were observed ($\bar{x}$ = 1.96 per litter, SE = 0.117, N = 23). The sex ratio of young (21♂ to 20♀) was not significantly different from the sex ratio of adults (40♂ to 51♀) (2 x 2 contingency table test, Chi-square = 1.24, P = 0.27). Young were marked and released from 14 of those nests after reaching at least 8 weeks of age: mothers and young vacated 8 others before the young were old enough to mark.

Using the weight and length data for young flying squirrels from birth through 1 year reported by Linzey and Linzey (1979), birth dates for each of the 23 litters were estimated (fig. 4). Several of the litters were discovered only 1 or 2 days after birth. Birth dates tanged from February 8 to March 13 ($\bar{x}$ = February 25). Allowing for a 40-day gestation period (Sollberger 1943), the corresponding range of days during which conception occurred was between December 30 and February 1. These conception dates largely agree with other reports that have indicated dates of conception for flying squirrels during late January and early February in Arkansas (Heidt 1977, Stojeba 1978, Stone 1993) and northern Louisiana (Goertz and others 1975). Gihnore and Gates (1985) recorded conception dates in southern flying squirrels ranging from

Table I.- Summary of flying squirrels marked during spring 1993 in nest boxes on the 21 experimental stands grouped according to the 7 future treatments in the Ouachita Mountains of Arkansas

Treatment category*	Adults marked	Gender	Young marked	Gender	Total marked	Stand area (ha)†	Squirrel density (#/ha)
1 Cont	5	1♂ 4♀	7	36 4♀	12	14.9	0.81
2 Cont	6	26 4Q	3	2♂ 1♀	9	16.0	0.56
3 Cont	8	46 4♀	3	3♀	11	15.8	0.70
4 PH/STS	3	2♂ 1♀	0		3	16.1	0.19
5 PH/STS	16	9♂ 7♀	3	id 2♀	19	14.9	1.28
6 PH/STS	1	1♀	0		1	15.0	0.07
7 P/STS	3	16 2♀	0		3	16.0	0.19
8 P/STS	10	7♂ 3Q	2	16 1♀	12	15.6	0.77
9 P/STS	0		0		0	13.3	0
10 PH/SW	0		0		0	15.4	0
11 PH/SW	6	3♂ 3♀	2	1♂ 1♀	8	17.0	0.47
12 PH/SW	0		0		0	16.0	0
13 P/SW	3	26 1♀	0		3	15.2	0.20
14 P/SW	2	2♀	2	1♂ 1♀	4	16.5	0.24
15 P/SW	1	1♀	0		1	14.9	0.07
16 PH/ST	0		0		0	16.0	0
17 PH/ST	20	8♂ 12♀	4	4♀	24	14.5	1.66
18 PH/ST	0		0		0	15.5	0
19 P/ST	2	2Q	0		2	14.5	0.14
20 P/ST	1	1♀	1	1♂	2	16.6	0.12
21 P/ST	4	16 3♀	0		4	15.0	0.27
TOTALS	91	40♂ 51♀	27	14♂ 13Q	118	$\bar{x}$ = 15.5 SE = 0.19	$\bar{x}$ = 0.37 SE = 0.10

* Future treatment groups: Cont - control, PH/STS - pine-hardwood/single-tree selection, P/STS - pine/single-tree selection, PH/SW - pine-hardwood/shelterwood, P/SW - pine/shelterwood, PH/ST - pine-hardwood/seedtree, P/ST - pine/seedtree.

† Stand boundaries determined by ground traverse; mapping and subsequent calculation of stand area performed using Generic Cadd 6.0 (Autodesk Retail Products c1992).

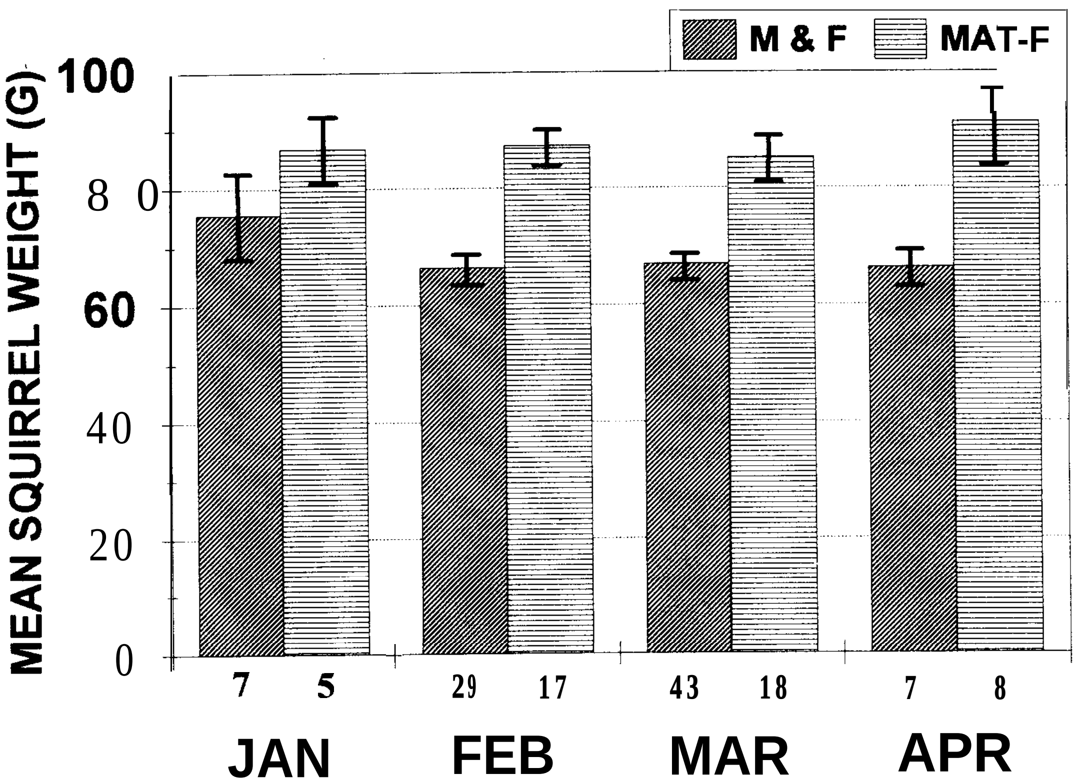

Figure 3.—*Mean weights ($\bar{x}$ ± 1 SE) for maternal females and other adult males and females during each month of the sampling period, January - April, 1993. Numbers below bars indicate numbers of squirrels used to calculate mean. M & F = all males and nonmaternal females combined, MAT-F = maternal females. Means for neither category were different across months (M & F chi-square = 1.01, P = 0.80, d.f. = 3; MAT-F chi-square = 0.148, P = 0.98, d.f. = 3).*

Table 2.—*Adult mean weights (g) of sexually active and inactive males and pregnant and nonpregnant females during the sampling period, January to April, 1993. Changes in proportions for each group across months were investigated with the chi-square test, using mean weight for sexually active and inactive males and nonmaternal females combined as the expected weight for those three groups, and the mean for maternal females as the expected weight for that group*

Gender	Sexually active	January	February	March	April	Mean weight	Comb. mean‡	Chi-square	Prob.
Male	no	63.00 (1.00)* 2†	64.44 (1.89) 9	65.39 (2.11) 18	63.67 (1.86) 3	64.81 (1.29) 32	67.45 (0.85) 86	0.705	P = 0.87
Male	yes	80.60 (2.75) 5	71.83 (2.82) 6	69.80 (1.18) 10	68.00 1	72.73 (1.42) 22	67.45 (0.85) 86	2.93’	P = 0.40
Female	no	0 0	65.50 (2.62) 14	67.00 (1.61) 15	68.33 (1.20) 3	66.47 (1.36) 32	67.45 (0.85) 86	0.07’	P = 0.96
Female	yes	86.80 (2.96) 5	87.12 (1.79) 17	85.06 (1.78) 18	91.00 (3.56) 8	86.96 (1.14) 48		0.15§	P = 0.98

* Standard error of mean.

† Number of squirrels used to calculate mean.

‡ Mean of weights of all sexually active and inactive males and nonmaternal females used as expected value to calculate chi-square for each of those groups.

§ Tbree degrees of freedom.

¶ Two degrees of freedom.

late February through early March in Maryland. Linzey and Linzey (1979) reported mating dates from mid-July through early January in southern Alabama.

Four different adult females, two of them maternal, were observed nesting with other adults. One lactating female and two young were captured together in a box with two adult males in February. In March, the female and males were recaptured, but the young were not present. Another maternal nest contained an additional adult female. That litter was apparently successful, as the maternal female, the second female, and the two 9-week-old juveniles were released and the box closed in April. These are apparently the first records of nest-sharing by maternal southern flying squirrels. Bendel and Gates (1987) found that the core activity areas of adult female home flying squirrels in Maryland did not overlap and that adult females did not share dens with other adults. Of four adult females (three of them maternal) tracked in New Hampshire by Fridell and Litvaitis (1991), core activity areas of two overlapped by 50 percent, though none shared nesting sites. Stapp (1991) also reported solitary nesting in captive maternal females following parturition. Mull(1968), Sollberger (1943), and Stone (1993) reported overlap of home ranges and sharing of nest boxes between adults, with the exception of brood nest defense by maternal females. Sollberger (1943) found that females with pups would kill strange adult males introduced into the cage.

Ecological Relationships

Descriptive statistics on numbers of flying squirrels and on habitat variables used in analysis of stand relationships are given in Table 3. Table 4 shows means for several habitat variables and numbers of marked squirrels by stands grouped according to future treatment. Mean totals across all 21 stands are given for each variable. Results of the Kruskal-Wallis one-way ANOVA show no differences in the means of any variables across the seven future treatment groups (table 4). Comparing means of all variables across replicated zones showed that only azimuth differed between groups of stands (table 5). The Mann-Whitney U test comparing means of habitat variables between stands inhabited by squirrels and those without showed no differences between the two groups for any variable. Based on logistic regression, none of the habitat variables were significantly associated with squirrel presence or absence.

Stem counts of upper and lower midstory hardwoods (16.7 - 24.2 cm in d.b.h. and 8.9 - 16.6 cm in d.b.h., respectively) tended to increase with increasing squirrel density (r_s = 0.39, P = 0.08, N = 21; and r_s = 0.37, P = 0.09, N = 21, respectively). Basal area of overstory hardwoods (oaks and hickories ≥ 24.3 cm in d.b.h.) was not correlated with squirrel numbers (r_s = -0.16, P = 0.50, N = 21). Hard mast production was not directly measured on these study areas, and it is possible that differences in mast crop success across experimental stands were partially responsible for the observed differences in squirrel population numbers. The average slope on each stand was negatively correlated with the number of marked squirrels (r_s = -0.480, P = 0.028, N = 21). The prevailing percentage slope of stands with squirrels (N = 16) tended to be lower than on stands without squirrels (N = 5) (U = 16.5, P = 0.052). Slope was again somewhat flatter in macroplots with nests (N = 12) compared with average slope of each stand across all areas (N = 21) (U = 76.5, P = 0.064). These results suggest a tendency for squirrel numbers to increase on a stand as average slope decreases.

Weigl and others (1989) found that food supply was the most critical factor limiting the distribution of fox squirrels in North Carolina. Where food resources declined below a certain level, fox squirrels "disappeared," regardless of the presence of other ecological necessities. Food resources may play an equally vital role in the use of habitat by southern flying squirrels.* While harvesting operations and other logistical limitations precluded hard mast surveys on pretreatment stands, mast surveys will be conducted during fall 1994 and 1995. Data on acorn and hickory nut production will provide an additional variable with which to better understand squirrel habitat use during 1995 and 1996.

Mean stem counts of lower midstory pines were negatively correlated with numbers of marked squirrels (r_s = -0.442, P = 0.045, N = 21), suggesting that stands with lower numbers of smaller pines and a relatively more open lower midstory canopy tended to have more squirrels. Comparing habitat means from plots across all stands (N = 21) with only macroplots that contained boxes with nests (N = 12) indicated that fewer pines in the lower midstory class (8.9 to 16.6 cm d.b.h.) were found in plots containing squirrel nests (U = 66, P = 0.024). Squirrel numbers tended to increase as snag densities increased (r_s = 0.57, P = 0.10, N = 9). Horizontal foliage density was not correlated with numbers of marked squirrels across the 9 sampled stands at any of the three vertical strata.

These results partially corroborate the findings of Bendel and Gates (1987) that flying squirrel habitat should include trees of considerable height and a relatively open midstory. The trend toward higher density of snags as squirrel population increases is consistent with the results of Bendel and Gates (1987), Doby (1984), Gilmore and Gates (1985), Muul (1974), Sawyer and Rose (1985), and Weigl (1978). While other reports have not investigated the influence of slope on squirrel

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[4] Weigl, P.D. 1993. Wake Forest University. Personal communication with author dated October 21, 1993.

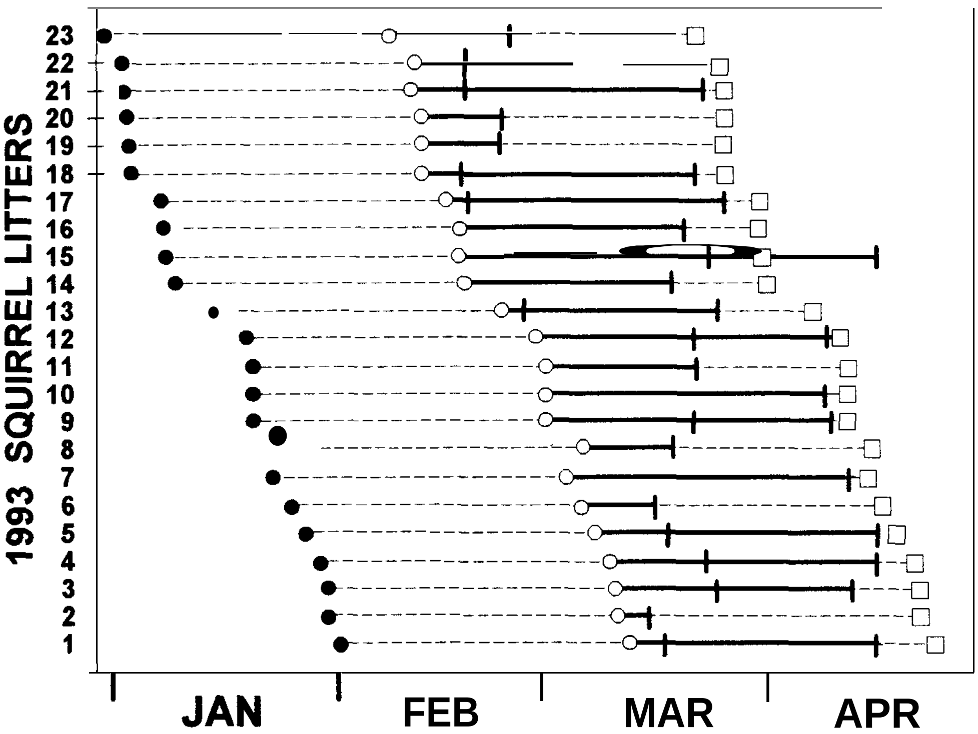

Figure *4.-Estimated dates of conception, birth, and weaning for each of 23 flying squirrel litters found in nest boxes during 1993. Vertical marks indicate dates on which litters were actually observed and handled. Length, weight, and general appearance were used to estimate birth dates according to the growth tables of Linzey and Linzey (1979). Conception dates were estimated at 40 days prior to birth, and dates for weaning were estimated at 6 weeks after birth (Sollberger 1943). Format of figure after Weigl and others (1989). Black circles represent estimated conception dates, open circles represent birth dates, and open squares represent estimated weaning dates at 6 weeks after birth.*

Table 3.—*Descriptive statistics for flying squirrel numbers and habitat variables across 21 mature stands*

Variable[a]	Mean	SE	Minimum	Maximum
Marked squirrels	5.62	1.46	0	24.0
Slope	10.63	0.87	6.0	19.20
Azimuth	184.0	7.94	128.0	256.0
BA pine	80.48	1.89	67.50	97.86
BA hardwood	11.56	1.42	1.07	31.10
PINECTLG	3.62	0.50	0.80	10.21
PINECTSM	4.26	0.51	0.71	10.50
HDWDCTLG	2.75	0.19	1.00	4.29
HDWDCTSM	12.0	0.66	6.50	17.64
TRREHTMN	22.09	0.36	19.30	24.70
TREEAGMN	62.84	1.29	55.0	84.10

[a] Variable descriptors: Habitat means based on measurements taken at 14 - 0.04 ha macroplots per stand. BA pine - basal area of pine trees ≥ 24.3 cm in d.b.h., BA hardwood - basal area of hardwood trees ≥ 24.3 cm in d.b.h., PINECTLG -mean numbers of pine stems 16.7 - 24.2 cm in d.b.h. in macroplots. PINECTSM - mean numbers of pine stems 8.9 -16.6 cm in d.b.h. in macroplots, HDWDCTLG - mean numbers of hardwood stems 16.7 - 24.2 cm in d.b.h. in macroplots, HDWDCTSM - mean hardwood stems 8.9 - 16.6 cm in d.b.h. in macroplots, slope - mean of 14 measurements per stand taken in degrees at the center of each macroplot, azimuth - measured in degrees similarly to slope, TRREHTMN - mean height (m) of dominant pines across all stands (one in each of 14 macroplots per stand), TREEAGMN - mean age of dominant pines (one in each macroplot).

Table 4.—*Means and standard errors for numbers of flying squirrels and habitat variables grouped by future treatments (three stands each). Kruskal-Wallis one-way ANOVA results with P-level shown at right*

Habitat variables†	1 CONT	2 PH/STS	3 P/STS	4 PH/SW	5 P/SW	6 PH/ST	7 P/ST	Kruskal-Wallis H, d.f. = 6, N = 21	Probability‡
	Future treatment groups (Three stands per group)*								
Marked squirrels	10.7§	7.7	5.0	2.7	2.7	8.0	2.7	4.88	0.56
	0.89¶	5.70	3.61	2.67	0.88	8.0	0.67		
Slope	7.1	8.0	12.9	10.8	11.3	11.9	12.4	7.16	0.31
	1.03	1.57	2.38	2.75	1.26	2.69	3.46		
Azimuth	183	201	148	197	196	193	168	6.50	0.37
	22.11	21.05	12.44	30.50	15.10	21.38	24.66		
BA pine	86.1	75.1	76.2	91.4	77.8	83.0	73.7	7.77	0.26
	6.61	3.82	2.01	3.27	1.77	5.84	3.26		
BA hardwood	8.2	13.2	19.2	10.8	9.5	11.9	8.1	5.38	0.50
	3.21	4.03	6.05	2.32	4.29	2.44	2.21		
PINECTLG	2.7	2.9	3.6	2.7	3.2	5.0	5.2	3.02	0.81
	I.51	0.46	1.28	0.33	1.04	1.52	2.52		
PINECTSM	4.0	4.1	4.7	3.1	4.5	4.2	5.3	2.21	0.90
	1.08	1.62	2.95	1.25	1.41	0.52	0.72		
HDWDCTLG	2.6	2.9	2.7	2.8	3.0	3.0	2.3	1.32	0.97
	0.53	0.69	0.71	0.58	0.41	0.53	0.66		
HDWDCTSM	11.3	10.9	12.1	10.2	14.4	12.4	12.8	4.71	0.58
	1.67	3.44	2.64	0.55	0.12	0.77	1.53		
TREEHTMN	23.4	21.1	21.8	23.3	22.3	21.0	21.7	7.11	0.31
	0.50	1.77	0.78	0.35	1.38	0.23	0.29		
TREEAGMN	63.7	62.5	59.7	69.2	61.3	61.3	62.2	2.78	0.84
	2.15	0.70	2.49	7.59	3.58	2.12	1.63		

* Future treatment groups defined in table 1.

† Habitat variable descriptors given in table 3.

‡ A probability level less than 0.05 indicates that at least one of the treatment group means differs significantly from the others.

§ Mean

¶ Standard error

Table 5.—*Means and standard errors for numbers of flying squirrels and habitat variables for stands grouped by replicated zone (seven each). Kruskal-Wallis one-way ANOVA results and P-value shown at right**

Habitat variables†	Replicated treatment groups 1	2	3	Kruskal-Wallis H d.f. = 2, N = 21	Probability
Marked squirrels	4.43‡	6.71	5.71	0.14	0.93
	1.91§	3.16	2.70		
slope	12.89	9.10	9.93	3.99	0.14
	1.50	1.39	1.42		
Azimuth	181.0 A	211.7 A	159.3 B	7.04	0.03
	13.67	10.57	10.04		
BA pine	81.79	80.10	79.54	0.64	0.73
	2.94	3.77	3.52		
BA hardwood	12.90	8.92	12.86	2.75	0.25
	1.26	1.44	3.86		
PINECTLG	3.51	4.48	2.86	0.79	0.67
	0.84	1.13	0.54		
PINECTSM	4.06	5.06	3.66	0.83	0.66
	0.54	1.19	0.84		
HDWDCTLG	2.57	2.79	2.90	0.21	0.90
	0.37	0.36	0.31		
HDWDCTSM	12.36	11.43	12.21	0.36	0.84
	1.16	1.25	1.18		
TREEHTMN	21.47	21.70	23.11	4.53	0.10
	0.61	0.60	0.53		
TREEAGMN	65.91	62.74	59.86	4.87	0.09
	3.16	1.71	0.90		

* Group means followed by unlike letters are significantly different ($P < 0.05$).

† Variable descriptors defined in table 3.

‡ Mean

§ Standard error

habitat suitability, the indication of a possible trend in these results toward squirrels occupying flatter stands or portions of stands may reflect a greater mast production in wetter areas or the difficulty of squirrels foraging on the ground effectively and safely in steeper terrain.

Fifty-four nests were collected. Nesting material consisted almost entirely of shredded eastern redcedar bark. Most nests filled the box and contained a central chamber; a few were platforms in which nesting material filled about one-third of the box. Occasionally oak leaves and twigs lined the bottom of the box. All collected nests were dried using the Berlese apparatus and invertebrates were preserved in 75 percent alcohol. Preliminary analysis of 23 nests (43 percent) yielded invertebrates representing 4 classes, including 29 families from 11 orders of insects and 10 families of mites and ticks from 2 orders of arachnids (table 6). Six of the families identified are ectoparasites of flying squirrels: Ceratophyllidae (fleas); Glycyphagidae, Trombiculidae, Laelapidae, and Macronyssidae (mites); and Ixodidae (ticks). No vertebrates other than flying squirrels were found in nest boxes. Flying squirrel nests clearly support a diverse and extensive invertebrate fauna. Changes in the kinds and relative abundances of ectoparasites in nests on harvested stands compared with those in nests on control and pretreatment stands may help to elicidate any differences in environmental stress on local populations of squirrels.

Human activities, such as logging or livestock grazing, can cause habitat fragmentation and other changes on a time scale that precludes the adaptive modification of predator-avoidance behaviors in prey species. The alteration of critical habitat features required for camouflage or preferred nesting sites, for example, may give a predator an advantage that can lead to the decimation of an affected bird population (Martin 1993). While this study will concentrate on responses of southern flying squirrels to habitat manipulations, it must be acknowledged that any changes that affect the predator-prey interactions of squirrels with owls, for example (see Rosenberg and Anthony 1992), may play a significant, though unknown, part in observed differences in squirrel population dynamics and habitat use.

Future Research Activities

The next phase of this study will attempt to ascertain responses of local populations of flying squirrels to the cutting treatments imposed during summer 1993, and to evaluate squirrel use of those areas that they continue to inhabit. Winter nest box monitoring will continue, and squirrels will be tracked by radio telemetry on selected control and harvested stands during the summers of 1994 and 1995. Four questions will be addressed:

(1) Are there differences in the demographics of flying squirrel populations on experimental stands before and after treatment?
(2) Are there differences in squirrel population densities on stands before and after treatment?
(3) How do home range sizes and core activity areas vary between control stands and altered stands?
(4) Are there apparent differences in habitat use patterns among the treated and control stands?

Based on the resource-dispersion hypothesis (Macdonald 1983), we expect that squirrel ranges may be larger where the density of limiting resources such as mast-producing trees and cavity trees is reduced. This hypothesis is supported by the results of Geffen and others (1992) in which home range of Blanford's foxes (*Vulpes cana*) were found to be enlarged where favored creek bed habitats were widely dispersed.

Squirrels that remain on or return to treated stands will probably concentrate their activity in the more productive uncut greenbelt areas along ephemeral creeks, as suggested by the "ideal free distribution" theory of Fretwell and Lucas (1970). The decrease in resource levels on manipulated stands combined with the already low density of squirrels on uncut stands should permit a more unequivocal evaluation of habitat-use patterns through radio telemetry than would be possible were squirrels abundant (Rosenzweig 1985). Single-tree selection methods will likely produce the smallest changes in population parameters. Nixon and others (1980) found that selective cutting of forests in Illinois had no apparent effect on resident fox or gray squirrel populations.

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Table 6.—*Invertebrates collected from squirrel nests, with probable ecological associations (Borror and DeLong 1964, Krantz 1978). Generic and specific names provided when known*

Class	Order	Family	Ecological Association
Insecta	Isoptera	Kalotermitidae	Termites, damp wood
	Epbemeroptera	Baetidae	Small mayfly, larva
	Collembola	Poduridae	Springtail, found in decaying vegetation
		Emtomobryidae	Springtail, found in decaying vegetation
	Psocoptera	Liposcelidae	*Liposcelis* spp., fungus feeders, common in wood structures
		Pseudocaeciliidae	*Lachesilla spp.*, found in straw and plant matter
	Homoptera	Cicadellidae	Leaf hopper, plant feeders
	Lepidoptera	Pyralidae	Snout moth, found in shelters, grass feeders
	Orthoptera	Blattidae	Roach, found in shelters, diet varied
		Gryllidae	Cricket
	Coleoptera	Carahidae	Ground beetle, *Calosoma* spp., larvae predatory on other invertebrates
		Histeridae	Hister beelle, predaceous on other insects in decaying organic matter
		Staphylinidae	Rove beetle, predaceous on insects in decaying vegetation
		Sylvanidae	*Oryzaephilus spp.*, sawtooth grain beetle
		Helodidae	Found in damp rotting litter or tree cavities
	Siphonaptera	Ceratophyllidae	*Diamanus spp.*, *Orchopeas* spp., rodent ectoparasites, known disease vector*
	Diptera	Cecidomyiidae	Resin midge, *Retinodiplosis resinicoloides*, associated with tree resin
		Psychodidae	*Psychoda spp.*, found in decaying vegetation
		Phoridae	Humpbacked By, found in decaying vegetation
		Asilidae	Robber flies, predatory on other insects
		Sciaridae	Fungus gnat, found in decaying plant matter
	Hymenoptera	Braconidae	Parasitic on other insects
		Pteromalidae	Parasitic on other insects
		Mymaridae	Parasitic on other insects
		Sphecidae	*Trypoxylon spp.*, *organ* pipe mud dauber
		Formicidae	Ant, *Myrmica* spp.
		Apidae	Bumble bee, *Bombus spp.*
		Vespidae	Paper wasp, *Polistes* spp., construct nests in sheltered sites
		Cynipidae	Gall wasp, parasites on fly pupa
Arachnida	Acarifonnes	Bdellidae	Parasitic on other invertebrates
		Chelytidae	Free-living predator on insects, may cause mange in mammals
		Glycyphagidae	*Glycyphagus* spp., parasitic mite*
		Oribatidae	*Cepheus* spp., *Carobes* spp., found in leaf litter
		Epilohmanniidae	*Epilohmannia* spp., found in decaying vegetation
		Pyemotidae	Found in decaying vegetation
		Trombicnlidae	Chigger, *Trombicula* spp., parasite on mammals*
	Parasitiformes	Ixodidae	Tick, *Ixodes scapularis*, parasitic on mammals*
		Macronyssidae	*Macronyssus* spp., mammal parasite, disease vector*
		Laelapidae	*Androlaelaps spp.*, *Hirstionyssus* spp., *Hypoaspis spp.*, parasites found on skin and fur of mammals, known transmitter of disease in mammals*
Diplopoda			Millipede, found in decaying plant matter
Nematoda			Free Bving larva

• Known m-al ectoparasites

Experiment Station, in the planning phase of the study is greatly appreciated. D. Harris (Womble district headquarters of the Ouachita National Forest) and R. Grounds (Ouachita National Forest Headquarters) provided vehicles needed during nest box installation. J.G. Guldin of the USDA Forest Service, Southern Forest Experiment Station, and T. Foti of the Arkansas National Heritage Commission graciously shared habitat data collected by the silviculture and biodiversity research groups, respectively. J. Singleton of the University of Arkansas at Fayetteville provided invaluable assistance with identification of invertebrates. In addition to funding provided through the USDA Forest Service, Southern Forest Experiment Station, this research was also supported by a grant from the Theodore Roosevelt Memorial Fund of the American Museum of Natural History and a University of Arkansas Doctoral Fellowship.

LITERATURE CITED

Autodesk Retail Products. c1992. Generic Cadd 6.0. Bothell, WA. 3 vol.

Baker, J.B. 1994. An overview of stand-level ecosystem management research in the Ouachita/Ozark National Forests. In: Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings: 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Bendel, Peter R.; Gates, J. Edward. 1987. Home range and microhabitat partitioning of the southern flying squirrel ***(Glaucomys volans).*** Journal of Mammalogy. 68(2): 243-255.

Borror, Donald J.; DeLong, Dwight M. 1964. An introduction to the study of insects. New York: Holt, Rinehart and Winston. 819 p.

Braun, Janet K. 1988. Systematics and biogeography of the southern flying squirrel, ***Glaucomys volans.*** Journal of Mammalogy. 69(2): 422-426.

Burt, William Henry. 1940. Territorial behavior and populations of some small mammals in Southern Michigan. Miscellaneous Publications of the Museum of Zoology, University of Michigan, 45. Ann Arbor, MI: University of Michigan Press. 58 p.

Conner, Richard N.; Rudolph, D. Craig. 1989. Red-cockaded woodpecker colony status and trends on the Angelina, Davy Crockett and Sabine National Forests. Res. Pap. SO-250. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 15 p.

Dennis, John V. 1971. Species using red-cockaded woodpecker holes in northeastern South Carolina. Bird Banding. 42(2): 79-87.

Doby, Wiley Jacob. 1984. Resource base as a determinant of abundance in the southern flying squirrel ***(Glaucomys volans).*** Winston-Salem, NC: Wake Forest University. 121 p. Ph.D. dissertation.

Eberhardt, L.L. 1976. Quantitative ecology and impact assessment. Journal of Environmental Management. 4: 27-70.

Eberhardt, L.L.; Thomas, J.M. 1991. Designing environmental field studies. Ecological Monographs. 61(1): 53-73.

Fischer, Richard A.; Holler, Nicholas R. 1991. Habitat use and relative abundance of gray squirrels in southern Alabama. Journal of Wildlife Management. 55(1): 52-59.

Fretwell, Stephen Dewitt; Lucas, Henry L., Jr. 1970. On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical development. Acta Biotheoretica. 19:16-36.

Fridell, R.A.; Litvaitis, J.A. 1991. Influence of resource distribution and abundance on home-range characteristics of southern flying squirrels. Canadian Journal of Zoology. 69: 2589-2593.

Geffen, Eli; Hefner, Reuven; Macdonald, David W.; Ucko, Michal. 1992. Habitat selection and home range in the Blanford's fox, *Vulpes cana*: compatibility with the resource dispersion hypothesis. Oecologia. 91: 75-81.

Gihnore, Robert M.; Gates, J. Edward. 1985. Habitat use by the southern flying squirrel at a hemlock-northern hardwood ecotone. Journal of Wildlife Management. 49(3): 703-710.

Goertz, John W.; Dawson, Robert M.; Mowbray, Elmer E. 1975. Response to nest boxes and reproduction by *Glaucomys volans* in northern Louisiana. Journal of Mammalogy. 56(4): 933-939.

Guldin, James M.; Baker, J.B.; Shelton, Michael G. 1994. Pretreatment conditions in mature pine/hardwood stands on south-facing slopes of the Ouachita/Ozark National Forests: midstory and overstory plants. In: Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings; 1993 *October* 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Harlow, Richard F.; Doyle, Arlene T. 1990. Food habits and southern squirrels (Glaucomys volans) collected from red-cockaded woodpecker (*Picoides* borealis) colonies in South Carolina. American Midland Naturalist. 124(1): 187-191.

Harlow, Richard F.; Van Lear, D.H. 1987. Silvicultural effects on wildlife habitat in the south (an annotated bibliography)--1980-1985. Tech. Pap. 17. Clemson, SC: Clemson University Department of Forestry. 42 p.

Heidt, Gary A. 1977. Utilization of nest boxes by the southern flying squirrel, ***G laucom ys vo lans*****,** in central Arkansas. Proceedings of the Arkansas Academy of Science. 31: 55-57.

Jordan, James S. 1948. A midsummer study of the southern flying squirrel. Journal of Mammalogy. 29(1): 44-48.

Kantola, Angela Torres; Humphrey, Stephen R. 1990. Habitat use by Sherman's fox squirrel (*Sciurus niger shermani*) in Florida. Journal of Mammalogy. 71(3): 411-419.

Krantz, G. W. 1978. A manual of acarology. Corvallis, OR: Oregon State University Book Stores, Inc. 509 p.

Linzey, Donald W.; Linzey, Alicia V. 1979. Growth and development of the southern flying squirrel (Glaucomys voluns volans). Journal of Mammalogy. 60(3): 615-620.

Loeb, Susan C. 1993. Use and selection of red-cockaded woodpecker cavities by southern flying squirrels. Journal of Wildlife Management. 57(2): 329-335.

Macdonald, David W. 1983. The ecology of carnivore social behaviour. Nature. 301: 379-384.

Madden, Jacalyn R. 1974. Female territoriality in a Suffolk County, Long Island, population of ***G laucom ys vo lans.*** Journal of Mammalogy. 55(3): 647-652.

Martin, Thomas E. 1993. Nest predation and nest sites. Bioscience. 43(8): 523-532.

Muul, Illar. 1968. Behavioral and physiological influences on the distribution of the flying squirrel, ***G laucom ys vo lans.*** Miscellaneous Publications of the Museum of Zoology, University of Michigan, 134. Ann Arbor, MI: University of Michigan Press. 66 p.

Muul, Illar. 1974. Geographic variation in the nesting habits of ***G laucom ys*** *volans*. Journal of Mammalogy. 55(4): 840-844.

Nixon, Charles M.; Havena, S. P.; L. P. Hansen. 1980. Initial response of squirrels to forest change associated with selection cutting. Wildlife Society Bulletin. 8: 298-306.

Pollock, Kenneth H.; Nichols, James D.; Brownie, Cavell; Hines, James E. 1990. Statistical inference for capture-recapture experiments. Wildlife Monographs. 107: l-97.

Rosenberg, Daniel K.; Anthony, Robert G. 1992. Characteristics of northern flying squirrel populations in young second- and old-growth forests in western Oregon. Canadian Journal of Zoology. 70: 161-166.

Rosenzweig, Michael L. 1985. Some theoretical aspects of habitat selection. In: Cody, Martin L., ed. Habitat selection in birds. Orlando, FL: Academic Press. 558 p.

Sawyer, Sherrie L.; Rose, Robert K. 1985. Homing in and ecology of the southern flying squirrel *Glaucomys volans* in southeastern Virginia. American Midland Naturalist. 113(2): 238-244.

Sealander, John A.; Heidt, Gary A. 1990. Arkansas mammals: their natural history, classification, and distribution. Fayetteville, AR: University of Arkansas Press. 308 p.

Smith, Kimberly G.; Petit, Daniel R. 1988. Breeding birds and forestry practices in the Ozarks: Past, present, and future relationships. In: Bird Conservation. Madison, WI: University of Wisconsin Press. 177 p.

Sollberger, Dwight E. 1943. Notes on the breeding habits of the eastern flying squirrel *(Glaucomys voluns voluns).* Journal of Mammalogy. 24: 163-173.

Sonenshine, Daniel E.; Levy, Gerald F. 1981. Vegetative associations affecting *Glaucomys volans* in central Virginia. Acta Theriologica. 26,23: 359-171.

Stabb, M.A.; Gartshore, M.E.; Aird, P.L. 1989. Interactions of southern flying squirrels, *Glaucomys voluns,* and cavity-nesting birds. Canadian Field-Naturalist. 103: 401-403.

Stapp, Paul; Jenkins, Peter J.; Mautz, William W. 1991. Winter energy expenditure and the distribution of southern flying squirrels. Canadian Journal of Zoology. 69: 2548-2555.

Statsoft. c1991. CSS:Statistica. Statsoft, Inc. Tulsa, OK. 3 vol.

Stojeba, Roger Charles. 1978. Nest box utilization by the southern flying squirrel, Glaucomys volans L., and related life history information in relation to habitat factors. Fayetteville, AR: University of Arkansas. 84 p. M.S. thesis.

Stone, Karen D. 1993. Home range of the southern flying squirrel (*Glaucomys voluns)* in west-central Arkansas, Memphis, TN: Memphis State University. 75 p. M.S. thesis.

Tappe, Philip A.; Thill, Ronald E.; Heidt, Gary A. 1994. Small mammals in mature pine/hardwood stands in the Ouachita/Ozark National Forests. In: Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Taulman, James F. 1990. Observations on scent marking in hoary marmots (*Marmota caligata*). Canadian Field-Naturalist. 104(3): 479-482.

Thill, Ronald E.; Tappe, Philip A.; Martin, Thomas E. 1992. Impacts of alternative silvicultural practices on habitat and wildlife populations on the Ouachita and Ozark National Forests. Nacogdoches, TX: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, study plan, FS-SO-4251-3.2. 22 p.

Weigl, Peter D. 1978. Resource overlap, interspecific interactions and the distribution of the flying squirrels, *Glaucomys volans* and G. *sabrinus*. American Midland Naturalist. 100(1): 83-96.

Weigl, Peter D.; Steele, M.A.; Sherman, L.J.; Ha, J.C.; Sharpe, T. 1989. The ecology of the fox squirrel (*Sciurus niger*) in the coastal plain of North Carolina with implications for the entire southeast. Tall Timbers Research Bulletin. 24: l-93.

Wilson, Kenneth R.; Anderson, David R. 1985. Evaluation of two density estimators of small mammal population size. Journal of Mammalogy. 66(1): 13-21.

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Breeding Birds of Late-Rotation Pine-Hardwood **Stands:** **Community** Characteristics and Similarity to Other Regional Pine Forests[1]

Daniel R. Petit, Lisa J. Petit, Thomas E. Martin, Ronald E. Thill, and James F. **Taulman**[2]

ABSTRACT

The relative abundances of bird species and the ecological characteristics of the overall **avian** community were quantified within 20 late-rotation pine-hardwood sites in the Ouachita and Ozark National Forests in Arkansas and Oklahoma during 1992 and 1993. In addition, similarities in species composition and guild representation were compared with those of forest types in other areas of the Southeastern United States to assess the possible extent of generalizations to be made from this Ecosystem Management research. A total of 55 bird species was recorded within survey plots during 1992 and 1993, but only 10 species accounted for more than 80 percent of all individuals detected. Pine warblers comprised approximately 40 percent of all individuals. Rank abundances of the 55 species were relatively consistent between years, especially for the most common species. Numbers of species and individuals detected during point count surveys were different between 1992 and 1993, although some of that discrepancy may be due to interobserver variation. No significant differences were detected in bird species richness, abundance, or diversity among the four geographic zones or among future harvesting treatments. Bird communities were dominated by species that nest and forage in the canopy. Similarity was relatively low between bird assemblages characterized on the Ouachita Mountain sites and assemblages in other studies. Representation of nesting and foraging guilds, however, was more closely aligned with guild structure found in other forests. **In** general, results from Ecosystem Management Research should be most applicable to loblolly-shortleaf pine and oak-hickory forest types in the Southeast.

INTRODUCTION

The Ecosystem Management Research Program of the USDA Forest Service was designed to assess the effects of traditional and nontraditional cutting and regeneration techniques on the flora, fauna, ecosystem function, and esthetic and cultural properties of our national forests as well as the economic costs associated with each harvesting program. The philosophy behind the ecosystem-level approach to managing federal lands is based on the perception that to serve the **long-**term, multiple interests of society, preservation of biodiversity and sustainability of natural resources must be viewed in a holistic fashion (Salwasser 1991, 1992). This "new perspective" suggests that neither societal (monetary and cultural) considerations nor ecosystem integrity (including sustainability) can be viewed independently of the other, and that management units must be viewed simply as components within the scope of larger-scale watershed processes and functions. The interactions of these complex, and often controversial, issues (e.g., **Frissell** and others 1992) are being investigated in a series of demonstration projects within National Forests.

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Ecosystem Management Research in the Ouachita and Ozark National Forests in western Arkansas and eastern Oklahoma is comprised of three phases: Phase I provided a demonstration of the logistical aspects and feasibility of different harvesting treatments. Phase II and Phase III are designed to assess the economic effectiveness of different harvesting treatments as well as treatment effects on the biological, chemical, physical, and esthetic properties of pine-hardwood ecosystems at the stand and watershed levels, respectively (Baker, this volume).

Natural pine forests and pine plantations often support fewer species of birds compared with mature deciduous stands in the Southeastern United States (Hamel 1992, Smith and Petit 1988). Mixed pine-hardwood forests, on the other hand, often equal or exceed pure hardwood forest types in species richness (Dickson and others 1980, Hamel 1992, Meyers and Johnson 1978). Yet, both pine and mixed-pine forest types represent critical habitats for economically and socially important game birds, declining neotropical migratory bird populations, and threatened/endangered species (Evans 1978, Hamel 1992, Jackson 1988). The value of pine-associated habitats to bird and wildlife populations, coupled with increasing demands on these lands for timber production and urban development (Jackson 1988, Knight 1987), has created an urgency among wildlife biologists to better understand bird-habitat relationships and the impact of different management practices on bird populations in the Southeast (Childers and others 1986, Harris and others 1974, Johnson 1987, Noble and Hamilton 1975). Critical in this research is documentation of bird species that are associated with mature, naturally regenerated pine forests, "controls" against which to compare different stand ages and management techniques.

This report summarizes information on the relative abundances and community characteristics of breeding birds associated with late-rotational pine-hardwood forests before stand-level ecosystem management harvesting treatments *were* applied (Phase II). Bird assemblages occupying these sites were compared with assemblages inhabiting mature pine anpine-hardwood stands in other areas of the Southeastern United States. The degree of similarity among the different regional bird communities allowed projection of the generality of the harvesting treatments on Southeastern pine/pine-hardwood bird communities.

METHODS

Study Sites

In 1991, nine late-rotation pine-hardwood stands were selected in the Ouachita (7) and Ozark (2) National Forests of northwestern Arkansas (table 1) to establish bird and vegetation sampling protocols to be used once Phase II treatment plots were selected (see below). (At that time, these sites were targeted to represent pretreatment controls. However, timing of Phase II timber harvesting allowed pretreatment data to be collected within the actual 20 Phase II sites. Consequently, these nine sites provided only supplemental information on late-rotation pine-hardwood bird assemblages.) South-facing slopes (including southeast and southwest) predominated on most sites. Stands had not been harvested for 75 to 90 years, and pine and hardwood basal areas averaged approximately 7.7 m^2/ha (range: 7.0 to 8.1 m^2/ha) and 3.8 m^2/ha (range: 2.5 to 4.3 m^2/ha), respectively. Canopies were largely closed (Percent canopy cover, mean = 84 percent; range = 79 to 88 percent, N = 9), with mean canopy heights between 15 and 23 m (overall mean = 18 m). Most sites had well-developed understories and midstories comprised mainly of *Vaccinium corymbosum* L., *Cornus florida* L., *Nyssa sylvatica* Marsh., *Quercus marilandica* Muenchh., and Q. *stellata* Wangenh. Quercus *velutina* Lam., Q. *rubra* L., *Carya* spp., and *Pinus echinata* Mill. were the primary overstory trees. All sites encompassed 16 to 25 ha.

In 1992 and 1993, bird surveys were conducted on 20 additional sites on which 5 different Phase II harvesting treatments were to be applied during summer and autumn 1993. All stands had predominantly south-facing aspects (including southwest and southeast) with slopes that ranged between 0 to 15 percent. Stand age (> 70 years), vegetative structure (mean canopy cover = 82 percent, range = 78 to 87 percent; mean canopy height = 17 m, range = 15 to 20 m), and tree species composition were similar to the late-rotational tracts studied in 1991 (Thill and others [this volume] provide additional details of sites used in 1992 and 1993). The 20 Phase II sites were loosely grouped (based upon possible edaphic and climatic differences [Baker, this volume]) into four geographic zones (five stands per zone) primarily in the Ouachita National Forest in Arkansas and Oklahoma, but several sites were located in the southernmost district of the Ozark National Forest (table 1). Each group of five sites included one replicate of each of the four harvesting treatments (clearcutting, shelterwood, group selection, and single tree selection) that were to be performed in 1993, in addition to an untreated control site (Thill and others, this volume). All sites *were* 14 to 16 ha.

Table 1 .— Locations *of late-rotation pine-hardwood stands studied* in *1991-93* in *the* Ouachita and Ozark National *Forests in Arkansas and Oklahoma*

Year	National Forest	Zone'	Compartment	Stand
1991	Ozark		2	25
	Ozark		2	16
	Guachita		1601	11
	Guachita		1610	11
	Guachita		1614	24
	Guachita		603	17
	Guachita		1457	ACEF†
	Guachita		473	11
	Chtachita		462	11
1992-93	Guachita	North	458	16
	Guachita	North	457	12
	Ozark	North	46	18
	Ozark	North	70	10
	Guachita	North	284	11
	Guachita	East	1067	15
	Guachita	East	1119	21
	Chtachita	East	1124	11
	Guachita	East	609	9
	Guachita	East	605	5
	Guachita	South	1658	5
	Guachita	South	27	1
	Guachita	South	35	42
	Guachita	South	1649	13
	Guachita	South	23	10
	Guachita	West	1292	2
	Guachita	West	833	1
	Ouachita	West	62	6
	Guachita	West	248	17
	Ouachita	West	896	7

. Geographic zone used in the Ecosystem Management experimental design. No designation of zone is appropriate for preliminary data collected on the nine sites in 199 1.

† Alum Creek Experimental Forest.

Bird Surveys

Bird abundance was estimated in five or six (depending on size of the site) 40-m radius (0.5 ha) circular plots spaced evenly over each site. Bird survey plots (hereafter "plots") were usually more than 150 m apart, but size or shape of some stands permitted only 130 to 150 m of separation. Plots were more than 90 m away from edges (e.g., roads, younger successional growth, different forest types). On 3 different days (= 3 visits) between 5 to 24 May 1991, 28 April to 2 June 1992 (75 percent of surveys completed before 15 May), and 1 to 14 May 1993, all birds seen or heard within plots on each site were recorded. Ten minutes were spent at each plot. Individuals detected beyond 40 m, but within the site boundaries were also noted. Birds seen flying or soaring above canopy trees and species that do not breed in the region (transients) were excluded. Surveys were conducted between 06:00 and 12:00 (> 90 percent were completed before 11:00) on days without strong winds or prolonged precipitation. (On several days, surveys were continued when light rainfall began after initiation of bird counts on a site.) Bird surveys were conducted by four observers in 1991, three in 1992, and three in 1993. Only one observer (Taulman) surveyed birds during all 3 years. With the exception of Taulman, the bird censusers in 1992 were different from those in 1993.

Guild Analysis

Species were grouped into the following foraging and nesting guilds to examine the relative contributions of these groups to the overall bird community inhabiting late-rotation pine-hardwood stands: (1) open-cup, canopy (> 3 m); (2) open-cup, shrub (< 3 m); (3) ground; (4) cavity; and (5) other (e.g., rock faces). Foraging/trophic guilds were based on breeding season diets/foraging tactics and designated as either: (1) foliage-gleaning insectivore, canopy (> 3 m); (2) foliage-gleaning insectivore, shrub (< 3 m); (3) ground-foraging insectivore; (4) aerial flycatcher; (5) bark insectivore; (6) carnivore; (7) granivore; (8) nectarivore; and (9) omnivore. Classifications were based upon Ehrlich and others (1988) and Hamel (1992).

Breeding bird community composition on sites in the Ouachita and Ozark National Forests was compared with that of 12 other studies conducted within mature (> 40 years) pine-associated forest types in the Southeastern United States. Raptors and waterbirds were not included in this analysis because populations are not easily quantified using fixed-radius point counts (e.g., raptors); presence of a species on a given site may be highly dependent upon water (e.g., waterfowl); and many studies reported only terrestrial landbirds. Similarity in bird community composition was calculated by Sorensen's Index (SI): $200C/(A + B)$, where A = number of species in forest type A, B = number of species in forest type B, and C = number of species shared between two forests (Mueller-Dombois and Ellenberg 1974). Sorensen's Index can range from 0 percent (no species in common) to 100 percent (identical species composition).

Similarity indices may not accurately reflect the actual overlap in species composition in two areas because species assemblages quantified at local levels may be strongly influenced by the intensity of sampling (e.g., number of sites, number of years), Hamel (1992) presented complete bird species lists for different forest types in the Southeastern United States. Those data were used to provide some indication of the "potential" similarity in bird community composition between mature mixed-pine hardwood stands (forest type represented by Ouachita and Ozark National Forest research) and six other forest types in the Southeast: loblolly-shortleafpine (*Pinus taeda* L.-*P. echinata*), Virginia-pitch pine (*P. virginiana* Mill. -*P. rigida* L.), longleaf-slash pine (*P. palustris* Mill.-P. *elliottii* Engelm.), sandhills longleaf pine, longleaf pine-scrub oak (*Quercus* spp.), and oak-hickory (*Carya* spp.). Similarity indices were calculated as described above.

Data Analysis

The bird survey technique allowed calculation of an index of density for each species rather than a measure of absolute density. Relative abundance of each species on a site was presented as the average number of individuals detected per survey point (based upon three visits). Species richness was based upon: (1) only those individuals detected within survey plots on each of the 20 sites (S_p); and (2) all species detected on the site, i.e., both within and outside survey plots (S_s). The Shannon-Weiner diversity index (H') was calculated as $H' = -\Sigma p_i \ln p_i$, where p_i was the proportion of all individuals detected that were represented by species i (Pielou 1969). Data from 1992 and 1993 were analyzed separately because of between-year differences in species richness and abundance (see below). Comparisons of bird community metrics (i.e., abundance, diversity, richness) across future treatments and geographic zones were made with two-way analysis of variance (ANOVA). Only the main effects model for each bird community metric was reported here because no interactions existed among the factors (Neter and Wasserman 1974, p. 582). Other statistical tests are included in the text. Differences were considered to be significant if $P \leq 0.05$.

RESULTS

Adequacy of Bird Sampling Effort

Thoroughness of bird surveys is difficult to assess without extraordinary effort (e.g., by spot-mapping) to determine all species breeding on sites and their relative densities. However, when estimating species richness, for example, adequate sampling intensity can be achieved when species-effort curves become asymptotic. Bird surveys in 1991 demonstrated that, on average, one visit to a site (cumulative sum from all plots on a site during a given day) detected nearly three-fourths of the species, and that two visits registered more than 90 percent of the species recorded within survey plots after three visits. Data from 1992 and 1993 revealed species-effort curves similar to those found in 1991, especially for results after two visits (fig. 1).

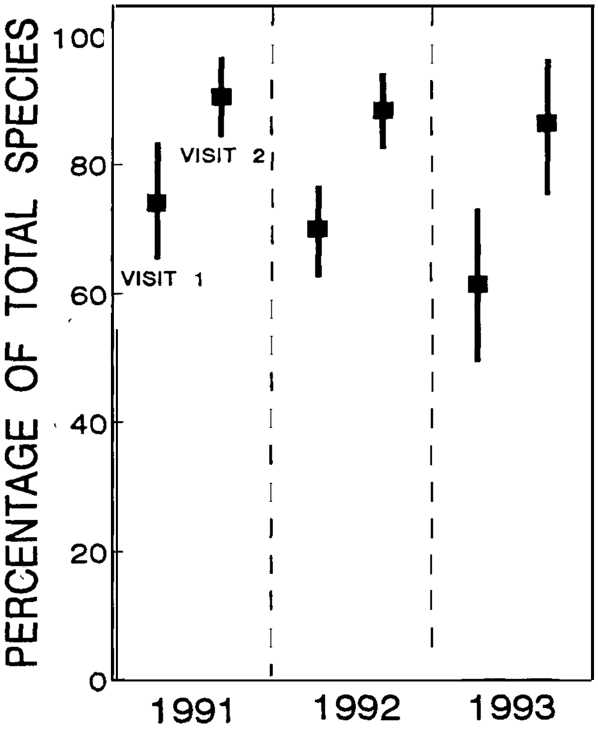

Figure 1.– Effect *of number of visits on estimates of species richness during 1991-93. Squares represent the mean percentage of species detected after one and two visits compared with the total number of species recorded a&r three visits (N = 9 sites in 1991, and 20 sites in 1992 and 1993). Vertical bars represent one standard deviation.*

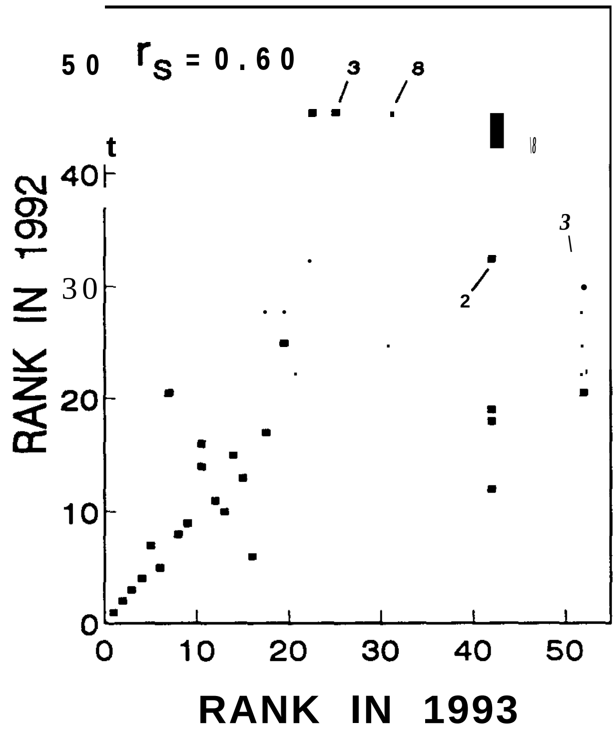

Figure 2.– *Relationship (Spearman's correlation coefficient) between rank-o&r abundance of 55 species observed in 1992 and/or 1993. Numbers within graph represent multiple points.*

Bird Community Characteristics

Specks Richness, Abundance, and Diversity

Few of the 55 species detected within Ouachita and Ozark survey plots in 1992 and 1993 were common (table 2). Pine warblers (scientific names are listed in table 2) and red-eyed vireos comprised half of all individuals detected within plots; 10 species accounted for 82 percent of the 2,248 individuals counted in 1992 and 1993. The rank-order of abundance of these 55 species was generally stable between years (Spearman's rank correlation coefficient; r_s = 0.60, df = 53, $P < 0.001$), although abundances of relatively rare species were much less consistent (fig. 2). Hence, when the 29 rarest (ranked higher than median rank) species were removed from the analysis (including those that were recorded in only one year), the relationship became stronger (r_s = 0.77, df = 24, $P < 0.001$).

Relative abundance was compared between years for each of the 11 species that comprised more than 2 percent of the bird community in 1992-93. When analyzed within regions; only 4 of the 44 comparisons (11 species x 4 regions) showed significant differences (pine warbler, north; scarlet tanager, south; worm-eating warbler, south and west). Over all 20 sites, only these 3 species showed significant (paired r-tests; $P < 0.05$) between-year variation.

Table 2.— *Relative abundances (percentage of total) of bird species recorded within 40-m radius circular plots in 1992 and 1993. Species are arranged according to their rank abundance (in parentheses) in 1992. In cases of ties, average ranks were assigned to species*

Common name	Scientific name	Percentage of total (rank) 1992	1993
Pine warbler	*Dendmica pinus*	40.1 (1)	35.2 (1)
Red-eyed vireo	*Vireo olivaceus*	12.9 (2)	11.9 (2)
Summer tanager	*Piranga rubra*	5.8 (3)	7.2 (3)
Black-ard-white warbler	*Mniotilta varia*	4.6 (4)	6.9 (4)
Ovenbird	*Seiurus aurocapillus*	4.5 (5)	4.5 (6)
Scarlet tanager	*Pimnga olivacea*	4.4 (6)	0.8 (16)
Carolina chickadee	*Parus camlinensis*	4.1 (7)	4.8 (5)
Tufted titmouse	*Parus bicolor*	3.4 (8)	2.7 (8)
Blue jay	*Cyanocitta cristata*	2.5 (9)	2.4 (9)
Carolina-	*Thyrothorus ludovicianus*	2.1 (10)	1.9 (13)
Pileated woodpecker	*Dryocopus pileatus*	1.8 (11)	2.1 (12)
Brown-headed cowbird	*Molothrus ater*	1.6 (12)	0.1 (42)
American crow	*Corvus brachyrhynchos*	1.6 (13)	1.2 (15)
Blue-gmy gnatcatcher	*Polioptila caerulea*	1.5 (14)	2.3 (10.5)
Great created flycatcher	*Myiarchus crinitus*	1.4 (15)	1.8 (14)
Indigo bunting	*Passerina cyanea*	1.2 (16)	2.3 (10.5)
Acadian flycatcher	*Empidonax virescens*	1.1 (17)	0.7 (17.5)
Northern cardinal	*Cardinalis cardinalis*	0.8 (18)	0.1 (42)
Hairy woodpecker	*Picoides villosus*	0.7 (19)	0.1 (42)
Worm-eating warbler	*Helmithcms vermivorus*	0.5 (20.5)	4.2 (7)
chuck-will's widow	*Caprimulgus camlinensis*	0.5 (20.5)	0.0 (52)
White-breasted nuthatch	*Sitta camlinensis*	0.4 (22.5)	0.5 (21)
Yellow-billed cuckoo	*Coccyzus americanus*	0.4 (22.5)	0.0 (52)
Mourning dove	*Zenaida macroura*	0.3 (25)	0.0 (52)
Red-bellied woodpecker	*Melanerpes carolinus*	0.3 (25)	0.2 (3 1)
wood thrush	*Hylocichla mustelina*	0.3 (25)	0.6 (19.5)
Downy woodpecker	*Picoides pubescens*	0.2 (28)	0.7 (17.5)
Eastern wood-pewee	*Contopus virens*	0.2 (28)	0.0 (52)
Kentucky warbler	*Oporornis formosus*	0.2 (28)	0.6 (19.5)
Barred owl	*Strix varia*	0.1 (32.5)	0.1 (42)
Northern flicker	*Colaptes auratus*	0.1 (32.5)	0.0 (52)
Gray catbird	*Dumetella carolinensis*	0.1 (32.5)	0.1 (42)
Prairie warbler	*Dendmica discolor*	0.1 (32.5)	0.0 (52)
Rufousaided towhee	*Pipilo erythrophthalmus*	0.1 (32.5)	0.0 (52)
Yellow-throatedvireo	*Vireo flavifrons*	0.1 (32.5)	0.4 (22.5)
Broad-wingedhawk	*Buteo platypterus*	0.0 (45.5)	0.2 (31)
Great-homed owl	*Bubo virginianus*	0.0 (45.5)	0.1 (42)
Northernbobwhite	*Colinus virginianus*	0.0 (45.5)	0.1 (42)
American goldfinch	*Carduelis tristis*	0.0 (45.5)	0.2 (3 1)
American redstart	*Selophaga ruticilla*	0.0 (45.5)	0.1 (42)
Black-billed cuckoo	*Coccyzus erythropthalmus*	0.0 (45.5)	0.1 (42)
Brown-headed nuthatch	*Sitta pusilla*	0.0 (45.5)	0.1 (42)
Chipping sparrow	*Spizella passerina*	0.0 (45.5)	0.2 (31)
common grackle	*Quiscalus quiscula*	0.0 (45.5)	0.3 (25)
Cooper's hawk	*Accipiter cooperii*	0.0 (45.5)	0.4 (22.5)
Hooded warbler	*Wilsonia citrina*	0.0 (45.5)	0.2 (3 1)
Louisiana waterthrush	*Seiurus motacilla*	0.0 (45.5)	0.2 (31)
Northern parula	*Parula americana*	0.0 (45.5)	0.2 (3 1)
Red-shouldered hawk	*Buteo lineatus*	0.0 (45.5)	0.2 (31)
Ruby-throatedhummingbird	*Archilochus colubris*	0.0 (45.5)	0.2 (31)
Swainson's warbler	*Limnothlypis swainsonii*	0.0 (45.5)	0.3 (25)
Cedar waxwing	*Bombycilla cedrorum*	0.0 (45.5)	0.3 (25)
Red-headed woodpecker	*Melanerpes erythrocephalus*	0.0 (45.5)	0.1 (42)
White-eyed vireo	*Vireo griseus*	0.0 (45.5)	0.1 (42)
Yellow-throated warbler	*Dendmica dominica*	0.0 (45.5)	0.1 (42)
Wild turkey	*Meleagris gallopavo*	+*	+
Red-tailed hawk	*Buteo jamaicensis*	-†	+
Belted kingfisher	*Megaceryle alcyon*		+
Yellow-breasted chat	*Icteria virens*		+

* Detected on sites, but only outsideof bird survey plots.
† Not detected on sites in 1992.

Thirty-seven percent more species were recorded within plots in 1993 (S_p [Total] = 48) than in 1992 (S_p [Total] = 35). On average, the number of species recorded within survey plots per site in 1993 (mean S_p = 13.40, SD = 3.07, N = 20) exceeded that of 1992 (mean S_p = 12.35, SD = 2.41) by one, but this difference was not significant (paired f-test; t = 1.60, P = 0.12). Likewise, when all species detected on sites were considered (i.e., both within and beyond survey plot boundaries), more species were documented in 1993 (S, [Total] = 57) than in 1992 (41). On average, approximately 4 more species were recorded on each site in 1993 (mean S_s = 22.70, *SD* = 2.96, N = 20) than in 1992 (mean S_s = 18.10, *SD* = 2.99; paired t-test, t = 8.93, $P < 0.001$). In contrast to species richness, relative abundance of birds within survey plots was **significantly** greater (t = 3.54, P = 0.002) in 1992 (number of individuals **per** survey point; mean = 3.63, *SD* = 0.56, N = 20) than in 1993 (mean = 3.04, *SD* = 0.63). Species diversity (H') at the site level averaged 1.92 (*SD* = 0.28) in 1992 and 2.04 (0.35) in 1993 (paired t-test; t = 1.66, df = 18, $P = 0.11$). (Annual differences in bird species richness, abundance, and diversity were corroborated with **ANOVA** -- see Methods).

Discrepancies in bird community metrics between years could reflect either *real* differences in bird community characteristics or interobserver variation. Some insight into these alternatives can be obtained by comparing results of the only observer to survey birds in both 1992 and 1993 (**Taulman**). The number of individuals per survey point declined 16 percent between years for both the overall results (see abovej and when analyses were restricted to the single observer, although the latter difference was not significant @aired f-test; t = 1.67, $P = 0.11$). Species richness also did not differ between years at either the plot or site level for the single observer (S_p, t = 0.91, P = 0.37; S,, t = 1.23, P = 0.23). These results suggest that, although bird abundance may have been lower in 1993 compared with 1992, observer variation was partly responsible for the recorded differences in species richness during that same period.

Nesting and Foraging Guilds

Canopy nesters comprised approximately two-thirds of the individuals recorded in both 1992 and 1993. The high densities of two canopy-nesters, pine warbler and red-eyed **vireo,** accounted largely for that domination (fig. 3a). At the species level, canopy-nesters still were the best represented nesting guild, but cavity-, shrub-, and ground-nesters also contributed substantially to species richness (fig. 3b). Shrub-nesters represented approximately 18 percent of the species detected but only 3 percent of the individuals. Representation of nesting guilds within the community did not vary significantly between years (log-likelihood ratio test; G = 0.72, df = 4, P = 0.95).

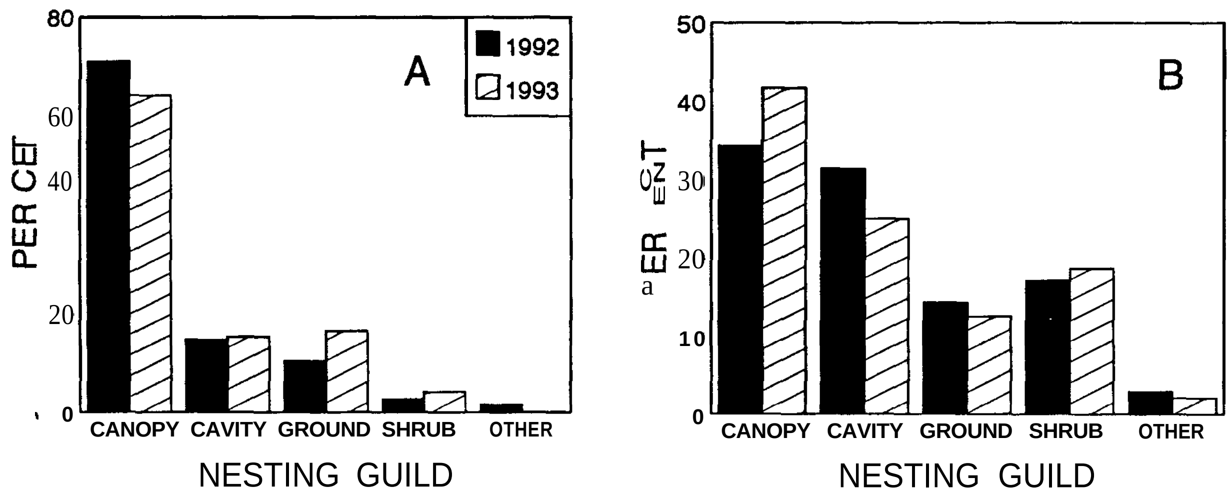

Figure 3.-- *Representation of different nesting guilds on late-rotation pine-hardwood sites in* **1992** and **1993.** *Bars represent the percentage of (A) individuals and (B) species* that *comprised each of* the *five guilds. Nesting guilds are open-cup, canopy (CANOPY); tree cavity (CAVITY); ground; open-cup, shrub layer (SHRUB); and other.*

Canopy foliage-gleaning insectivores, of which pine warblers and red-eyed vireos were the most abundant, accounted for approximately two-thirds of the individuals detected, but only one-fourth of the species (fig. 4a). No other foraging guild comprised more than 11 percent of the individuals detected in either year. When species were equally weighted (i.e., no measure of abundance), however, bark-, ground-, and shrub-foraging insectivores, in addition to canopy foragers, were comparable in their representation (fig. 4b). Carnivores were represented by 3 percent and 10 percent of the species in 1992 and 1993, respectively, although less than 1 percent of the individuals detected each year were raptors. Granivorous and nectarivorous species were scarce on Ecosystem Management sites. No significant shifts occurred between years in the relative structure of trophic guilds ($G = 3.69$, df = 6, $P = 0.72$).

Differences Among Geographic Zones

No significant differences existed in bird species richness (S_p [1992]: $F = 0.77$; df = 3, 12; $P = 0.53$; S_p [1993]: $F = 0.95$, $P = 0.45$; S_s [1992]: $F = 0.45$, $P = 0.72$; S_s [1993]: $F = 2.13$, $P = 0.15$), relative abundance (1992: $F = 0.10$, $P = 0.96$; 1993: $F = 3.31$, $P = 0.06$), or species diversity (1992: $F = 1.03$, $P = 0.41$; 1993: $F = 0.62$, $P = 0.62$) among the four'geographic zones in either year (fig. 5).

Differences Among Future Treatments

No significant differences were detected in bird species richness (S_p [1992]: $F = 0.18$; df = 3, 12; $P = 0.94$; S_p [1993]: $F = 0.16$, $P = 0.96$; S_s [1992]: $F = 0.83$, $P = 0.53$; S_s [1993]: $F = 1.26$, $P = 0.34$), relative abundance (1992: $F = 0.21$, $P = 0.93$; 1993: $F = 1.43$, $P = 0.28$), or species diversity (1992: $F = 0.17$, $P = 0.95$; 1993: $F = 0.49$, $P = 0.75$) among the five future harvesting treatments in either year (fig. 6).

Similarity to Other Southeastern Forest Types

The overall bird community (terrestrial landbirds only) recorded on Ecosystem Management Research sites was compared to bird communities from 12 other studies conducted within pine and mixed pine-hardwood forests of the Southeast. In general, similarity indices (SI) were relatively low (mean = 55 percent, range = 36 to 78 percent) and showed no clear relationship with forest type, number of sites sampled, or geographic proximity to the Ouachita and Ozark National Forests (table 3). However, SI was highly correlated with total number of bird species recorded in each of the studies ($r = 0.87$, $P < 0.01$).

Analysis of "potential" similarity in bird communities using Hamel's (1992) data showed that the pool of species in mixed pine-hardwood forests in the Southeastern United States was most similar to those of loblolly-shortleaf (SI = 78 percent) and oak-hickory (SI = 85 percent) forest types. Bird communities in forests dominated by slash, Virginia, pitch, and/or longleaf pines showed less similarity (mean = 62 percent, range = 57 to 67 percent, N = 4) to communities occupying mixed pine-hardwood forests, the pine component of which is usually loblolly or shortleaf. Percent similarity was significantly correlated with the hypothetical number of species occurring in each of the six forest types ($r = 0.89$, $P < 0.01$). Furthermore, the ratio of SI to SI_{max} (the maximum value possible given the number of species occurring in each of two forest types) ranged between 0.85 and 0.98 for the six forest types, suggesting that the less speciose bird communities (all but oak-hickory) were nearly perfect subsets of that found in mixed-pine hardwood forests, and that the mixed pine-hardwood bird community was a subset of the oak-hickory bird community.

Nesting and foraging guild composition of the Ecosystem Management sites in the Ouachitas and Ozarks was comparable to that of other sites and forest types in the Southeastern United States, but only when species were equally weighted (fig. 7). When species were weighted by relative abundance, canopy insectivores and canopy nesters clearly dominated the guild structure on the Ouachita/Ozark sites (see figs. 3 and 4), whereas guild representation did not change appreciably in the other areas.

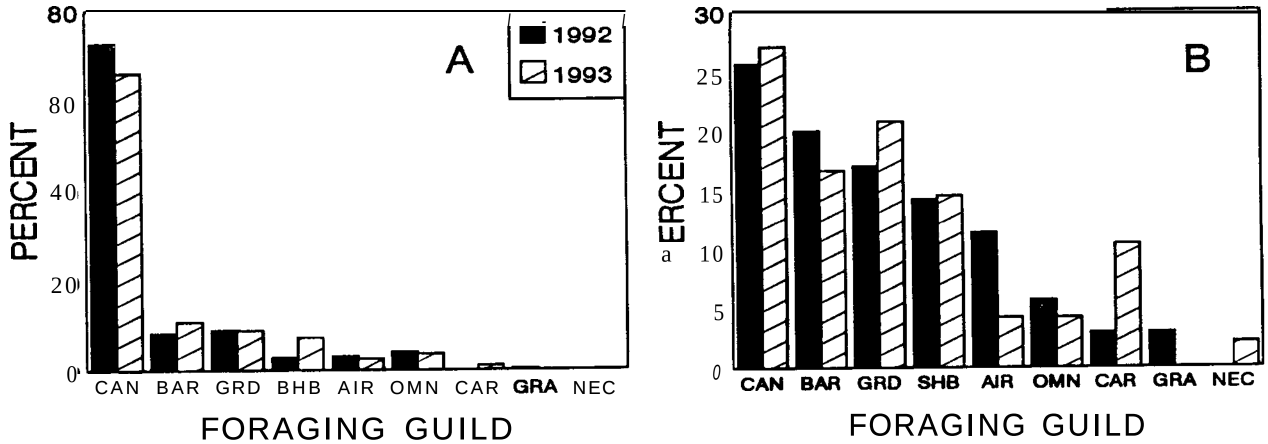

Figure 4.– *Representation of different foraging guilds on late-rotation pine-hardwood sites in 1992 and 1993. Bars represent the percentage of (A) individuals and (B) species that comprised each of the nine guilds. Foraging guilds are foliage-gkaning insectivore, canopy (CAN); bark insectivon (BAR); ground insectivon (GRD); foliage-gleaning insectivon, shrub layer (SHB); aerial insectivon (AIR); omnivore (OMN); carnivore (CAR); granivore (GRA); and nectarivore (NRC).*

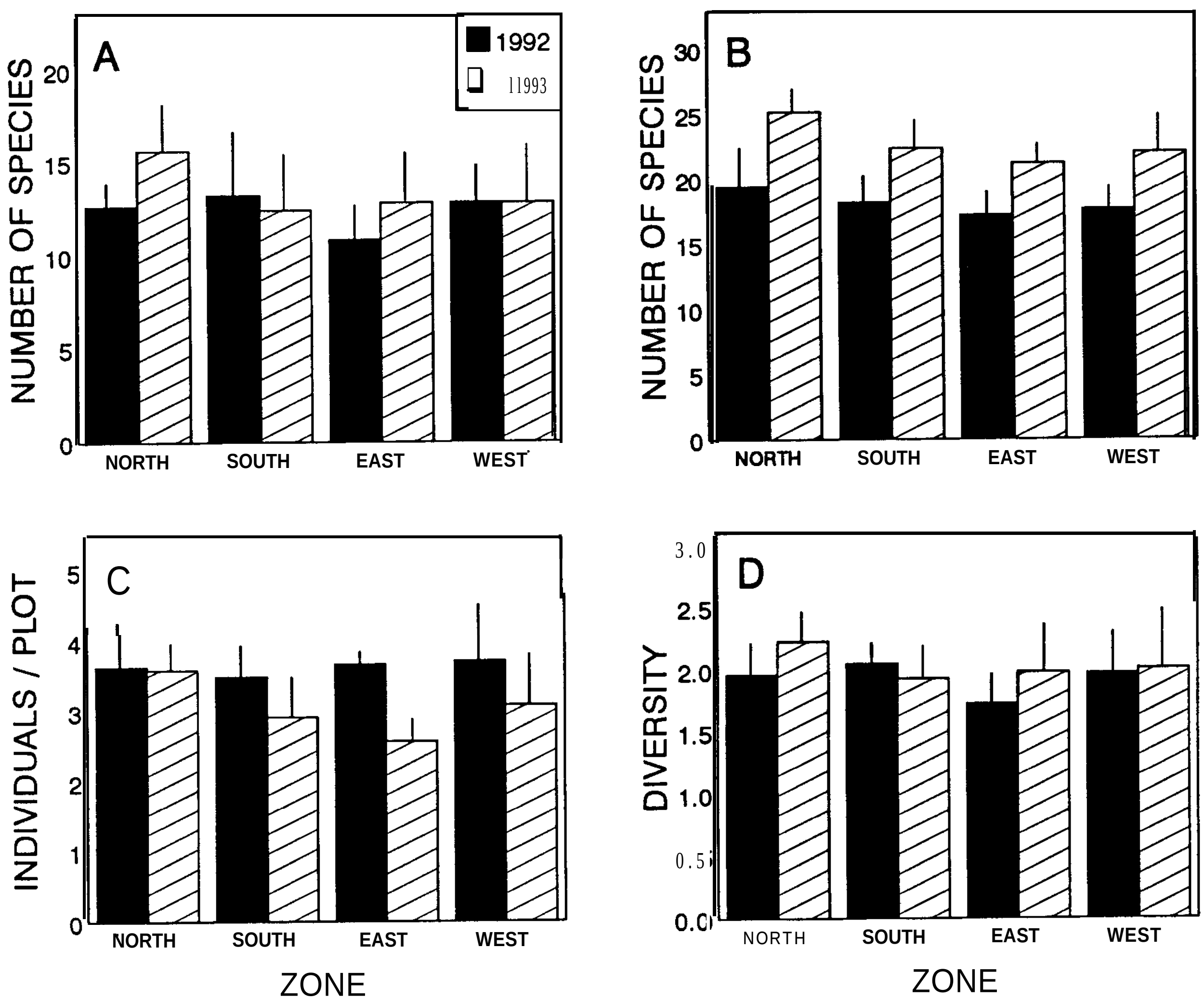

Figure 5.– Comparison of bird community metrics across different geographic zones in late-rotation pine-hardwood stands in 1992 and 1993. Bars represent the mean value (vertical lines equal I SD) across five sites for (A) species richness within bird survey plots, (B) species richness on entire site, (C) number of individuak detected per 40-m radius plot per survey, and (D) Shannon-Weiner diversity index (H').

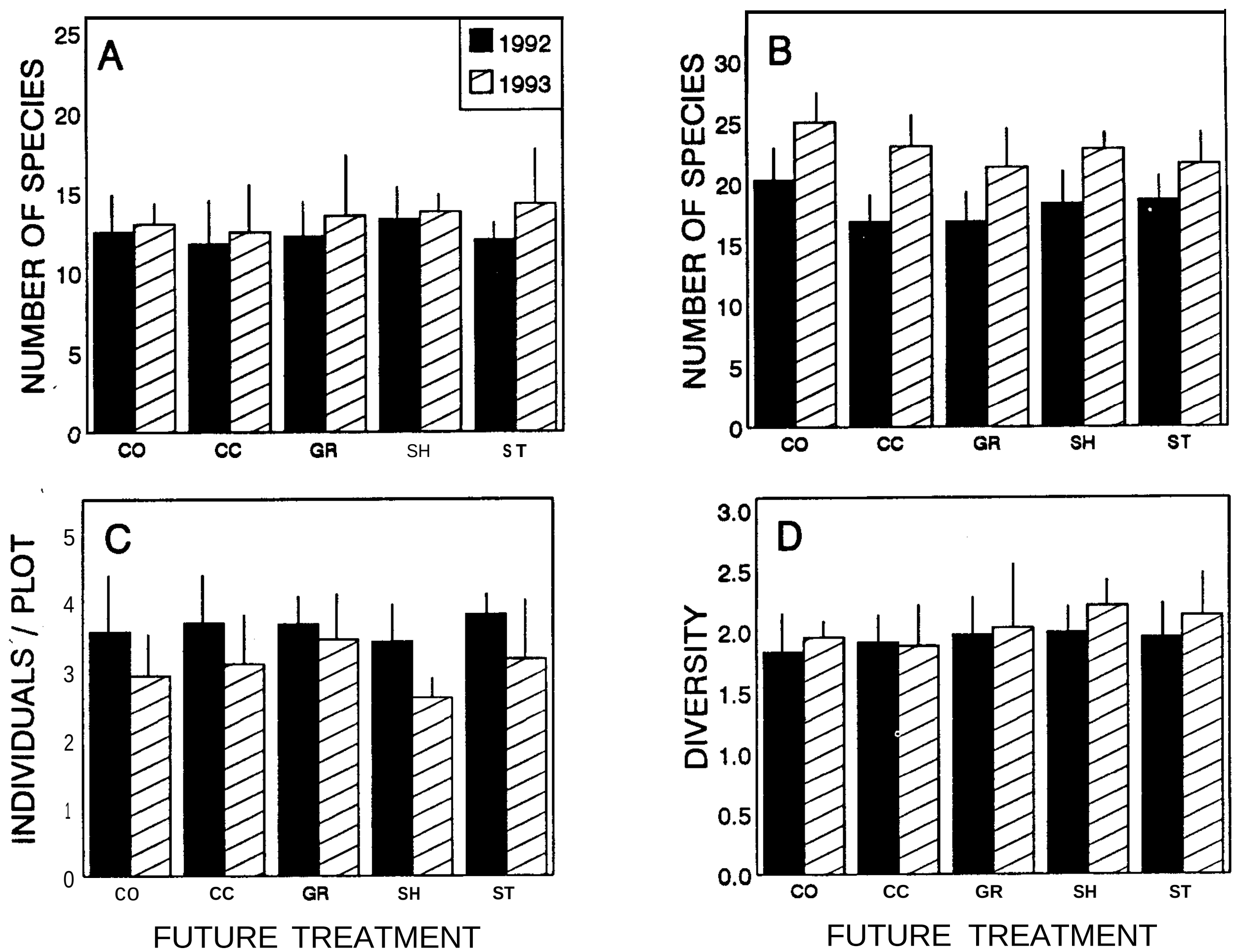

Figure 6.-- *Comparison of bird community metrics on late-rotation pine-hardwoods stands that will be subjected to different silvicultural treatments. Bars represent the mean value (+ 1 SD) across five sites for (A) species richness within bird survey plots, (B) species richness on entire site, (C) number of* individuals *detected per 40-m radius plot per survey, and (D)* Shannon- Weiner *diversity index (H'). CO = control, CC = clearcut, GR = group selection, SH = shelterwood, and ST = single-tree selection.*

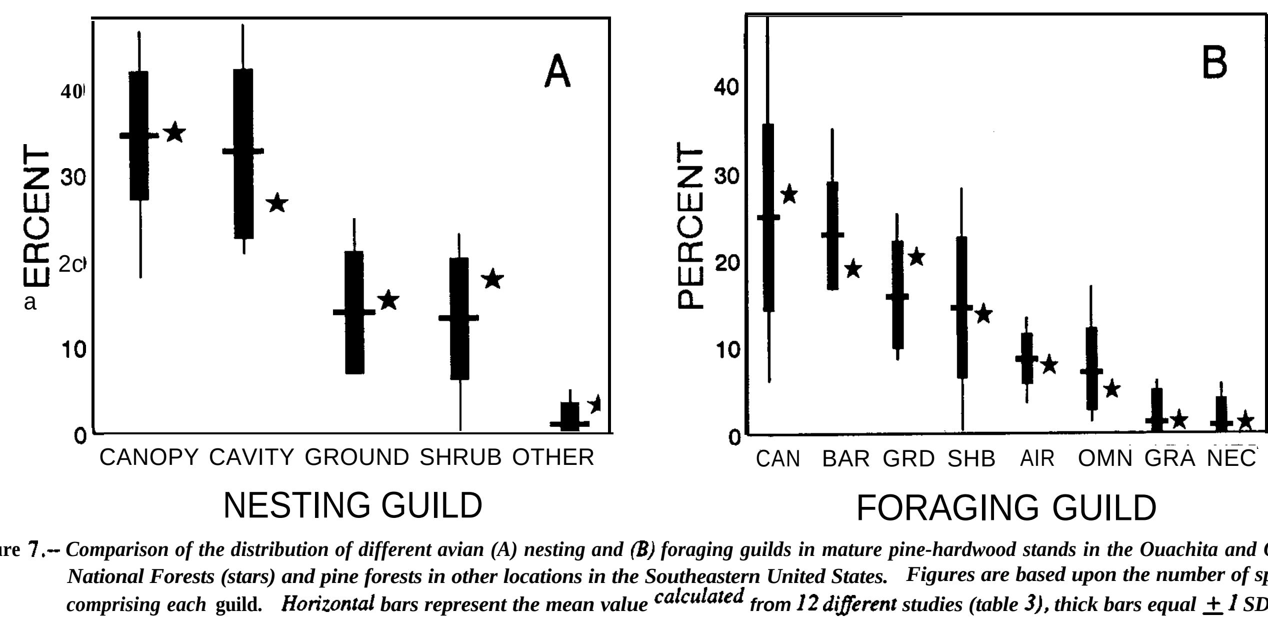

Figure 7.-- *Comparison of the distribution of different avian (A) nesting and (B) foraging guilds in mature pine-hardwood stands in the Ouachita and Ozark National Forests (stars) and pine forests in other locations in the Southeastern United States. Figures are based upon the number of species comprising each* guild. *Horizontal bars represent the mean value calculated from 12 different studies (table 3), thick bars equal* $\pm$ *1 SD, and thin vertical lines represent the range of values. Nesting guilds are open-cup, canopy (CANOPY); tree cavity (CAVITY); ground; open-cup, shrub layer (SHRUB); and other. Foraging guilds are foliage-gleaning insectivore, canopy (CAN); bark insectivore (BAR); ground insectivore (GRD): foliage-gleaning* insectivore, *shrub layer (SHB); aerial insectivore (AIR); omnivore (OMN); granivore (GRA); and nectarivore (NEC).*

Table 3.— Sorensen's Index *(SI)* of *bird community similarity between late-rotation, pine-hardwood stands in the Ouuchita and Ozark National Forests and other pine-associated forest types and areas* in *the Southeastern United States*

Forest type	Location	Number of sites	SI	Author
Longleaf-slash pine	Multiple States	3	36	Dickson and others 1980
Longleaf pine	Florida	3	39	Repenning and Labisky 1985
Slash pine	Florida	3	39	Repenning and Labisky 1985
Loblolly pine	Virginia	3	48	Childers and others 1986
Loblolly pine	Louisiana	1	53	Noble and Hamilton 1975
Loblolly-shortleaf pine	Texas	1	53	Dickson and Segelquist 1979
Mixed pine-hardwood	Texas	1	53	Dickson and Segelquist 1979
Pitch pine	New Jersey	6	53	Kerlinger 1983
Pitch pine-oak	Virginia	1	65	Conner and others 1979
Mixed pine-hardwood	Louisiana	1	73	Noble and Hamilton 1975
Loblolly-shortleaf pine	Multiple States	ca 5	75	Dickson and others 1980
Mixed pine-hardwood	Multiple States	4	78	Dickson and others 1980

DISCUSSION

Fixed-radius point counts appeared to be an appropriate means for estimating relative bird abundance in mature pine-hardwood forests. Three visits to each site were probably sufficient to detect nearly all species that would be recorded within survey plots with a moderate increase in effort (perhaps, five visits), because in all 3 years detection of new species slowed dramatically after the second visit (fig. 1). Similarly, Twedt and others (1993) conducted unlimited-distance point counts in Mississippi Alluvial Plain forests and found that the number ofspecies recorded after four visits did not differ significantly from the number detected after five visits. In the Ouachita and Ozarks, however, 30 to 40 percent of the total number of species recorded on a site were not detected within survey plots. Thus, by restricting survey plots to 0.5 ha, relative abundances of many species that occurred on each site were underestimated. Those species that were not detected within plots were extremely rare (each species comprised < 1 percent of the total individuals), often being detected on only one occasion. This rarity is evident in that, over three visits, rate of accumulation of species on the entire site (S_s) closely paralleled that found for species detected only within survey plots. Because these unlimited-distance counts covered a much larger area than the 40-m fixed-radius survey plots, a more rapid rate of species accumulation should have been exhibited if most species were at least moderately common (and detectable). Unlimiteddistance counts, as used in this study, will improve estimates of species richness compared to fixed-radius plots, although estimates of relative abundance may be more tenuous. Therefore, to maximize the information gained from general bird surveys in forests, wildlife biologists should incorporate both fixed-radius and unlimited-radius methods into survey protocols (Petit and others, in press).

The ramifications of underestimation of rare species are probably not significant in the scope of this research. Difficulty in quantifying abundance of rare species is common to all bird survey techniques (Ralph and Scott 1981). Furthermore, underestimation of abundance of rare species within fixed-radius plots should not hinder assessment of Ecosystem Management harvesting treatments, particularly if those rare species become more abundant after treatments are applied because of changes in successional stage or vegetative structure. In addition, although all species were not detected by the fixed-radius bird sampling technique, limited resources necessitated examination of relative differences among treatments. Thus, harvesting treatments that result in increases in abundance of species should be (statistically) detectable even though some of those species were underestimated during pretreatment surveys. In addition, several of those rare species (e.g., owls, hawks, and some woodpeckers) characteristically occupy large (> 10 ha) breeding territories, such that any survey technique focussed on stand-level populations would detect relatively few individuals. For those species, the effects of harvesting and management practices on breeding ecology might be most effectively assessed during the watershed-level manipulations of Phase III Ecosystem Management Research.

Not surprisingly, pine warblers were the most abundant bird species occupying mature mixed pine-hardwood stands of western Arkansas and eastern Oklahoma. Pine warblers reach their greatest densities in pine and mixed-pine forests of the Southeastern United States including the Ozark-Ouachita physiographic stratum (Hamel 1992, Robbins and others 1986). Although high relative abundances of breeding pine warblers have been reported by others (e.g., 30 percent of all individuals [Land and others 1989], 18 percent [Noble and Hamilton 1975], 14 percent [Conner and others 1979], 13 percent [Dickson and Segelquist 1979], and 10 percent [Kerlinger 1983]), our results suggest that pine warblers may comprise one-third or more of the total individuals in mature pine-hardwood forests in the Ozark and Ouachib plateaus. Caution must be used in interpreting our measure of abundance, however, because our survey technique does not fully account for variation in detectabilities among species. Nevertheless, such domination by a single species indicates that estimates of overall densities of birds in these pine-hardwood forests may be primarily influenced by the abundance of pine warblers. Summaries of bird population data from pine-hardwood stands may need to be more detailed than simple measures of overall density and richness, because numerical domination by one or a few species could cause those quantitative measures to be misleading. Rather, inferences about the bird community as a whole need to consider such characteristics as sex ratios, reproductive output, and the distribution of individuals and species among ecological guilds.

Red-eyed vireo was the only other species to comprise more than 10 percent of the individuals. Based on breeding densities, pine-hardwood forests apparently are not optimal habitats for red-eyed vireos (e.g., Hamel 1992), but they will occupy a wide range of pine-associated habitats depending on the extent of deciduous canopy and understory trees (Hamel 1992). Local population densities of pine warblers and red-eyed vireos apparently are correlated to similar habitat features, but in opposite ways. Pine warblers respond positively to increased pine composition, whereas red-eyed vireos would decline under those conditions (Hamel 1992, Johnston and Odum 1956). Hence, the mixed-tree species composition found on the Ouachita and Ozark stands allowed both species to persist in relatively high numbers.

Individuals that build open-cup nests in the canopy contributed most to guild membership largely because of the abundance of pine warblers and red-eyed vireos. At the species level, nesting guilds were much more evenly distributed. A similar pattern was revealed for foraging/trophic guilds; that is, canopy insectivores, such as red-eyed vireos and pine warblers, comprised the majority of individuals detected. Discounting relative abundance, species that forage from bark, canopy foliage, shrub foliage, and the ground were well represented. These results suggest that management or harvesting methods that alter basal area, leaf litter characteristics, or foliage density at canopy/subcanopy or shrub levels may have negative repercussions on many forest species that require those resources for nesting and foraging (see L. J. Petit and others, this volume).

Comparison of bird community composition of mixed pine-hardwoods in the Ouachita Mountains with other pine-associated forests throughout the Southeastern United States suggests that application of results from Ecosystem Management Research in Arkansas and Oklahoma may not be highly useful in predicting community-level responses in other National Forests in the region. This was not surprising given differences in species ranges and abundances across the Southeast. Yet, even representation of foraging and nesting guilds varied substantially among sites and forest types (although Ouachita/Ozark sites were closely aligned with general trends throughout the region). In addition, Ecosystem Management Research described in this paper incorporated only a portion of the microclimatic and vegetative variability found in pine-hardwood stands in this region because only south-facing aspects were considered. These restrictions, although necessary in this highly controlled experiment, may further hinder generalizations to other areas within the Southeastern United States.

Based upon Hamel's (1992) compilation of potential bird communities, USDA Ecosystem Management Research in Arkansas and Oklahoma should be most applicable to loblolly-shortleaf and oak-hickory forest types in the Southeast region. Nevertheless, predicting bird community- or guild-level responses to harvesting treatments still may be difficult in many locations, or for some foraging and nesting guilds. That uncertainty could create a dilemma for forest managers. For example, forest managers often attempt to maintain or enhance local diversity of species on lands under their jurisdiction (Thomas and Salwasser 1989). If the current Ouachita Ecosystem Management Research suggests that a certain timber harvesting treatment should be applied to increase diversity, should that recommendation be followed even though bird species composition in the two areas are not highly similar? Thus, caution must be used when applying Ecosystem Management Research results to predict changes in species diversity or richness at other sites.

However, community-wide predictions in other areas still may be possible because nearly all species found in Southeastern pine forests also were recorded in the Ouachita Mountains. Similarities between the bird communities in mixed pine-hardwood forest and the other six major forest types (Hamel 1992) were positively correlated with species richness in the latter group. This indicates that the bird communities in the five types of pine forest were subsets of the bird community characteristic of mixed pine-hardwoods, which itself was a subset of that in oak-hickory forest. Thus, although results of this study will be most valuable for predicting bird responses to harvesting treatments on a species-by-species basis, forest managers in other National Forests also may be able to develop community-wide predictions from this Ecosystem Management Research.

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LITERATURE CITED

Childers, Eddie L.; Sharik, Terry L.; Adkisson, Curtis S. 1986. Effects of loblolly pine plantations on songbird dynamics in the Virginia Piedmont. Journal of Wildlife Management. 50(3): 406-413.

Conner, Richard N.; Via, Jerry W.; Prather, Irvine D. 1979. Effects of pine-oak clearcutting on winter and breeding birds in southwestern Virginia. Wilson Bulletin. 91(2): 310-316.

Dickson, James G.; Segelquist, Charles A. 1979. Breeding bird populations in pine and pine-hardwood forests in Texas. Journal of Wildlife Management. 43(2): 549-555.

Dickson, James G.; Conner, Richard N.; Williamson, J. Howard. 1980. Relative abundances of breeding birds in forest stands in the Southeast. Southern Journal of Applied Forestry. 4(2): 174-179.

Ehrlich, Paul R.; Dobkin, David S.; Wheye, Darryl. 1988. The birder's handbook: a field guide to the natural history of North American birds. New York: Simon and Schuster; 785 p.

Evans, Keith E. 1978. Oak-pine and oak-hickory forest bird communities and management options. In: DeGraaf, Richard M., tech. coord. Management of southern forests for nongame birds: proceedings of the workshop. Gen. Tech. Rep. SE-14. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 76-89.

Frissell, Christopher A.; Nawa, Richard K.; Noss, Reed. 1992. Is there any conservation biology in "New Perspectives?": a response to Salwasser. Conservation Biology. 6(3): 461-464.

Hamel, Paul B. 1992. The land manager's guide to the birds of the South. Chapel Hill, NC: The Nature Conservancy, Southeastern Region; 437 p.

Harris, Larry D.; White, L. D.; Johnston, J. E.; Milchunas, D. G. 1974, Impact of forest plantations on north Florida wildlife and habitat. Proceedings of the Southeastern Association of Game and Fish Commissioners. 28: 659-667.

Jackson, Jerome A. 1988. The southeastern pine forest ecosystem and its birds: past, present, and future. In: Jackson, Jerome A., ed. Bird Conservation 3. Madison, WI: University of Wisconsin Press: 119-159.

Johnson, A. Sydney. 1987. Pine plantations as wildlife habitat: a perspective. In: Dickson, James G; Maughan, 0. E., eds. Managing southern forests for wildlife and fish. Gen. Tech. Rep. SO-65. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 12-18.

Johnston, David W.; Odum, Eugene P. 1956. Breeding bird populations in relation to plant succession on the Piedmont of Georgia. Ecology. 37(1): 50-62.

Kerlinger, Paul. 1983. Avian community structure along a successional gradient in the New Jersey pine barrens. Records of New Jersey Birds. 9(4): 71-78.

Knight, H. A. 1987. The pine decline. Journal of Forestry. 85(1): 25-28.

Land, Darrell; Marion, Wayne R.; O'Meara, Timothy E. 1989. Snag availability and cavity nesting birds in slash pine plantations. Journal of Wildlife Management. 53(4): 1,165-l) 17 1.

Meyers, Joseph M.; Johnson, A. Sydney. 1978. Bird communities associated with succession and management of loblolly-shortleaf pine forests. In: DeGraaf, Richard M., tech. coord. Management of southern forests for nongame birds: proceedings of the workshop. Gen. Tech. Rep. SE-14. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 50-65.

Mueller-Dombois, D.; Ellenberg, E. 1974. Aims and methods of vegetation ecology. New York: John Wiley and Sons.

Neter, John; Wasserman, William. 1974. Applied linear statistical models. Homewood, IL: Richard D. Irwin, Inc (p. 582). 842 p.

Noble, Robert E.; Hamilton, Robert B. 1975. Bird populations in even-aged loblolly pine forests of southeastern Louisiana. Proceedings of the Southeastern Association of Game and Fish Commissioners. 29: 441-450.

Petit, Daniel R.; Petit, Lisa J.; Saab, Victoria A.; Martin, Thomas E. [In press]. Fixed-radius point counts in forests: factors influencing effectiveness and efficiency. In: Ralph, C. John; Sauer, John R.; Droege, Sam, eds. Proceedings of the symposium on monitoring bird population trends by point counts; November 6-7, 1991, Beltsville, Maryland. Gen. Tech. Rep. PSW-GTR-OOO. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station.

Pielou, E. C. 1969. An introduction to mathematical ecology. New York: Wiley-Interscience.

Ralph; C. John; Scott, J. Michael, eds. 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: l-630. Lawrence, KS: Cooper ornithological Society.

Repenning, Robert W.; Labisky, Ronald F. 1985. Effects of even-age timber management on bird communities of the longleaf pine forest in northern Florida. Journal of Wildlife Management. 49(4):1,088-1,098.

Robbins, Chandler S.; Bystrak, Danny; Geissler, Paul H. 1986. The breeding bird survey: its first fifteen years, 1965-1979. Resour. Publ. 157. Washington, D.C.: U.S. Department of Interior, Fish and Wildlife Service. 196 p.

Salwasser, Hal. 1991. New Perspectives for sustaining diversity in U.S. national forest ecosystems. Conservation Biology. 5(4): 567-569.

Salwasser, Hal. 1992. From New Perspectives to ecosystem management: response to Frissell et al. and Lawrence and Murphy. Conservation Biology. 6(3): 469-472.

Smith, Kimberly G.; Petit, Daniel R. 1988. Breeding birds and forestry practices in the Ozarks: past, present, and future relationships. In: Jackson, Jerome A., ed. Bird Conservation 3. Madison, WI: University of Wisconsin Press: 23-49.

Thomas, Jack Ward; Salwasser, Hal. 1989. Bringing conservation biology into a position of influence in natural resource management. Conservation Biology. 3(1): 123-127.

Twedt, Daniel J.; Smith, Winston P.; Cooper, Robert J.; Ford, Robert P.; Hamel, Paul B.; Wiedenfeld, David A. 1993. Sampling bird communities in bottomland hardwood forests of the Mississippi Alluvial Valley: number of points visited versus number of visits to a point. In: Smith, Winston P., ed. Proceedings of the 4th meeting of the Southeast Management Working Group, Partners in Flight: abstracts; November 12-14, 1992; Memphis, TN. Gen. Tech. Rep. SO-95. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 16.

Predicting the Effects of Ecosystem Management Harvesting Treatments on Breeding Birds in Pine-Hardwood Forests[1]

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ABSTRACT

Habitat relationships of birds are well known compared to those of other taxa. However, a major obstacle to developing rigorous management plans for birds is the collation and transfer of information from widely scattered technical and academic publications to a form that can be applied directly to the management of species. Recognizing this dilemma, Hamel (1992) produced a comprehensive summary of bird-habitat relationships for 23 forest types in the Southeastern United States. The explicit purpose of Hamel's summary was to aid land managers in projecting the impacts of silvicultural practices and management activities on bird populations. Ecosystem Management Research offered a unique opportunity to develop and test predictions derived from Hamel's bird-habitat matrices. Given its probable widespread use by wildlife biologists and land managers, Hamel's compilation needs its strengths and weaknesses identified for the future development of accurate predictive models of wildlife habitat in the Southeastern United States. Predictions of immediate changes in abundances of species and guilds occupying late-rotation pine-hardwood stands were developed in this paper for four harvesting treatments. Clearcutting and shelterwood harvesting were predicted to be more detrimental to the overall breeding bird community in late-rotation stands than were group or single-tree selection, although at least several species were predicted to increase in each silvicultural treatment. Bark, aerial, and canopy insectivores were predicted to exhibit more substantial declines in populations than carnivores, shrub insectivores, and ground foragers. In addition, species that place their nests in shrubs were predicted to undergo fewer declines than species that place nests in the canopy, tree cavities, and on the ground.

INTRODUCTION

The negative environmental consequences associated with human population growth and economic expansion have focused much attention on the long-term sustainability of natural resources as well as prompting detailed examination of the ways in which those resources are managed. For wildlife biologists involved in those issues, the goal is often to develop predictive algorithms that relate land-use practices or management techniques to the density and viability of wildlife populations on local (e.g., Vemer and others 1986) and regional (e.g., Joyce and others 1990) scales. Those efforts, however, are often hindered because of lack of detailed information on the habitat associations, nesting and food requirements, and life-history traits of most species (DeGraaf 1991, Martin 1992).

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Ecology and habitat relationships of North American birds are well known relative to those of other **taxa,** such as mammals, amphibians, and reptiles **(Capen** 1981, **DeGraaf** 1978, Evans 1978, Evans and **Kirkman** 1981, Ruggiero and others 1991). Nevertheless, one major obstacle to developing rigorous management plans for birds is the collation and transfer of information from technical academic publications to a form that can be applied directly to the management of those species. Recognizing this dilemma, several authors have synthesized large volumes of literature on regional habitat relationships of birds in attempts to provide comprehensive, yet condensed, summaries to land managers (e.g., **Hamel** and others 1982, Vemer and Boss 1980). These summaries have the explicit purpose of guiding land managers in evaluating the projected impact of different management practices on terrestrial land birds. However, not only are these bird-habitat matrices incomplete due to a scant primary literature and lack of geographic specificity, but the nonquantitative format might allow land managers to construct only generalized predictions. For example, extreme types of habitat manipulations (e.g., clearcutting) may have predictable outcomes on bird populations, but consequences of more subtle management prescriptions (e.g., thinning of hardwoods) may be impossible to estimate from bird-habitat matrices or even from existing primary literature. ‘The potential widespread use of bird-habitat matrices by wildlife and land managers requires that the accuracy and precision of projections from those summaries be tested before actually being put into field use.

In 1992, Paul **Hamel** produced the most comprehensive regional summary of bird-habitat relationships ever published in the United States, a revision of a document completed 10 years earlier **(Hamel** and others 1982). **Hamel's** (1992) summary of information for 23 forest types in the Southeastern United States provided state-of-the-art guidelines for land managers in that 13-state region. The guide had two primary uses, one of which was “to aid the manager both in prescribing treatments aimed at improving avian habitats and in assessing and ameliorating the impacts of other management activities on bird communities” **(Hamel** 1992, **p.** 3). **Hamel** also stressed that guidelines provided in the manual could be improved through further testing and supplementation of information.

The USDA Forest Service’s Ecosystem Management Research in the Guachita and Ozark National Forests offers a unique opportunity to assess the predictability of **Hamel's** bird-habitat matrices, as well as to improve upon the information contained therein. In this paper, **Hamel's** bird-habitat matrices were used to project changes in relative population densities of species and in representation of foraging and nesting guilds that will occur within the **first** few (1 to 3) years following different Ecosystem Management harvesting regimes. (Examination of predicted trends with observed outcomes will be completed after **several** years of posttreatment data are gathered.) Given the immediate widespread use of **Hamel's** landmark guide by USDA Forest Service personnel, as well as other government and private land managers, identification of strengths and weaknesses of this compilation is both timely and critical for development of accurate predictive models of wildlife habitat in the Southeastern United States.

METHODS

Study Sites

Birds were surveyed on 20 of the Ecosystem Management Research stands in the Ozark and Ouachita National Forests of Arkansas and Oklahoma (Thill and others, this volume). Each 14 to 16 ha site corresponded to an individual USDA Forest Service compartment and stand and was separated from other sites by more than 5 km. Stands were comprised of mixed pine-hardwoods that were more than 70 years old. Dominant **midstory** and overstory tree species included ***Carya*** spp. ***Pinus echinata*** Mill., ***Quercus alba*** L., ***Q. marilandica*** Muenchh., ***Q. rubra*** L., ***Q. stellata*** Wangenh., **and Q.** ***velutina*** Lam. Canopies were largely closed and had attained heights of **15-25** m. All sites were positioned on southeast-, south-, or southwest-facing slopes. Additional details of site and vegetative characteristics can be found in Baker (this volume) and Thill and others (this volume).

Pretreatment Data: Breeding Bird Communities of Late-Rotation Pine-Hardwood Stands

Bird abundance was quantified in five or six (depending on size and shape of the site) 40-m radius (0.5 ha) circular plots spaced at greater than 130 m intervals over each site. Between 28 April and 2 June in 1992 and 1993, three visits were made to each site during which time all birds seen or heard within bird survey plots were recorded. Bird counts lasted 10 minutes and were conducted between **06:00** and 12:O0. Birds seen outside of survey plots were noted but were not included in this paper (see D.R. Petit and others [this volume] for additional details).

Fifty-five species were recorded on the 20 sites in 1992 and 1993. Most species were rare, with 82 percent of all individuals being represented by just 10 species (D.R. Petit and others, this volume). All species were assigned to a nesting and **foraging/trophic** guild based upon **Hamel** (1992) and Ehrlich and others (1988).

Ecosystem Management Harvesting Treatments

Four harvesting treatments are to be applied to each of four sites (four additional stands will act as control sites where no harvesting will be performed). On all sites (except controls), understory hardwoods will be controlled (herbicide or mechanical methods) when necessary to ensure regeneration of an appropriate pine and hardwood mixture. Treatment descriptions below are taken from the Ecosystem Management study plan (summarized in Baker [this volume]) and represent general harvesting goals.

(1) ***Clearcut*** -- All pine and hardwoods will be harvested or removed, except for hardwoods in greenbelt buffer strips along drainages. Altogether, approximately 10 percent of hardwoods will be retained for den-trees and mast production.

(2) ***Pine/hardwood shelterwood*** -- Twenty to forty overstory pines and hardwoods (4 to 5 m^2 basal area [BA]) per hectare (ha) are to be retained throughout the stand (i.e., approximately 70 to 80 percent of merchantable trees harvested).

(3) ***Pine/hardwood group selection*** -- All merchantable pines and hardwoods will be harvested within 0.04 to 0.40 ha group openings. Cutting will be on a lo-year rotation. No hardwoods outside openings will be harvested, but pines in those areas will be thinned to approximately 7 m^2 BA/ha (i.e., approximately 10 to 20 percent of the merchantable pines removed).

(4) ***Pine/hardwood single-tree selection*** -- Approximately 40 to 50 percent of overstory pines (5 to 7 m^2 BA/ha retained) and hardwoods (2 to 4 m^2 BA/ha retained) will be harvested in the initial thinning. Subsequent, less intensive thinning on a lo-year cycle will be used to create an uneven-aged forest structure.

Hamel's Bird-Habitat Matrices and Development of Predictions

Hamel (1992) included in his summarization information on forest types, seral stages, and vertical vegetative layers used by species during the breeding season. In addition, specific requirements for nesting and foraging and minimum tract sixes for each species were provided, when known. Bird-habitat matrices primarily consisted of qualitative assessments of whether a given resource category (e.g., seral stage or vegetative layer) was used by each species. With the exception of seral stages and minimum tract sixes, neither the extent of use of those resources (e.g., weighted use of vegetative layers) nor estimates of optimal conditions (e.g., percent canopy cover) were given. Predictions developed in this paper were based upon data from the mixed pine-hardwood forest type. See Hamel (1992) for additional information.

Use of qualitative measures to predict general changes from pretreatment bird population densities is difficult because of the subjectiveness involved in estimating the magnitude of treatment effects on those populations. The projected relative changes in seral stage, tree density, vegetative structure, and other environmental features (e.g., leaf litter, fragmentation) associated with each of the four harvesting treatments (table 1) were estimated through examination of Ecosystem Management harvesting goals (Baker, this volume) and Phase I summaries of pretreatment and posttreatment stand conditions (Baker 1992).[3] Those changes were compared to key habitat and condition requirements indicated for each bird species by Hamel (1992), and predictions were generated on whether harvesting treatments would result in changes in relative population densities. Magnitudes of predicted changes in bird populations were estimated by assigning a score to each environmental feature within each treatment that would reflect the degree of change in the stand environment from the pretreatment (control) conditions (table 1). Subtle differences in initial harvesting volumes between group selection and single-tree selection made differentiation between effects of the two treatments on bird populations particularly difficult.Hence, projections were based on differences in spatial configurations of habitat alterations in addition to residual pine and hardwood basal area.

[3] Baker, James B. 1992. New Perspectives research on the Ouachita/Ozark National Forests: Phase I -- an unreplicated pilot test. 10 p. Monticello, AR: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station, Forestry Sciences Laboratory, Establishment/Progress Report FS-SO-4106-81.

Table 1.-- *Changes in environmental features associated with different harvesting treatments. Environmental variables were taken from Hamel (1992). Projected estimates represent the relative changes in extent and/or condition compared to pretreatment (control) characteristics. Posttreatment conditions reflect stand chamcteristics expected during the initial 1 to 3 year postharvesting period*

	Harvestine treatment			
Environmental variable	Clearcut	Shelterwood	Group selection	Single tree
Seral stage				
Grass/forb	I3[a]	I3	11	11
Shrub/seedling	I3	I3	I1	I1
Saplinglpoletimber	D3	D2	D1	D1
Sawtimber	D3	D2	D1	D1
Vegetative layer				
Bare soil	11	I1	11	I1
Leaf liir	D2	D2	D1	D1
Herbs	I2	I2	I1	I1
Shrubs	I2	I2	I1	I1
Midstory	D3	D2	D1	D1
Overstory	D3	D2	D1	D1
Key requirements				
Closed canopy	D3	D3	D2	D2
Open canopy	11	I3	I2	I3
Grassy openings	I2	I2	13	I2
Bii trees	D3	D2	D1	D1
Snags/cavity trees	D3	D2	D1	D1
Forest continuity	D2	D2	D2	D1

[a] Letters represent decrease (D) or increase (I) in resource. Numbers represent extent of change: 1 = slight, 2 = moderate, 3 = major.

The algorithm used to project bird population changes was simply the sum of the key individual environmental components identified for each species (e.g., 13 = +3, D2 = -2). Based upon the distribution of these scores, arbitrary cutpoints were designated which corresponded to each level of predicted change (e.g., moderate increase). These methods represent a relatively parsimonious approach that can be updated as knowledge of species and environmental changes associated with harvesting treatments increased. Predictions were developed only for those species recorded within fixed-radius plots. Species detected on the sites, but outside of bird survey plots were excluded because those species were extremely rare, such that statistical tests aimed at testing the predictions may not be powerful. Bird species not recorded in late-rotation stands during pretreatment surveys, but known to occur in other seral stages or habitats in the region, also were not included because of the lack of information about local population levels of those species. For instance, one could predict that a certain early-successional species, which was not detected during pretreatment surveys, should be present on clearcut stands. However, if that prediction was not supported by data collected during posttreatment bird surveys, it would be difficult to conclude that clearcutting had no effect on populations of that species because factors other than habitat manipulation (e.g., geographic distribution, local abundance) could account for the lack of response.

RESULTS

Based upon information provided by Hamel (1992), harvesting treatments were predicted to have different effects on the bird species breeding in late-rotation, mixed pine-hardwood forests. Clearcut (CC) and sheltenvood (SH) probably will have the most dramatic effects on the pretreatment bird communities (table 2; see the companion paper in this volume [D.R. Petit and others] for scientific names). A total of 52 (88 percent) and 50 (85 percent) of the 59 species detected within fixed-radius plots in 1992 and 1993 were expected to exhibit appreciable decreases in population density within 1 to 3 years after clearcutting and shelterwood cuts, respectively. In contrast, only 38 (64 percent) and 36 (61 percent) of the bird species were predicted to decline after the group (GR) and single-tree (ST) treatments, respectively. Moreover, the declines under the latter two harvesting treatments were projected to be much less severe than the former treatments. Overall, population declines associated with harvesting treatments were predicted to be highest in CC, followed by SH, GR, and ST.

Table 2.– *Predicted population responses by bird species breeding in late-rotation pine-hardwood stands to harvesting treatments in the Ouachita and Ozark National Forests*

SPECIES	GUILD N	GUILD F	TREATMENT CC	TREATMENT SH	TREATMENT GR	TREATMENT ST
COOPER'S HAWK	C	CA	--	--	0/-	0/-
RED-SHOULDERED HAWK	C	CA	-	0/-	0/-	0/+
BROAD-WINGED HAWK	C	CA	-	0/-	0/-	0/+
RED-TAILED HAWK	C	CA	0/-	0/-	0/+	0/+
WILD TURKEY	G	G	--	-	0/-	0/-
NORTHERN BOBWHITE	G	G	+	++	++	++
MOURNING DOVE	C	GR	0/-	0/+	+	+
BLACK-BILLED CUCKOO	C	C	--	--	0/-	0/-
YELLOW-BILLED CUCKOO	C	C	--	--	0/-	0/-
BARRED OWL	H	CA	--	--	0/-	0/-
GREAT-HORNED OWL	C	CA	-	0/-	0/+	0/+
CHUCK-WILL'S WIDOW	G	A	--	--	0/-	0/-
RUBY-THROATED HUMMINGBIRD	C	N	--	-	0/+	0/+
BELTED KINGFISHER	0	P	--	-	0/-	0/-
RED-HEADED WOODPECKER	H	B	-	0/-	0/+	0/+
RED-BELLIED WOODPECKER	H	B	--	--	-	0/-
DOWNY WOODPECKER	H	B	--	--	0/-	0/-
HAIRY WOODPECKER	H	B	--	--	-	-
NORTHERN FLICKER	H	B	--	-	0/+	0/+
PILEATED WOODPECKER	H	B	--	--	--	-
EASTERN WOOD-PEWEE	C	A	--	--	0/-	0/-
ACADIAN FLYCATCHER	C	A	--	--	-	0/-
GREAT CRESTED FLYCATCHER	H	A	--	--	-	-
BLUE JAY	C	O	-	-	0/+	0/+
AMERICAN CROW	C	0	-	-	0/-	0/-
CAROLINA CHICKADEE	H	C	--	--	0/-	0/-
TUFTED TITMOUSE	H	C	--	--	0/-	0/-
WHITE-BREASTED NUTHATCH	H	B	--	--	-	-
BROWN-HEADED NUTHATCH	H	B	--	--	0/-	0/-
CAROLINA WREN	H	G	-	0/-	0/+	0/+
BLUE-GRAY GNATCATCHER	C	C	--	--	0/-	0/-
WOOD THRUSH	S	G	---	--	-	0/-
GRAY CATBIRD	S	S	-	0/-	0/+	0/+
CEDAR WAXWING	C	C	-	0/-	0/+	0/+
WHITE-EYED VIREO	S	S	0/-	o/t	t	t
YELLOW-THROATED VIREO	C	C	--	--	0/-	0/-
RED-EYED VIREO	C	C	--	--	-	0/-
NORTHERN PARULA	C	C	--	--	-	0/-
YELLOW-THROATED WARBLER	C	C	--	---	-	--
PINE WARBLER	C	C	--	--	-	0/-
PRAIRIE WARBLER	S	S	++	++	+	+
BLACK-AND-WHITE WARBLER	G	B	--	--	--	-
AMERICAN REDSTART	C	C	-	- -	- 0/-	0/-
WORM-EATING WARBLER	G	S	-	--	-	0/-
SWAINSON'S WARBLER	S	G	--	-	0/-	0/-
OVENBIRD	G	G	-	-	0/-	0/-
LOUISIANA WATERTHRUSH	G	G	-	-	0/-	0/-
KENTUCKY WARBLER	G	G	-	0/-	0/-	0/+
HOODED WARBLER	S	S	--	-	0/-	0/-
YELLOW-BREASTED CHAT	S	S	++	++	++	+
SUMMER TANAGER	C	C	--	--	-	0/-
SCARLET TANAGER	C	C	--	--	-	-
NORTHERN CARDINAL	S	S	-	0/-	0/+	0/+
RUFOUS-SIDED TOWHEE	S	G	-	0/-	0/+	0/+
CHIPPING SPARROW	S	G	0/+	+	++	++
COMMON GRACKLE	C	G	-	0/-	0/+	0/+
BROWN-HEADED COWBIRD	O	G	0/+	+	++	++
AMERICAN GOLDFINCH	S	S	0/+	+	+	+
INDIGO BUNTING	S	S	0/+	+	++	++

Note: Nesting (N) guilds: C = canopy, S = shrub, G = ground, H = hole (cavity) in tree, 0 = other.

Foraging (F) guilds: CA = carnivore, C = canopy insectivore, S = shrub insectivore, B = bark insectivore, A = aerial insectivore, G = ground, P = piscivore, N = nectarivore, 0 = omnivore.

Harvesting treatments: CC = clearcut, SH = shelterwood, GR = group selection, ST = single-tree selection.

Predicted population responses: '++' = major increase, '+' = moderate increase, '0/+' = slight increase, '--' = major decrease, '-' = moderate decrease, '0/-' = slight decrease.

Harvesting treatments were not predicted to affect all nesting and foraging guilds equally. Bark, aerial, and canopy insectivores probably will exhibit more declines than carnivores, shrub insectivores, and ground foragers (fig. 1). At least 90 percent of the bark, air, and canopy foragers were predicted to decline under CC and SH treatments compared with 10 to 60 percent of those species after single-tree and group selection cuts. Fewer than 10 percent of the species which are shrub insectivores, ground foragers, and carnivores were expected to show marked declines after ST and GR cuts. In contrast, clearcutting was predicted to result in declines for approximately 80 percent of carnivores and ground foragers. Shelterwood cuts were predicted to be intermediate in their impact on carnivores and ground foragers. Only 25 percent and 40 percent of shrub insectivores were predicted to exhibit declines after SH and CC, respectively.

Ecosystem Management harvesting treatments probably will have relatively small initial negative effects on birds that place their nests in shrubs compared to those species that build nests in tree canopies, on the ground, or in cavities (fig. 2). The GR and ST harvests may reduce populations of 10 to 40 percent of the species in each of the latter three nesting guilds, whereas CC and SH methods may result in declines in 75 to 100 percent of the species comprising those guilds.

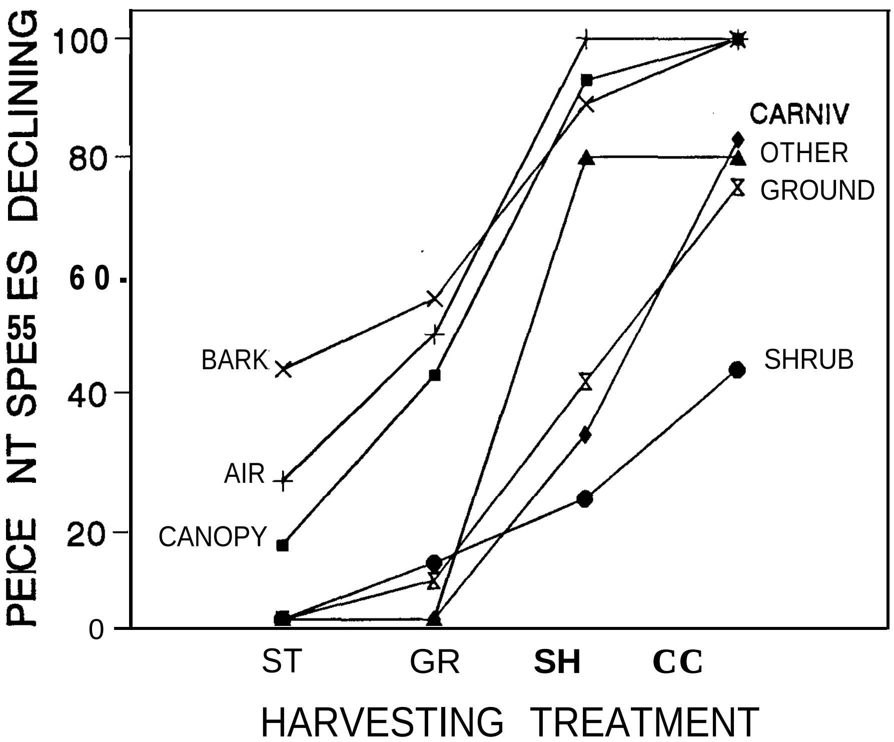

Figure 1.—*Effects of Ecosystem Management harvesting treatments on avian foraging guilds. Symbols represent the percentage of species in each guild predicted to exhibit substantial declines in population density. Harvesting treatments: ST = single-tree selection; GR = group selection; SH = shelterwood; CC = clearcut. See text for descriptions of treatments. Foraging guilds: Canopy = canopy (>3 m) insectivore; Shrub = shrub (< 3 m) insectivore; Ground = ground insectivore; Bark = bark insectivore; Air = aerial insectivore; Carniv = carnivore; Other = nectarivore, granivore, piscivore, omnivore.*

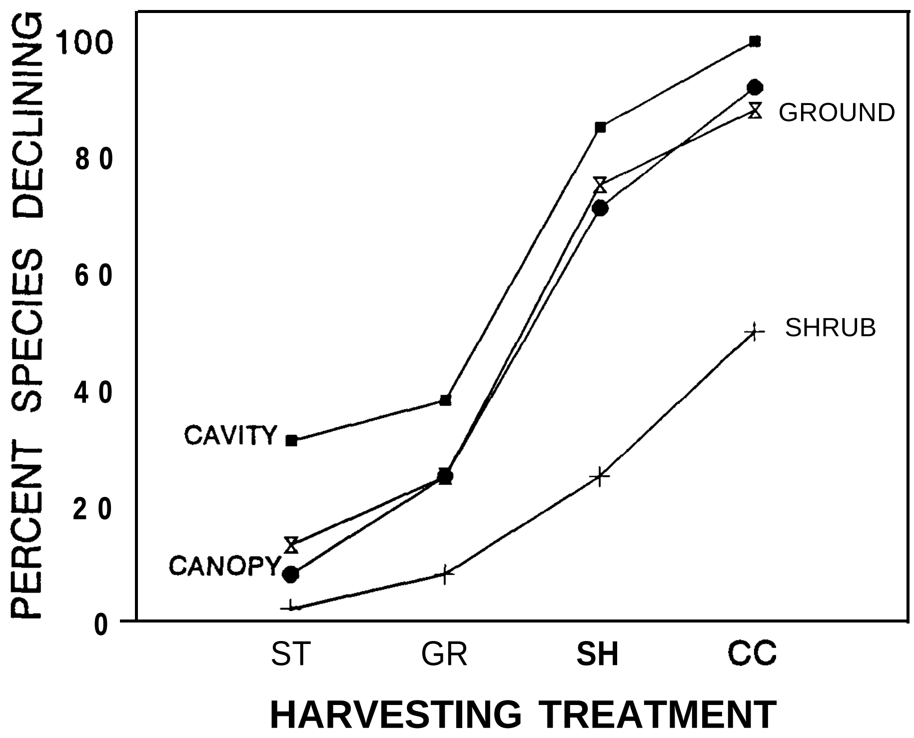

Figure 2.-- *Effects of Ecosystem Management harvesting treatments on avian nesting guilds. Symbols represent the percentage of species in each guild predicted to exhibit substantial declines in population density. Harvesting treatments: ST = pine/hardwood single-tree selection; GR = pine/hardwood group selection; SH = pine/hardwood shelterwood; CC = clearcut. See text for descriptions of treatments. Nesting guilds: Canopy = open-cup, canopy; Shrub = open-cup, shrubs; Cavity = tree cavity; Ground.*

DISCUSSION AND CONCLUSIONS

Projected posttreatment habitat characteristics in this study (table 1) were based upon conditions expected within *3 years* of harvest because of uncertainty about long-term continuation of bird surveys on these sites. Clearly, however, turnover in species composition through time occurs after habitat alteration, so that bird community characteristics in any given period are likely to be different from those during other periods (Johnston and Odum 1956). Thus, predictions of changes in relative bird densities made in this paper are applicable only during a relatively brief postharvest period. Monitoring bird populations on these sites over several decades or longer would provide critical information on the *long-term* impacts of Ecosystem Management harvesting treatments. In fact, following timber harvesting, ecosystem structure and function may take a century *or* more to return to a state similar to preharvest conditions (e.g., Duffy and Meier 1992). Nevertheless, knowledge of the immediate effects of forest management on wildlife populations is imperative for development of effective wildlife management plans.

If population projections presented in this paper are accurate, wildlife biologists can expect that foraging and nesting guilds will be differentially affected by the Ecosystem Management timber harvesting treatments. Predicted decreases in these guilds are closely related to key ecological requirements that are altered by the various harvesting regimes. Knowledge of those requirements may allow forest managers to modify harvesting schemes to optimize the tradeoff between retention of ecological features critical for maintenance of forest bird assemblages and production of timber.

Projected changes in bird population and guild densities generally were consistent with changes documented in previous empirical studies of avian responses to different types of habitat alteration (e.g., Crawford and others 1981, Conner and others 1979, **Medin** 1985, Webb and others **1977),** as well as with general impressions of the direction and magnitude of changes baaed upon our knowledge of bird-habitat relationships. This may not seem surprising given the fact that **Hamel's** (1992) bird-habitat matrix was built upon those previous studies, as well as expert opinion. However, although a logical basis exists for concurrence between the predictions and the data upon which the matrix was constructed, one main purpose of this exercise was to **assess** the efficacy of the matrix to produce reasonable predictions of population change without application of sophisticated mathematical manipulations. Given the qualitative format of **Hamel's** (1992) guide, we were encouraged by the apparently accurate projections of bird population densities. In fact, predictions developed in this paper appear to provide support for this type of approach in wildlife management. Predictions derived from **Hamel's** (1992) work, whether needing substantial refinement or not, may be the best that land managers have to work with until predictions are tested and additional research is conducted to evaluate the effects of traditional and nontraditional silvicultural treatments on bird populations.

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LITERATURE CITED

Capen, David E., **ed.** 1981. The use of multivariate statistics in studies of wildlife habitat. Gen. Tech. Rep. RM-87. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 249 p.

Conner, Richard N.; Via, Jerry W.; Prather, Irvine D. 1979. Effects of pine-oak clearcutting on winter and breeding birds in southwestern Virginia. Wilson Bulletin. **91(2):** 301-316.

Crawford, H. S.; **Hooper,** R. G.; Titterington, R. W. 1981. Songbird population response to silvicultural practices in central Appalachian hardwoods. Journal of Wildlife Management. **45(3):** 680692.

DeGraaf, Richard M., tech. coord. 1978. Proceedings of the workshop on **nongame** bird habitat management in the coniferous forests of the western United States. Gen. Tech. Rep. PNW-64. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 100 p.

DeGraaf, Richard M. 1991. Breeding bird assemblages in managed northern hardwood forests in New England. In: Rodiek, Jon E.; Bolen, Eric G., eds. Wildlife and habitats in managed landscapes. Washington, DC: Island Press: 155171.

Duffy, David Cameron; Meier, A.J. 1992. Do Appalachian herbaceous understories ever recover from clearcutting? Conservation Biology. **6(2):** 196-201.

Ehrlich, Paul R.; Dobkin, David S.; Wheye, Darryl. 1988. The birder's handbook: a field guide to the natural history of North American birds. New York: Simon and Schuster. 785 p.

Evans, Keith E. 1978. Oak-pine and oak-hickory forest bird communities and management options. In: DeGraaf, Richard M., tech. coord. Proceedings of the workshop on management of southern forests for **nongame** birds. Gen. Tech. Rep. SE-14. Asheville, NC: Department of Agriculture, Forest Service, Southeast Forest Experiment Station: 76-89.

Evans, Keith E.; **Kirkman,** R.A. 1981. Guide to bird habitats of the Ozark Plateau. Gen. Tech. Rep. NC-68. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 79 p.

Hamel, Paul B.; **LeGrand,** Harry E., Jr.; Lennartz, Michael R.; Gauthreaux, Jr., Sidney A. 1982. Bird-habitat relationships on southeastern forest lands. Gen. Tech. Rep. SE-22. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 417 p.

Hamel, Paul B. 1992. Land manager's guide to the birds of the South. Chapel Hill, NC: The Nature Conservancy, Southeastern Region. 437 p.

Johnston, David W.; **Odum,** Eugene P. 1956. Breeding bird populations in relation to plant succession on the Piedmont of Georgia. Ecology. **37(1): 50-62.**

Joyce, Linda A.; **Flather,** Curtis H.; Flebbe, Patricia A.; Hoekstra, Thomas W.; **Ursic,** Stan J. 1990. Integrating forage, wildlife, water, and fish projections with timber projections at the regional level: a case study in southern United States. Environmental Management. **14(4):** 489-500.

Martin, Thomas E. 1992. Breeding productivity considerations: what are the appropriate habitat features for management? In: **Hagan,** John M., III; Johnston, David W., eds. Ecology and conservation of neotropical migrant land birds. Washington, DC: Smithsonian Institution Press: 455-473.

Medin, Dean E. 1985. Breeding bird responses to diameter-cut logging in west-central Idaho. Res. Pap. INT-355. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 12 p.

Ruggiero, Leonard F.; Aubry, Keith B.; Carey, Andrew B.; Huff, Mark H., tech. **coord.** 1991. Wildlife and vegetation of unmanaged Douglas-fir forests. Gen. Tech. Rep. PNW-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 533 p.

Vemer, **Jared;** Boss, A.S. 1980. California wildlife and their habitats: western Sierra Nevada. Gen. Tech. Rep. PSW-37. **Fresno,** CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 439 p.

Vemer, **Jared;** Morrison, Michael L.; Ralph, C. John, eds. 1986. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Madison, WI: University of Wisconsin Press. 470 p.

Webb, William L.; Behrend, Donald F.; Saisom, Boonruang. 1977. Effects of logging on songbird populations in a northern hardwood forest. Wildlife Monogr. 55. Washington, DC: The Wildlife Society. 35 p.

Wildlife Habitat Conditions in Mature Pine-Hardwood Stands in the Ouachita/Ozark National Forests[1]

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ABSTRACT

A long-term, stand-level, interdisciplinary research and demonstration project was initiated on the Ouachita (ONF) and Ozark-St. Francis National Forests in Arkansas in 1990 to compare the impacts of alternative reproduction cutting methods on commodity and noncommodity forest resources including wildlife habitat and populations. Habitat measurement procedures and pretreatment habitat conditions for 20 of the **52 stands** included in this study are summarized here. The wildlife component of this study consists of a completely randomized block design involving four physiographic zones (blocks), each containing one replication of five treatments (four future treatments and an untreated, late-rotation control). Of the 69 habitat parameters analyzed to date, 11 differed significantly ($P < 0.05$) by physiographic zone, but only 1 differed by future treatment. From a wildlife standpoint, these late-rotation stands primarily consisted of south-facing, relatively xeric sites characterized by high canopy coverage, an abundance of mostly small hardwoods, very limited winter herbage and browse supplies, moderate snag abundance, and limited amounts of down wood. Most of the hardwoods are too small to produce much mast, and densities of the larger (≥35 cm in d.b.h.) snags are insufficient to accommodate high populations of several of the larger resident cavity-dependent wildlife species. Snags and down logs of recent origin were generally scarce. Recent amendment of the USDA Forest Service ONF Forest Plan should help to ameliorate these conditions.

INTRODUCTION

Even-aged silviculture employing clearcutting, site preparation, and planting of pines has been the primary method of regeneration on southern national forests for more than 25 years. Although young plantations provide excellent habitat for many wildlife species, even-aged management on short rotations is generally detrimental to those species that require an abundance of snags, cavity and den trees, hardwoods, hard mast, large down wood, and other mature-forest features (Thill 1990). The USDA Forest Service has been under increasing pressure to consider alternatives to even-aged management (especially to clearcutting), such as single-tree and group selection and expanded management for pine-hardwood mixtures.

In response to growing public concern over management of the national forests in Arkansas, a long-term, multidisciplinary, stand-level research and demonstration project was initiated on the Ouachita and Ozark-St. Francis National Forests in 1990 to compare alternative reproduction cutting methods relative to their silvicultural feasibility and their impacts on commodity and noncommodity forest resources (Baker, this volume). Determining the effects of these treatments on wildlife populations and habitat features is a primary objective of this research.

The objective in this paper is to characterize pretreatment wildlife habitat conditions in 20 stands (table 1) that are being studied under this initiative. Habitat measurements and procedures are described, the 20 stands are characterized, and differences by physiographic zones and future treatments are presented. Pretreatment bird and small mammal data are presented in separate papers within this proceedings.

[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

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Table 1.—*Identification of wildlife research plots by physiographic zone (block), future treatment, district, compartment, and stand*

ID no.	Zone	Treatment	District	Compartment	Stand
1	North	Clearcut	Fourche	458	16
2	North	Shelterwood	Fourche	457	12
3	North	Group selection	Magazine[1]	46	18
4	North	Single-tree selection	Magazine[1]	70	10
5	North	Untreated control	Cold Springs	284	11
6	East	Clearcut	Oden	1067	15
1	East	Shelterwood	Oden	1119	21
8	East	Group selection	Oden	1124	11
9	East	Single-tree selection	Jessieville	609	9
10	East	Untreated control	Jessieville	605	5
11	South	Clearcut	Womble	1658	5
12	South	Shelterwood	Caddo	27	1
13	South	Group selection	Caddo	35	42
14	South	Single-tree selection	Womble	1649	13
15	South	Untreated control	Caddo	23	10
16	West	Clearcut	Poteau	1292	2
17	West	Shelterwood	Mena	833	1
18	West	Group selection	Choctaw	62	6
19	West	Single-tree selection	Kiamichi	248	17
20	West	Untreated control	Mena	896	7

[1]Ozark-St. Francis National Forest; all others on the Ouachita National Forest.

SELECTED HABITAT PARAMETERS

For the eventual development of wildlife-habitat relationship models, data were collected on a host of habitat parameters that are: (a) nondestructive to obtain, (b) relatively easy to collect, and (c) often correlated with and/or useful in predicting wildlife abundance and diversity (Gysel and Lyon 1980, Hays and others 1981). These parameters are described below.

Overstory Conditions

Characteristics of the forest overstory (e.g., tree density, spacing, and height; species composition; and the number of vertical layers) greatly influence understory floral composition and production, vertical structural complexity, microclimate, and a host of other habitat parameters that influence wildlife diversity and abundance. For example, hardwood retention within pine stands typically improves habitat conditions significantly for a broad range of wildlife species by increasing habitat and microsite diversity, forage substrate (e.g., bole, bark, leaves, and fruits), vertical structural complexity, dens and cavities, and/or through the amelioration of microclimatic influences. Forest avifaunal diversity is generally positively correlated with stand structural complexity (Dickson and Segelquist 1979, MacArthur and MacArthur 1961, Meyers and Johnson 1978), but dense, multilayered hardwood midstories can drastically limit available forage for vertebrate herbivores (Blair and Brunett 1976, Blair and Feduccia 1977).

Information on sizes, densities, and species composition of hardwoods is useful in predicting hard mast production (Goodrum and others 1971) and availability of natural cavities (Allen and Corn 1990).

Snags and Stumps

Snags provide foraging substrate, roosting and hiding sites, and cavity sites for numerous vertebrate and invertebrate species (Thomas and others 1979a). Stumps also provide additional structure, cover, and foraging substrate used by some species (Maser and others 1979). Absence of suitable nest sites is often a limiting factor for cavity nesting bids (Thomas and others 1979a), which comprise an ecologically important component of southeastern forest avifauna. Consequently, wildlife abundance and diversity can be increased through retention of snags of appropriate sizes. Snag preferences of cavity nesting species are dependent on a number of factors including tree species, diameter, height, and stage of decay (Evans and Conner 1979, Thomas and others 1979a).

Down Wood

Down woody material serves many crucial ecological functions, many of which have only recently been appreciated (Harmon and others 1986, Maser and others 1979). These functions influence floral and faunal diversity, site productivity, nutrient cycling, and soil and sediment transport and storage (Harmon and others 1986). From a wildlife standpoint, these materials are used as hiding cover, feeding sites, and reproduction sites (Maser and others 1979). For example, many *Plethodon salamanders* require moist, rotting logs and litter for egg development and adult cutaneous respiration (Stebbins 1966). Down woody material provides an energy/nutrient source and habitat for many bacteria and fungi. Some small mammals prefer to travel along down logs and branches rather than directly on the ground (Planz and Kirkland 1992). Capture success for deer mice *(Peromyscus maniculatus) was highly* correlated with coverage of down logs and stumps per acre in Arizona ponderosa pine (*Pinus ponderosa* Dougl. Ex Laws.) forests (Goodwin and Hungerford 1979).

Factors influencing animal use of down wood include size (diameter and length), species, decay state, and overall abundance/distribution of down wood (Harmon and others 1986). Larger down logs provide more cover and generally persist longer than smaller logs (Maser and others 1979, Maser and Trappe 1984). Transitional stages of decay afford different habitat features. For example, loose bark provides hiding and thermal cover for small vertebrates. In advanced stages of decay, small mammals can excavate burrows, which, in turn, may be utilized by amphibians and reptiles (Harmon and others 1986). Over a wide range of forest types and seral stages, Harmon and others (1986) indicated that small mammals that use down woody materials comprise 70 to 90 percent of the species richness and 75 to 99 percent of the total number of individuals.

Much less is known regarding herpetofaunal communities and their reliance on down wood. However, Pacific Northwest reptiles and amphibians that use down wood comprise 93 percent of the species and 99 percent of the individuals (Harmon and others 1986).

Ground Cover

Rocks and rock piles provide a host of habitat elements (e.g., sunning sites, thermal and hiding cover, and habitat structure) for smaller organisms including many amphibians, reptiles, and small mammals.

Litter depth influences a number of important biological processes including soil moisture evaporation, water infiltration, and soil heating and cooling. Litter provides forage and foraging sites, thermal and hiding cover, and can significantly influence microclimatic conditions for many amphibians and reptiles (Jones 1986), small mammals, and other smaller organisms. It also provides habitat for invertebrates that serve as food for vertebrates. Litter cover, thickness, and composition also influence nutrient cycling and soil erosion, which, in turn, influence long-term site productivity. Understory herbage production is generally inversely related to litter depth (Gaines and others 1954).

Plant Cover

To a large extent, wildlife abundance and diversity are closely related to the abundance, diversity, structure, and nutritional quality of available herbaceous and woody plants, mainly through their influences on forage availability and cover conditions. Forage and cover are generally most limiting during late winter; consequently, late-winter measures of these variables were assumed to be more highly correlated with animal abundance and diversity than growing season measures. Ocular estimates of percent cover (proportion of an area covered by the vertical projection of plant crowns to the ground surface) are much less expensive to collect than forage production data and are generally sufficiently correlated with forage production to derive meaningful inferences (Gysel and Lyon 1980).

Horizontal foliage cover (often referred to as security or hiding cover to distinguish from thermal cover) is a measure of the concealment that vegetation and other structural features (e.g., rock or down wood) afford an animal from its predators. Many animals have evolved preferences for certain cover conditions; consequently, cover measurements are often useful in developing wildlife-habitat relationships (Thomas and others 1979b). Patchiness, a structural habitat measure describing vegetation distribution in a horizontal plane, can be computed as the variance among horizontal cover estimates for each vertical layer measured (Anderson and Ohmart 1986). Measures of patchiness, together with vertical structure, are useful in predicting avian community structure (Rotenberry and Wiens 1980).

METHODS

Study Areas and Treatments

Four replications of twelve silvicultural treatments are currently being implemented on an operational basis in forty-eight 14.2- to 16.2-ha late-rotation stands. Four untreated control stands of this size and type were also established; these plots will remain untreated (except for insect and fire protection) to provide a minimum management scenario for comparative purposes. These treatments were randomly assigned to 13 late-rotation stands in each of 4 physiographic zones of the Ouachita National Forest and 2 southern districts of the Ozark-St. Francis National Forest. Logging was initiated during May 1993 and completed by the fall of that year.

Because of limited resources, habitat and wildlife responses are being monitored on only four replications of the following five treatments: untreated control, clearcut, shelterwcod, single-tree selection, and group selection. An overstory hardwood component (approximately 5 m^2/ha) will be maintained in the latter three treatments to enhance wildlife and esthetic values.

All stands selected for this study have a predominantly south, southeast, or southwest aspect and slopes of 5 to 20 percent. Prior to treatment, selected stands contained 13.8 to 25.3 m^2 of merchantable pine basal area (BA) and 4.6 to 11.5 m^2 of merchantable hardwood BA (Baker, this volume). Shortleaf pine (*Pinus echinata* Mill.), post oak (*Quercus stellata* Wangenh.), winged elm (*Ulmus alata* Michx.), and blackjack oak (Q. *marilandica* Muenchh.) tend to dominate these slopes (Clapp 1990). On south-facing slopes in the Crystal Mountain area, white oak (Q. *alba* L.) was dominant on lower slopes, blackjack oak on middle slopes, and post oak on upper slopes (Mayo and Raines 1986). For a complete description of climate, geology, treatments, physiographic zones, and stand selection and randomization procedures, see Baker (this volume).

Transects

Permanent transects were established in each of the 20 wildlife research stands for small mammal trapping, habitat measurements, and bicdi versity surveys. To ensure systematic coverage and adequate spacing between transects for small mammal trapping, the following procedures were used to establish these transects. An azimuth was selected that roughly paralleled the elevation contour of the stand. Each stand was then divided into imaginary 50-m-wide bands along this selected azimuth. One transect was then randomly established within each band across the width of the stand, with the limitation that no two transects could be closer than 30 m apart (fig. 1). Starting 50 m from the stand boundary, unnumbered stake flags were then placed at 15-m intervals along all transects to within 50 m of the opposite end of each transect. This ensured at least a 50-m buffer zone around the entire sampling area. Stake flags were then removed in concentric circles from the outside inward until 100 points remained in each stand, 80 of these points were randomly selected for use as small mammal trapping stations and associated habitat measurements. The entire transect length is being used for biodiversity surveys by another research team. Under this arrangement, actual buffer-zone widths varied depending on the size and shape of each stand. Where sufficient greenbelt areas (buffer strips that will be retained along drainages having a defined channel) were present, eight (10 percent) of the trap stations were placed in what were presumed to be future greenbelts. Thirty of the eighty stations were randomly selected to serve as permanent habitat sampling points for monitoring long-term habitat changes. Data from all 80 stations will eventually he used to develop small mammal habitat relationship models. However, only 1992 data from the 30 permanent sampling points were used in the analyses presented here.

Habitat Measurements

Habitat measurements at each station were confined to three adjacent 2- by 2-m quadrats (each containing a nested 1- by l-m quadrat), a 5-m-radius semicircle, and a 15-m-wide belt transect (fig. 2). With the exception of growing season (June/July 1992) measures of horizontal cover, all measurements were taken during late winter (February and early March) 1992.

Percent coverage of rock, bare ground, and litter were estimated ocularly within the three 1- by l-m quadrats. Litter depth was measured at three points in each 1- by l-m quadrat, averaged, and assigned to a 2-m increment class (0.00 to 1.99, *2.00 to 3.99,* etc.). Percent coverage of all down wood >2.54 cm in diameter was ocularly estimated within each of the three 2- by 2-m quadrats. Percent coverage of forbs and graminoids (grasses and grasslike plants, collectively) during late winter was estimated within each 1- by l-m quadrat; percent coverage of browse (leaves of evergreen and tardily deciduous woody plants to a height of 2 m) was estimated within the three 2- by 2-m quadrats. Data collected in each of the three equal-sized quadrats were averaged, yielding one value per station.

Dead logs lying within the 5-m-radius semicircle and having an average diameter ≥10 cm were measured for volume, identified as pine or hardwood, and classified into one of four classes (from least to most decayed): (1) branches and small

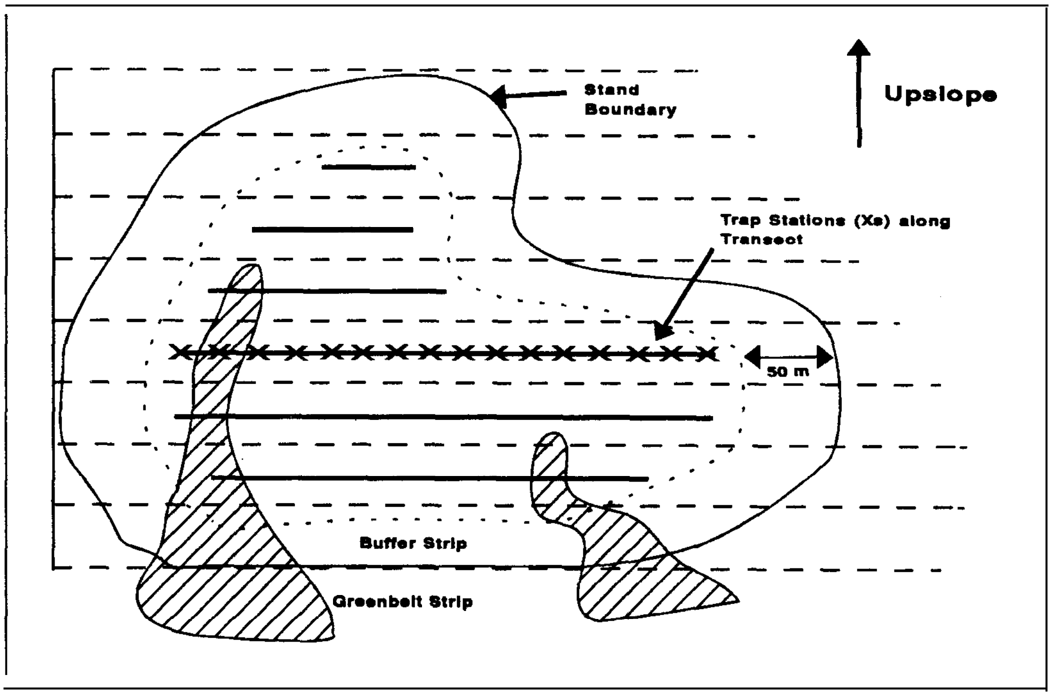

Figure 1.—Layout of small mammal trap stations at 15-m intervals along randomly selected transects within 50-m-wide bands (dashed lines). A buffer strip of at least 50 m separates sampling points from adjacent stands.

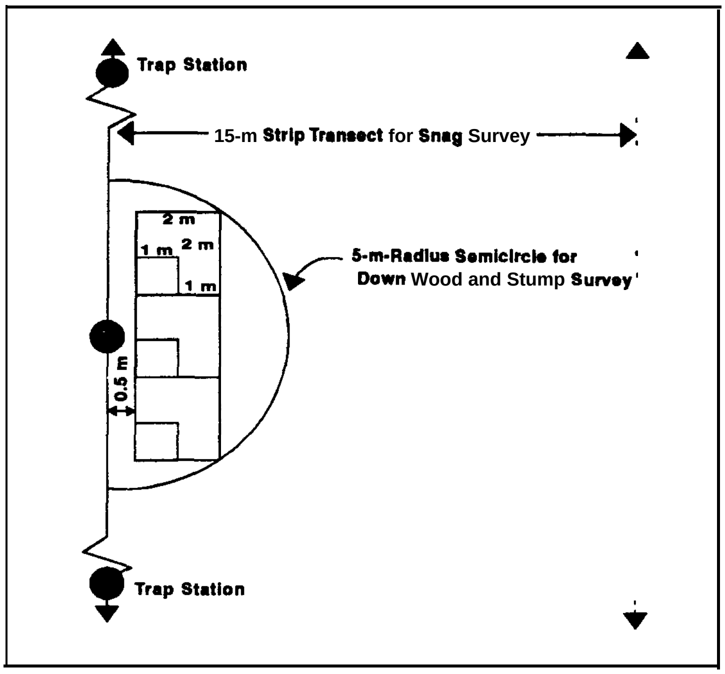

Figure 2.—Location of nested 1- by 1-m and 2- by 2-m quadrats, 5-m-radius semicircle, and 15-m-wide strip transects relative to small mammal trap stations. Trap stations (solid circles) are located at 15-m intervals along permanent transects.

twigs still intact; (2) larger branches still intact and often holding the log above ground; (3) lying on the ground but with most of the length still intact; (4) rotten and soft with much of the length reduced and the bole partly buried in litter.

Data on hardwood densities (means for each species by stand) were furnished by the Silvicultural Research Group.[3] One measurement of pine and hardwood basal area was also taken from the center of each S-m-radius semicircle using a 10-factor (English) prism; all data were converted to metric values. All snags (standing dead trees ≥10 cm in d.b.h. and ≥1 m tall) were tallied within the 15-m-wide belt transect (fig. 2) along its entire length (1,365 to 1,425 m depending on stand size and shape; 2.05 to 2.14 ha/stand) by decay class and measured for d.b.h. Decay classes were modified from Neitro and others (1985): (1) full height with branches and fine twigs; (2) some major branches remaining, may have lost up to one-half of upper bole; (3) no major branches remaining, >2 m tall, more than half the upper bole gone or trunk less than half its original diameter; (4) sapwood gone, <2 m tall, more decayed than class 3. Snag data presented here were grouped into three diameter classes based on minimum diameter requirements of primary cavity nesters (Hamel 1992): (1) below minimum size (10.0 to 14.9 cm), (2) adequate for smaller cavity nesters (15.0 to 34.9 cm), and (3) suitable for larger cavity nesters (≥35.0 cm). All stumps within the 5-m-radius semicircle having a diameter of ≥15.2 cm were tallied. Stump and snag data were converted to densities (number/ha).

Horizontal foliar cover was estimated using a 0.5- by 0.5-m density board (Nudds 1977). Readings were taken perpendicular to transect lines across the center of each 2- by 2-m quadrat from a fixed distance of 15 m between the density board (positioned on the transect side of each quadrat) and the observer. Three vertical readings (density board resting on the ground and centered at 1 and 2 m) were taken across each quadrat. Readings were averaged, yielding one value per height per station. The variance among readings for each zone across the 30 stations was computed as a measure of habitat patchiness (Anderson and Ohmart 1986).

Data being collected by several other research teams will eventually be used to complement our habitat data. For example, the Biodivemity Research Group is collecting foliage cover data by species for herbaceous and woody plants during summer. Inferences on availability of key wildlife forage species will be based on these data. Data being collected by the Silvicultural Research Group on hardwood diameters, species, and dominance (canopy position) will be used to compare relative hard mast production potentials for each of the treatments. These data were not available for inclusion in this report Avian microhabitat data that are being collected by Petit and others (this volume) on five to six 40-m-radius bird censusing plots located in each stand will be summarized at a later date.

ANALYSES

Two hypotheses were tested: (1) there were no differences in various habitat parameters among the four physiographic zones prior to treatment implementation and (2) there were no differences in habitat parameters among stands (grouped by future treatments) before treatment.

Differences among zones (blocks) and future treatments in horizontal cover, litter depth, ground/foliar cover (rock, bare ground, litter, down wood, forbs, graminoids, and woody plants), stump density, and basal area of pines and hardwoods were analyzed in a randomized block design with both experimental error and sampling error (n = 600 [20 experimental units by 30 points] except forb, graminoid, and woody plant cover [n = 597]). If the ratio of experimental error to sampling error was significant (P <0.05), experimental error was used to test for effects of future treatments and zones; if not, sampling error was used. This ratio was significant in all but two cases: percent bare ground (P = 0.3399) and percent woody cover (P = 0.5907).

Differences in horizontal patchiness (variance of horizontal cover in each stand), snag density (based on one value per stand), and hardwood density (obtained as a mean for each stand) data were tested using experimental error. Down log volume was also analyzed using experimental error because of the high incidence of zeros (81 to 100 percent of values).

Data were examined for normality and homogeneity of variance. For one-way ANOVAs, densities of stumps, snags, and hardwoods and volume of down logs were rank-transformed and analyzed using Conover and Iman's (1981) nonparametric procedure. Percentage data (cover and density board) were arcsine square root-transformed to improve variance homogeneity. Tukey's HSD was used for separation of means. All tests were at the 0.05 level of significance.

[3] Unpublished data file "T3NS.DAT" on file with USDA Forest Service, Southern Forest Experiment Station, Nacogodoches, TX 75962.

RESULTS

Habitat Characteristics--Study Wide

Descriptive statistics for the various habitat parameters collected on all 20 wildlife stands are shown in table 2. With the exception of snag densities (which are based on a 15-m-wide by 1,365- to 1,425m-long belt transect through each stand), each mean is an average across 20 stand means, each of which is based on data from 30 sampling plots.

From an overall wildlife standpoint, these stands are characterized by high canopy coverage, an abundance of mostly small hardwoods, very limited winter herbage and browse supplies, moderate snag densities (see discussion section), and small amounts of down woody materials.

Differences by Zones

When habitat parameters were compared among physiographic zones (n = 5 stands/zone), means of only 11 of the 69 variables (tables 3 through 5) were different (P <0.05). Even among these 11 variables, however, the magnitude of differences was generally small. Although these data indicate that these stands are relatively uniform across zones, future statistical tests for some habitat parameters are likely to be more powerful if zones are included as a separate source of variation

Differences by Future Treatments

Only 1 of the 69 variables (volume of down pine logs, decay class 3) differed significantly among future treatments (n = 4 replications/treatment) (tables 6 through 8). Only one additional variable (total volume of down logs, decay class 3) had a significance level of <0.10 (table 8).

DISCUSSION

Within inherent edaphic and climatic limitations, forest management practices in the Ouacbita Mountains arthe primary determinants of wildlife habitat sufficiency. Although snag densities and volume of down wood are partially a function of natural disturbance events (lightning, windthrow, wild fire, insects, and disease) and natural decay rates, forestmanagement activities (such as rotation length, frequency and extent of thinning operations, season and frequency of prescribed burning, and hardwood control practices) can greatly influence their abundance and availability over time.

The availability of snags in Southeastern and South Central States varies widely by forest type and stand age (McComb and others 1986); however, the range in densities is much narrower when only pine types are compared (table 9). Due to differences in diameter classes, data in table 9 are not directly comparable; however, they suggest that snag densities in this study fall within ranges typical of other regional sites.

The minimum snag requirements for cavity-nesting bird populations that have been developed for different regions vary widely depending on whether reserve snags are included to account for unsuitable/unused snags and those required as replacement snags (Carmichael and Guynn 1983, Evans and Conner 1979). Based on the very conservative minimum snag requirements developed by Carmichael and Guynn (1983), which included no provision for reserves, snag densities in this study are insufficient to support high populations of cavity nesters that require snags ≥35 cm in d.b.h.-such as pileated woodpeckers (*Dryocopus pileatus*), red-bellied woodpeckers (*Meherpes carolinus*), red-headed woodpeckers (*Melanerpes erythrocephalus*), *or* barred owls (*Strix varia)* (Hamel 1992). Pretreatment bird surveys also support this premise. Compared with other pine-associated forest types in the Southeast, these 20 stands had comparable numbers of bird species within all but the cavity nesting guild (Petit and others, this volume). A shortage of suitable cavity trees is most likely the primary cause for this difference. Furthermore, because few of the snags are of recent origin (decay class 1, tables 4 and 7), sustainable supplies of snags over time should be of concern.

Given their abundance and insectivorous diet, cavity-nesting birds play an important role in control of forest insect pests. As primary cavity nesters, woodpeckers create cavities needed by a wide variety of vertebrates and invertebrates. Consequently, cavity nesters (especially woodpeckers) are of major ecological importance, and their welfare should be a primary concern under ecosystem management.

The importance of large down woody debris bas not been adequately assessed for southeastern forests. Nevertheless, based on extensive research inthe Pacific Northwest, woody debris is presumably of major ecological significance elsewhere. Even though trees as small as 10 cm in diameter *were included, volume* of down wood was low on all sites. Furthermore, quantities of down logs within decay classes 1 and 2 (recent origin) were much lower than in decay classes 3 and 4 (tables 5 and 8), suggesting that down-log abundance will be even lower as decay classes 3 and 4 disappear. Down logs in decay

Table 2.-*Descriptive statistics for* ***habitat*** measurements ***from*** *wildlife research* ***stands*** *in the* ***Ouachita Mountains*** *of Arkansas, 1992**

Habitat parameter	Mean	SE	Minimum	Maximum	Coef. var. (%)
Basal area (m^2/ha)					
Pine	17.6	0.9	12.5	24.2	22.4
Hardwood	8.4	0.6	4.3	14.2	33.4
All	26.0	1.0	18.1	37.1	16.8
Hardwoods (no./ha)					
9.1-24.3 cm d.b.h.	351.2	18.9	218.9	538.3	24.1
24.4-39.5 cm d.b.h.	27.1	3.9	5.2	72.7	64.1
39.6-54.8 cm d.b.h.	3.5	0.9	0.4	18.0	111.9
154.9 cm d.b.h.	0.4	0.2	0.0	4.0	205.9
Snags (no./ha)†					
10.0-14.9 cm d.b.h.	10.1	1.3	0.9	20.6	59.7
15.0-34.9 cm d.b.h.	6.7	1.0	1.4	17.8	68.9
≥35.0 cm d.b.h.	0.8	0.2	0.0	2.8	95.6
Stumps (no./ha)	101.9	17.6	0.0	339.5	77.4
Down wood volume (m^3/ha)‡					
Decay class 1	0.09	0.1	0.0	0.8	273.6
Decay class 2	0.37	0.2	0.0	3.7	238.2
Decay class 3	2.70	0.4	0.1	6.3	70.3
Decay class 4	3.87	0.6	0.1	11.2	75.1
All	7.02	0.9	1.6	14.9	58.4
Ground/foliar cover (W)					
Rock	2.2	0.4	0.2	6.8	85.8
Bare ground	1.4	0.2	0.2	4.0	69.2
Litter	93.1	0.6	87.7	98.1	2.7
Down wood§	3.3	0.2	1.4	5.2	33.9
Forbs	2.3	0.5	0.6	9.4	88.2
Graminoids	1.4	0.3	0.1	5.4	96.4
woody plants	0.3	0.1	0.0	1.4	122.5
Litter depth (cm)	2.1	0.1	1.7	3.1	14.9
Horizontal cover (%)¶					
0.00-0.50 m	53.0	3.1	26.9	86.0	26.5
0.75-1.25 m	32.1	2.7	15.8	60.7	37.0
1.75-2.25 m	38.7	3.5	21.8	76.8	40.3
Horizontal patchiness					
0.00-0.50 m	976.9	59.3	546.6	1445.5	27.1
0.75-1.25 m	911.3	52.8	285.9	1444.8	25.9
1.75-2.25 m	971.9	52.1	714.4	1364.3	24.0

*Values were computed using stand averages ($n = 20$ stands). With the exception of snag densities (derived from one strip transect/stand), each stand average was based on 30 sampling points.

†Totals across pines, hardwoods, and four decay classes.

‡Values are totals for pine and hardwoods (≥10 cm average diameter); decay class 1 is least decayed, 4 is most decayed (see text).

§All woody material ≥2.54 cm in diameter.

¶Percent obscurity from 15 m.

Table 3.—*Habitat characteristics ($\bar{x}$ ± SE) in wildlife research stands in the Ouachita Mountains of Arkansas by physiographic zone. 1992*

Habitat parameter	F*	P†	West		North		South		East	
Basal area (m²/ha)										
Pine	3.73	0.0331	**15.9AB**	0.6	**21.2A**	2.0	**14.9B**	1.0	**18.5AB**	1.8
Hardwood	1.10	0.3768	7.8	0.7	9.8	1.7	6.8	1.2	9.0	1.1
All	12.45	0.0002	**23.8AB**	0.2	**31.0C**	1.6	**21.7A**	1.0	**27.5BC**	1.3
Hardwoods (no./ha)										
9.1-24.3 cm d.b.h.										
Oaks	0.59	0.6331	287.0	52.6	212.5	18.5	218.5	37.6	206.2	35.8
Hickories	2.42	0.1038	27.5	2.4	67.1	12.0	68.1	16.9	64.6	18.8
Others	1.05	0.3971	53.3	21.0	61.4	13.8	90.0	21.9	48.7	16.8
All	0.22	0.8844	367.8	46.4	341.0	30.7	376.7	50.1	319.5	26.5
24.4-39.5 cm d.b.h.										
Oaks	0.71	0.5619	23.1	5.9	30.5	9.8	22.0	7.7	14.3	2.0
Hickories	0.28	0.8361	1.6	1.3	1.7	0.6	1.5	0.9	2.7	1.3
Others	0.66	0.5858	2.8	1.4	3.6	1.6	3.6	1.8	1.1	0.8
All	0.66	0.5899	27.5	5.2	35.8	11.1	27.1	9.2	18.1	3.6
39.6-54.8 cm d.b.h.										
Oaks	0.31	0.8199	3.7	1.3	4.5	2.5	2.1	0.8	2.3	0.5
Hickories	0.34	0.7967	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Others	0.85	0.4865	0.0	0.0	0.7	0.6	0.3	0.3	0.1	0.1
All	0.08	0.9701	3.8	1.4	5.4	3.2	2.5	0.9	2.4	0.6
≥54.9 cm d.b.h.										
Oaks	0.65	0.5956	0.2	0.1	0.7	0.6	0.3	0.2	0.1	0.1
Hickories*			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Others	0.24	0.8669	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.1
All	0.62	0.6147	0.3	0.1	0.9	0.8	0.5	0.2	0.1	0.1
Stump density (no./ha)	2.56	0.0913	54.3	23.3	146.0	50.9	69.6	9.8	137.5	32.4
Ground/foliar cover (%)§										
Rock	0.05	0.9860	2.5	1.2	2.5	1.1	1.8	0.4	2.0	0.7
Bare ground	3.98	0.0080	**0.7A**	0.2	**1.5AB**	0.2	**1.2AB**	0.3	**2.3B**	0.6
Litter	2.04	0.1492	94.8	1.1	92.4	1.3	93.9	1.0	91.5	0.8
Down wood	0.60	0.6223	3.0	0.6	3.0	0.6	3.4	0.4	3.8	0.5
Forbs	1.47	0.2593	2.3	0.7	1.3	0.6	3.6	1.5	2.1	0.6
Graminoids	7.63	0.0022	**3.0A**	0.7	**0.3B**	0.2	**1.0B**	0.4	**1.2AB**	0.3
woody plants	0.64	0.5918	0.1	0.1	0.3	0.1	0.5	0.3	0.3	0.1
Litter depth (cm)	1.56	0.2387	2.1	0.1	2.2	0.2	2.2	0.1	1.9	0.1
Horizontal cover (%)										
0.00-0.50 m	1.15	0.3590	51.2	1.9	47.3	4.5	50.9	8.6	62.4	7.6
0.75-1.25 m	0.46	0.7174	31.8	1.7	28.7	1.3	37.7	7.5	30.3	7.9
1.75-2.25 m	3.66	0.0351	**34.9A**	2.6	**32.0AB**	4.2	**55.6B**	9.5	**32.4AB**	4.6
Horizontal patchiness										
0.00-0.50 m	3.03	0.0598	820	49	1200	88	844	113	1044	140
0.75-1.25 m	2.65	0.0841	856	64	1015	77	721	119	1053	106
1.75-2.25 m	2.14	0.1357	886	89	1048	130	825	54	1128	95

*One-way ANOVA F value (stump and hardwood density data were rank-transformed); means within rows followed by unlike letters are statistically different (P <0.05).

†Probability associated with one-way ANOVA F value.

‡All values were zero.

§Woody (≤2 m tall) and herbaceous plant cover measured in late winter.

Table 4.—*Snag* densities (no/ha; x̄ ± *SE)* in *wildlife research stands by decay and diameter classes and by physiographic zones, 1992**

Decay class[†]	Diameter class (cm)	F[‡]	P[§]	West		North		South		East	
1	10.0-14.9	13.73	0.0001	**2.31AB**	0.67	**0.19BC**	0.12	**3.83A**	0.80	**0.00C**	**0.00**
	15.0-34.9	7.77	0.0020	**0.19A**	0.12	**0.00A**	0.00	**1.96B**	0.73	**0.29A**	0.29
	≥35.0	0.95	0.4386	0.19	0.12	0.09	0.09	0.09	0.09	0.00	0.00
2	10.0-14.9	2.67	0.0824	2.78	0.84	1.14	0.32	2.62	0.82	***2.68***	***0.34***
	15.0-34.9	1.29	0.3133	1.73	0.43	0.57	0.46	1.59	0.48	1.24	0.45
	235.0	0.34	0.7967	0.19	0.19	0.10	0.10	0.09	0.09	0.00	0.00
3	10.0-14.9	1.26	0.3210	2.78	1.12	4.41	1.77	6.64	1.68	4.02	0.74
	15.0-34.9	0.95	0.4398	2.21	0.54	2.39	1.23	4.21	1.74	3.06	0.57
	≥35.0	2.21	0.1263	0.48	0.15	0.58	0.18	0.19	0.12	0.28	0.19
4	10.0-14.9	2.07	0.1440	0.67	0.36	2.11	0.62	1.40	0.51	2.78	0.87
	15.0-34.9	5.00	0.0124	O.%AB	0.42	**2.38AB**	1.21	**0.47A**	0.21	**3.46B**	0.95
	≥35.0	1.75	0.1981	0.00	0.00	0.38	0.28	0.00	0.00	0.38	0.24
All	10.0-14.9	0.98	0.4260	8.55	2.78	7.86	2.72	14.50	3.17	**9.49**	1.57
	15.0-34.9	1.22	0.3347	5.09	1.05	5.34	2.86	8.23	2.68	8.06	1.24
	235.0	1.03	0.4049	0.86	0.28	1.15	0.49	0.38	0.27	0.67	0.19

* Includes all pines **and** hardwoods **≥10** cm **in** d.b.h. **and ≥1** m tall

[†]**Decay** classes described in text.

[‡]**One-way ANOVA** ***F value; data were*** **rank-transformed. Means** within rows followed by **unlike** letters are statistically different ***(P*** **<0.05).**

[§]**Probability** associated with one-way **ANOVA** ***F*** **value** on **rank-transformed** data

Table 5.—*Volume of down logs (m^3/ha; $\bar{x} \pm SE$) in wildlife research stands by decay class and physiographic zone, 1992**

Decay class†	Class	F‡	P§	West		North		South		East	
1	Pine	1.00	0.4182	0.00	0.00	0.00	0.00	0.16	0.16	0.00	0.00
	Hardwood	2.66	0.0837	0.00	0.00	0.00	0.00	0.14	0.14	0.00	0.00
	unknown	1.00	0.4182	0.00	0.00	0.00	0.00	0.04	0.04	0.00	0.00
	All	5.90	0.0065	0.00A	0.00	0.00A	0.00	0.35B	0.18	0.00A	0.00
2	Pine	2.96	0.0635	0.07	0.07	0.00	0.00	0.15	0.07	0.00	0.00
	Hardwood	1.26	0.3199	0.29	0.13	0.75	0.75	0.23	0.23	0.00	0.00
	Unknown¶			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	All	1.66	0.2157	0.35	0.16	0.75	0.75	0.38	0.29	0.00	0.00
3	Pine	1.61	0.2257	0.66	0.34	2.16	0.80	2.03	0.67	1.93	0.62
	Hardwood	0.88	0.4745	0.42	0.37	2.12	1.07	0.32	0.29	0.97	0.57
	Unknown	1.75	0.1966	0.13	0.10	0.00	0.00	0.07	0.66	0.00	0.00
	All	3.11	0.0558	1.21	0.68	4.27	0.93	2.42	0.75	2.90	0.57
4	Pine	3.03	0.0599	2.24	0.92	2.34	1.26	2.08	0.34	6.17	1.46
	Hardwood	1.50	0.2527	0.50	0.50	0.67	0.22	0.12	0.12	0.49	0.43
	Unknown	8.25	0.0015	0.43A	0.12	0.00B	0.00	0.44AB	0.28	0.00B	0.00
	All	2.89	0.0677	3.17	1.12	3.01	1.45	2.63	0.42	6.65	1.36
All	Pine	1.95	0.1628	2.96	1.23	4.50	1.96	4.42	0.95	8.10	1.83
	Hardwood	0.83	0.4955	1.21	0.50	3.53	1.86	0.81	0.48	1.45	0.98
	Unknown	11.45	0.0003	0.56A	0.15	0.00B	0.00	0.55A	0.37	0.00B	0.00
	Au	1.39	0.2808	4.73	1.66	8.03	2.41	5.78	1.12	9.55	1.63

*Includes all logs with an average diameter of ≥10 cm.

†Decay classes described in text.

‡One-way ANOVA *F* value; data were rank-transformed. Means within rows followed by unlike letters are statistically different ($P < 0.05$).

§Probability associated with one-way ANOVA *F* value on rank-transformed data

¶All values were zero.

Table 6.-Habitat *characterictics* ($\bar{x} \pm SE$) in *wildlife research stands in the Ouachita Mountains of Arkansas by future treatment, 1992*

Habitat parameter	F*	P†	Clearcut		Shelterwood		Single-tree selection		Group selection		Control	
Basal area (m²/ha)												
Pine	0.45	0.7706	17.5	1.4	18.1	1.8	18.2	2.9	15.3	0.5	19.0	2.9
Hardwood	0.40	0.8032	7.2	0.8	8.1	1.5	7.8	1.5	9.6	1.8	8.9	1.6
All	0.28	0.8859	24.8	1.4	26.2	2.0	26.0	1.5	25.0	1.4	27.9	4.2
Hardwoods (no./ha)												
9.1-24.3 cm d.b.h.												
Oaks	0.70	0.6069	254.2	34.4	177.4	36.0	232.1	56.6	278.0	52.2	213.6	32.5
Hickories	1.06	0.4082	33.1	8.5	79.4	23.5	63.5	19.3	67.5	14.7	40.6	9.2
Others	1.16	0.3686	28.7	2.8	71.0	15.7	74.6	31.9	53.8	15.3	88.7	23.1
All	0.64	0.6418	315.9	33.9	327.8	20.2	370.2	77.6	399.3	30.4	342.9	36.8
24.4-39.5 cm d.b.h.												
Oaks	0.84	0.5220	27.5	6.5	16.4	4.6	27.3	8.0	25.4	13.3	15.6	5.1
Hickories	0.04	0.9965	1.5	0.9	2.3	1.4	2.0	1.6	2.3	1.4	1.2	0.5
Others	1.03	0.4228	0.8	0.5	2.4	0.9	4.2	2.2	1.4	1.1	5.1	2.0
All	0.48	0.7499	29.8	6.6	21.0	5.8	33.6	9.5	29.1	14.9	22.0	6.9
39.6-54.8 cm d.b.h.												
Oaks	0.36	0.8320	2.3	1.0	2.8	1.5	3.4	1.1	5.2	3.1	2.1	0.4
Hickories	0.50	0.7328	0.2	0.2	0.0	0.0	0.1	0.1	0.2	0.2	0.0	0.0
Others	1.05	0.4143	0.0	0.0	0.1	0.1	0.5	0.3	0.7	0.7	0.0	0.0
All	0.67	0.6218	2.5	1.1	2.9	1.5	4.0	1.1	6.1	4.0	2.1	0.4
≥54.9 cm d.b.h.												
Oaks	1.10	0.3942	0.2	0.1	0.1	0.1	0.3	0.2	1.0	0.7	0.1	0.1
Hickories‡			0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Others	0.52	0.7258	0.1	0.1	0.0	0.0	0.1	0.1	0.2	0.2	0.2	0.1
All	0.60	0.6682	0.3	0.2	0.1	0.1	0.4	0.2	1.2	1.0	0.3	0.2
Stump density (no./ha)	0.61	0.6647	104.0	39.6	163.4	58.8	99.7	45.4	61.5	20.3	80.6	19.8
Ground/foliar cover (%)§												
Rock	0.41	0.7975	2.7	0.8	1.7	0.4	1.5	0.7	2.2	1.5	2.8	1.2
Bare ground	1.41	0.2304	0.8	0.2	1.2	0.2	1.4	0.3	1.8	0.6	1.9	0.5
Litter	1.08	0.3992	93.6	1.5	94.2	0.4	93.9	0.8	93.2	2.2	90.8	0.3
Down wood	0.74	0.5799	3.1	0.7	3.0	0.2	3.4	0.5	2.9	0.8	4.0	0.5
Forbs	0.52	0.7238	1.7	0.5	2.1	1.0	1.6	0.6	2.6	0.7	3.6	2.0
Graminoids	0.47	0.7541	0.7	0.4	1.6	0.8	1.7	0.6	1.9	1.2	1.1	0.2
Woody plants	0.90	0.4608	0.1	0.0	0.3	0.1	0.4	0.2	0.2	0.1	0.6	0.4
Litter depth (cm)	0.40	0.8048	2.1	0.1	2.0	0.1	2.1	0.1	2.3	0.3	2.2	0.2
Horizontal cover (%)												
0.00-0.50 m	0.77	0.5597	42.1	5.7	54.2	1.2	55.3	11.1	54.3	8.7	59.0	5.0
0.75-1.25 m	0.79	0.5514	25.4	5.4	29.7	0.7	39.2	7.2	34.8	7.1	31.5	7.4
1.75-2.25 m	0.56	0.6967	31.2	5.0	39.7	3.8	46.9	8.3	40.9	12.2	34.8	9.0
Horizontal patchiness												
0.00-0.50 m	0.42	0.7920	923	128	1131	124	919	190	920	69	991	166
0.75-1.25 m	0.69	0.6080	841	187	863	108	1083	155	925	51	844	32
1.75-2.25 m	1.24	0.3349	972	113	1083	121	1113	144	858	117	833	53

*One-way ANOVA *F* value (stump and hardwood density data were rank-transformed); means within rows followed by unlike letters are statistically different ($P < 0.05$).

†Probability associated with one-way ANOVA *F* value.

‡All values were zero.

§Woody (≤2 m tall) and herbaceous plant cover measured in late winter.

Table 7.—*Snag* densities (*no./ha;* $\bar{x} \pm$ SE) in *wildlife research stands by &cay and diameter classes and by future treatments, 1992*[*]

Decay class[†]	Diameter class (cm)	F[‡]	P[§]	Clearcut		Shelterwood		Single-tree selection		Group selection		Control	
1	10.0-14.9	0.20	0.9353	2.25	1.33	1.28	1.28	1.30	0.80	1.89	1.07	1.19	0.74
	15.0-34.9	0.15	0.9589	0.35	0.22	0.23	0.23	0.94	0.94	1.06	0.90	0.48	0.34
	≥35.0	1.09	0.3985	0.12	0.12	0.00	0.00	0.12	0.12	0.24	0.14	0.00	0.00
2	10.0-14.9	0.88	0.5006	2.61	0.49	1.40	0.43	1.79	0.63	2.85	0.77	2.88	1.18
	15.0-34.9	0.25	0.9060	1.30	0.76	1.17	0.40	1.55	0.56	1.56	0.64	0.84	0.37
	≥35.0	1.56	0.2359	0.00	0.00	0.23	0.23	0.24	0.14	0.00	0.00	0.00	0.00
3	10.0-14.9	1.78	0.1863	4.86	1.38	1.75	0.88	3.54	1.96	6.87	1.61	5.31	1.45
	15.0-34.9	0.92	0.4804	2.49	0.92	1.63	0.73	4.38	2.18	4.16	1.06	2.16	0.57
	≥35.0	0.76	0.5647	0.36	0.23	0.35	0.22	0.48	0.00	0.60	0.23	0.12	0.12
4	10.0-14.9	0.92	0.4761	1.42	0.46	0.94	0.51	1.19	0.49	2.37	1.14	2.78	0.86
	15.0-34.9	0.90	0.4896	2.14	0.89	0.47	0.27	1.44	0.44	2.74	1.56	2.30	1.44
	≥35.0	1.20	0.3516	0.24	0.24	0.00	0.00	0.12	0.12	0.59	0.36	0.00	0.00
All	10.0-14.9	1.43	0.2725	11.14	3.47	5.37	2.23	7.82	3.08	13.99	2.71	12.16	2.76
	15.0-34.9	1.69	0.2047	6.29	1.50	3.50	1.04	8.30	3.34	9.52	2.37	5.79	2.48
	≥35.0	2.17	0.1221	0.72	0.24	0.58	0.35	0.96	0.28	1.43	0.51	0.12	0.12

*Includes all pines and hardwoods ≥10 cm in d.b.h. and ≥1 m tall

†Decay classes described in text.

‡One-way ANOVA *F va lue; data were* rank-transformed.

§Probability associated with one-way ANOVA *F* va lue on rank-transformed data

Table 8.—*Volume of down logs (m^3/ha; $\bar{x} \pm$ SE) in wildlife research stands by decay class and future treatments, 1992**

Decay class†	Class	F‡	P§	Clearcut		Shelterwood		Single-tree selection		Group selection		Control	
1	Pine	1.00	0.4380	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00
	Hardwood	0.75	0.5725	0.00	0.00	0.01	0.01	0.17	0.17	0.00	0.00	0.00	0.00
	Unknown	1.00	0.4380	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.05	0.00	0.00
	All	0.50	0.7328	0.00	0.00	0.21	0.21	0.17	0.17	0.05	0.05	0.00	0.00
2	Pine	0.26	0.8975	0.00	0.00	0.05	0.05	0.10	0.10	0.05	0.05	0.08	0.08
	Hardwood	0.52	0.7258	0.18	0.18	0.00	0.00	0.36	0.27	0.93	0.93	0.10	0.10
	Unknown¶			0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	All	0.31	0.8691	0.18	0.18	0.05	0.05	0.46	0.36	0.98	0.92	0.18	0.18
3	Pine	3.26	0.0411	1.47A	0.70	0.76A	0.31	1.74AB	0.29	0.78A	0.42	3.72B	0.68
	Hardwood	1.52	0.2472	0.12	0.09	0.35	0.35	1.50	0.85	1.97	1.33	0.84	0.48
	Unknown	0.88	0.5005	0.00	0.00	0.13	0.13	0.00	0.00	0.08	0.08	0.04	0.03
	All	2.61	0.0775	1.59	0.72	1.23	0.23	3.24	0.91	2.84	1.23	4.59	0.61
4	Pine	1.42	0.2758	3.67	2.52	2.99	1.40	1.92	0.84	2.01	0.21	5.46	0.93
	Hardwood	0.44	0.7766	0.10	0.10	0.67	0.61	0.73	0.52	0.38	0.21	0.33	0.33
	unknown	0.55	0.7039	0.42	0.24	0.11	0.11	0.03	0.03	0.44	0.32	0.09	0.09
	All	1.02	0.4294	4.19	2.34	3.76	1.59	2.68	1.26	2.83	0.45	5.88	1.16
All	Pine	2.27	0.10%	5.14	3.11	3.99	1.15	3.75	0.97	2.84	0.63	9.26	1.12
	Hardwood	1.15	0.3704	0.40	0.23	1.02	0.61	2.77	1.06	3.29	2.43	1.27	0.73
	unknown	0.30	0.8709	0.42	0.24	0.24	0.24	0.03	0.03	0.57	0.45	0.13	0.12
	All	1.14	0.3755	5.95	2.81	5.25	1.51	6.55	1.81	6.70	2.1	10.66	1.56

*Includes all logs with an average diameter of $\geq$10 cm.

†Decay classes described in text.

‡One-way ANOVA F value; data were rank-transfotmed. Means within rows followed by unlike letters are statistically different (P <0.05).

§Probability associated with one-way ANOVA F value on rank-trausfonued data

¶All values were zero.

Table 9.—*Comparative snag densities for pine forest types of the Southeastern United States**

State (region)	Forest type	Diameter class	Snag density	Reference
		-----cm-----	no./ha	
South Carolina (Upper Piedmont)	Pine-hardwood	10.140.0 ≥40.1	30.1 0.8	Carmichael and Guynn 1983
Texas[†] (eastern forests)	Lobloily-sho rtleaf	12.7-32.8 ≥33.0	12.1 1.5	Rudis 1988a
Louisiana[†] (Statewide)	Lobloily-sho rtleaf	12.7-32.8 233.0	9.5 1.3	Rudis 1988b
Arkansas (this study)	Shortleaf pine-hardwood	1X0-34.9 ≥35.0	6.7 0.8	This study
Mississippi[‡] (unknown)	Pine-hardwood	≥10.0	6.4	McComb 1979
Florida (Statewide)	Loblolly pine	≥12.7	5.4	McComb and others 1986
South Carolina (Coastal Plain)	Pine and pine-hardwood mix	12.7-35.6 ≥38.1	3.0 0.5	Harlow and Guynn 1983

*Data adapted from references shown.

†Values include salvable and nonsalvable dead trees.

‡Region unknown; cited by McComb and others 1986.

class 1 were absent in three of the physiographic zones, nor were any in decay class 2 found in east zone stands (table 5).

Production of hard mast (acorns and nuts) is dependent on many factors including density and species of mast-producing trees, site quality, tree age, canopy position, and canopy form. Reliable estimates of mast production are costly to obtain and were not attempted in this study. However, based on hardwood-stocking information and available literature, several general statements can be made regarding hard-mast availability.

Given their relatively young age (average of 65 years for all 52 stands) and low site indices (Guldin and others, this volume), these stands would not be expected to have an abundance of mature, large hardwoods regardless of past management practices. On a density basis, hardwoods ≥9.1 cm in d.b.h. comprise 51 percent (mean across 20 stands) of the trees in these stands, and hard mast producing species (oaks and hickories) comprise a majority of the hardwoods (table 3). However, most of the oaks and hickories are too small to produce much mast. Based on research from eastern Texas, oaks less than about 25.4 cm in d.b.h. produce little or no mast (Goodrum and others 1971).

In managed forests, sufficient supplies of critical habitat features (like large snags and den trees) must be achieved through intentional actions. Recent changes in management on the Ouachita National Forest reflect a more socially acceptable and ecologically sensitive management approach. For example, Amendment 12 (approved July 22, 1993) to the Forest Plan for the Ouachita National Forest will, among other things, ensure retention of additional hardwoods in pine management types. Where seed tree and shelterwood regeneration systems are to be employed, this amendment also requires that a mixed overstory (≥1.15 m^2 of hardwood and 2.30 to 3.44 m^2 of pine BA/ha) be retained indefinitely to enhance structural diversity, visual quality, and ecological complexity. Longer retention of more pines and hardwoods will eventually result in additional larger snags and down logs and greater hard mast supplies. This should improve wildlife abundance and species richness, especially for cavity nesters and bark-gleaning bids (Stribling and others 1990).

Low densities of small mammals captured on these sites (Tappe and others, this volume) are most likely due to a combination of factors including limited winter forage and down wood. All of the reproduction cutting methods being tested should increase forage availability, amounts of down wood, and cover for a number of years, and total numbers of small mammals should increase markedly. Responses of seed-eating species will be of special interest under those management systems dependent on natural regeneration.

Greenbelt strips along ephemeral drainages comprise a significant amount of area within these and similar stands and afford an excellent opportunity to increase habitat features that are in short supply within the surrounding stand. Management of these strips should be designed to increase supplies of snags, large down wood, hard mast, and den trees.

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LITERATURE CITATIONS

Allen, Arthur W.; Corn, Janelle G. 1990. Relationships between live tree diameter and cavity abundance in a Missouri oak-hickory forest. Northern Journal of Applied Forestry. 7: 179-183.

Anderson, Bertin W.; Ohmart, Robert D. 1986. Vegetation In: Cooperrider, Allen Y.; Boyd, Raymond J.; Stuart, Hanson R., eds. Inventory and monitoring of wildlife habitat. Denver, CO: U.S. Department of Interior, Bureau of Land Management Service Center: 639-660. Chapter 31.

Blair, Robert M.; Brunett, Louis E. 1976. Phytosociological changes after timber harvest in a southern pine ecosystem. Ecology. 57(1): 18-32.

Blair, Robert M.; Feduccia, Donald P. 1977. Midstory hardwoods inhibit deer forage in loblolly pine plantations. Journal of Wildlife Management. 41(4): 677-684.

Carmichael, D. Breck, Jr.; Guynn, David C., Jr. 1983. Snag density and utilization by wildlife in the upper Piedmont of South Carolina. In: Davis, Jerry W.; Goodwin, Gregory A.; Ockenfels, Richard A., tech. coords. Snag habitat management: Proceedings of the symposium; 1983 June 7-9; Flagstaff, AZ. Gen. Tech. Rep. RM-99. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 107-110.

Clapp, Daniel L. 1990. Availability and consumption of foods and importance of habitats used by black bears in Arkansas. Fayetteville, AR: University of Arkansas. 119 p. M.S. thesis.

Conover, W.J.; Iman, Ronald L. 1981. Rank transformations as a bridge between parametric and nonparametric statistics. American Statistician. 35(3): 124-133.

Dickson, James G.; Segelquist, Charles A. 1979. Breeding bird populations in pine and pine-hardwood forests in Texas. Journal of Wildlife Management. 43(2): 549-555.

Evans, Keith E., Conner, Richard N. 1979. Snag management. In:DeGraaf, Richard M.; Evans, Keith E.,comps. Management of north central and northeastern forests for nongame birds: workshop proceedings; 1979 January 23-25; Minneapolis, MN. Gen. Tech. Rep. NC-51. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 214-225.

Gaines, E.M.; Campbell, Robert S.; Brasington, J.J. 1954. Forage production on longleaf pine lands of southern Alabama. Ecology:35(1): 59-62.

Goodrum, P.D.; Reid, V.H.; Boyd, C.E. 1971. Acorn yields, characteristics, and management criteria of oaks for wildlife. Journal of Wildlife Management. 35(3): 520-532.

Goodwin, John G., Jr.; Hungerford, C. Roger. 1979. Rodent population densities and food habits in Arizona ponderosa pine forests. Res. Pap. RM-214. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 12 p.

Gysel, Leslie W.; Lyon, L. Jack 1980. Habitat analysis and evaluation. In: Schemnitz, Sanford D., ed. Wildlife management techniques manual. 4th ed. Washington, DC: The Wildlife Society: 305-327. Chapter 19.

Hamel, Paul B. 1992. Land manager's guide to the bids of the South. Chapel Hill, NC: The Nature Conservancy. 437 p. In cooperation with: U.S. Department of Agriculture, Forest Service, Southern Region: App. E.

Harlow, Richard F.; Guyrm, David C., Jr, 1983. Snag densities in managed stands of the South Carolina Coastal Plain. Southern Journal of Applied Forestry. 7(4): 224-229.

Harmon, M.E.; Franklin, J.F.; Swanson, F.J. [and others]. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research. 15: 133-302.

Hays, Robert L.; Summers, Cliff; Seitz, William. 1981. Estimating wildlife habitat variables. FWS/OBS-81-47. Washington, DC: U.S. Department of the Interior, Fish and Wildlife Service, Office of Biological Services. 111 p.

Jones, K. Bruce. 1986. Amphibians and reptiles. In: Cooperrider, Allen Y.; Boyd, Raymond J.; Stuart, Hanson R., eds. Inventory and monitoring of wildlife habitat. Denver, CO: U.S. Department of Interior, Bureau of Land Management Service Center: 267-290. Chapter 14.

MacArthur, Robert H.; MacArthur, John W. 1961. On bid species diversity. Ecology. 42(3): 594-598.

Maser, Chris; Anderson, Ralph G.; Cromack, Kermit, Jr. [and others]. 1979. Dead and down woody material. In: Thomas, Jack Ward, tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture: 78-95. Chapter 6. In cooperation with: The Wildlife Management Institute; U.S. Department of the Interior, Bureau of Land Management.

Maser, Chris; Trappe, James M., tech. eds. 1984. The seen and unseen world of the fallen tree. Gen. Tech. Rep. PNW-164. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 56 p. In cooperation with: The Wildlife Management Institute; U.S. Department of the Interior, Bureau of Land Management.

Mayo, Derwood C.; Raines, P.L. 1986. Woody vegetation of the Crystal Mountains region. Proceedings Arkansas Academy of Science. 40: 48-51.

McComb, William C. 1979. Nest box and natural cavity use by wildlife in mid-south hardwoods as related to physical and microclimatic characteristics. Baton Rouge, LA: Louisiana State University. 228 p. Ph.D. dissertation.

McComb, William C.; Bonney, Stephen A.; Sheffield, Raymond M.; Cost, Noel D. 1986. Snag resources in Florida-are they sufficient for average populations of primary cavity-nesters? Wildlife Society Bulletin. 14(1): 40-48.

Meyers, Joseph M.; Johnson, A. Sydney. 1978. Bird communities associated with succession and management of loblolly-shortleaf pine forests. In: DeGraaf, Richard M., tech. coord. Proceedings of the workshop management of southern forests for nongame birds; 1978 January 24-26; Atlanta, GA. Gen. Tech. Rep. SE-14. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 50-65.

Neitro, William A.; Binkley, Virgil W.; Cline, Steven P. [and others]. 1985. Snags (wildlife trees). In: Brown, E. Reade, tech. ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. R6-F&WL-192- 19 85. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region: 129-169 (pt. 1, chapter 7). In cooperation with: U.S. Department of Interior, Bureau of Land Management.

Nudds, Thomas D. 1977. Quantifying the vegetative structure of wildlife cover. Wildlife Society Bulletin. 5(3): 113-117.

Planz, John V.; Kirkland, Gordon L., Jr. 1992. Use of woody ground litter as a substrate for travel by the white-footed mouse, *Peromyscus leucopus*. Canadian Field-Naturalist. 106(1): 118-121.

Rotenberry, John T.; Wiens, John A. 1980. Habitat structure, patchiness, and avian communities in North American steppe vegetation: a multivariate analysis. Ecology. 61(5): 1,228- 1,250.

Rudis, Victor A. 1988a. Nontimber values of East Texas timberland. Resour. Bull. S0-139, New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 34 p.

Rudis, Victor A. 1988b. Nontimber values of Louisiana's timberland Resour. Bull. SO-132. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 27 p.

Stebbins, Robert C. 1966. A field guide to western reptiles and amphibians. Boston, MA: Houghton Mifflin Co. 27 p.

Stribling, H. Lee; Smith, Harvey R.; Yahner, Richard H. 1990. Bird community response to timber stand improvement and snag retention. Northern Journal of Applied Forestry. 7(1): 35-38.

Thill, Ronald E. 1990. Managing southern pine plantations for wildlife. In: Proceedings of 19th IUFRO [International Union of Forestry Research Organizations] world congress; 1990 August 5-11; Montreal, Canada. Montreal, Canada: Canadian International Union of Forestry Research Organizations: 58-68. Vol. 1.

Thomas, Jack Ward Anderson, Ralph G.; Maser, Chris; Bull, Evelyn L. 1979a. Snags. In: Thomas, Jack Ward, tech ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington. Agric. Handb. 553. Washington, DC: U.S. Department of Agriculture: 60-77. Chapter 5. In cooperation with: The Wildlife Management Institute; U.S. Department of the Interior, Bureau of Land Management.

Thomas, Jack Ward; Black, Hugh, Jr.; Scherzinger, Richard J.; Pedersen, Richard J. 1979b. Deer and elk. In: Thomas, Jack Ward, tech. ed. Wildlife habitats in managed forests: the Blue Mountains of Oregon and Washington Agric. Handb. 553. Washington, DC: U.S. Forest Service: 104-127. Chapter 8. In cooperation with: The Wildlife Management Institute; U.S. Department of the Interior, Bureau of Land Management.

Arthropod Biodiversity-Sampling Protocol Development[1]

C. E. Carlton, J. Bollinger, and L. C. Thompson[2]

ABSTRACT

To assess the effectiveness of a variety of sampling methods and determine optimal sampling intervals for arthropod biodiversity studies in the Ouachita National Forest, a preliminary survey was conducted on four pine-hardwood sites during the 1993 field season. Study sites represented a range of disturbance levels from different management practices and included a control site of undisturbed old-growth forest. Sampling methods included pitfall traps, Berlese sifting, flight intercept/malaise traps, and unbaited Lindgren traps. Preliminary results demonstrate methods of presenting biodiversity data and prioritizing data analysis to address specific concerns. A point-in-time comparison of 51 beetle families captured in flight intercept and malaise traps illustrates the differential effectiveness of the two techniques in sampling broadly defined habitat/functional groups. An analysis of 28 species of pselaphid beetles collected during a 2-month period demonstrates the value of high levels of taxonomic precision when small subsets of diversity data are selected for study. New distribution records and other novel findings for the Ouachita National Forest are presented as an annotated checklist of species. Finally, recommendations are provided for conducting arthropod biodiversity studies as a component of long-term ecosystem management.

INTRODUCTION

Identifying links between species, keystone species, and food-web properties are essential elements needed to relate the richness of functional species groups to the larger species networks (Solbrig 1991). This is especially important because human-caused disturbances are quickly fragmenting the ranges of many species of organisms (Barbault and Hochberg 1992). Thus, the dynamics of fragmented populations need to be understood in relation to landscape ecology so that relevant management solutions may be taken to conserve biodiversity and prevent extinctions.

Collins and Thomas (1989) provided a series of compelling articles dealing with the relationships between insect diversity studies and the conservation of habitats. A prevailing theme among these discussions is that arthropods represent a vast and underutilized resource in planning, implementing, and monitoring conservation programs. However, arthropods remain largely ignored in most large scale treatments of regional biodiversity. For example, Martin and others' (1993) treatment of the biodiversity of upland habitats in the Southeastern United States is excellent with regard to plant and vertebrate communities, but a brief perusal of the volume reveals only 59 references to arthropods (common and scientific names). This dearth of information reflects the general lack of broad-based arthropod diversity studies even though arthropods can comprise more than 60 percent of the species and are an integral functional component of virtually all terrestrial communities (Wilson 1988).

Arthropod biodiversity research has the potential to be complex and expensive because arthropods live on or with all plants and animals, are associated with most nonliving substrates in a community, and are inherently challenging to study due to their small sizes and often cryptic habits. Thus, determining which taxa and habitats to sample and how to sample them is a crucial undertaking.

During the 1993 field season a study was conducted on four stands in the Ouachita National Forest to meet the following objectives: (1) test various collecting protocols to establish each technique's usefulness and optimal sampling interval and (2) make preliminary assessments of the value of specific taxa as biological indicators. The sampling protocols tested are described, selected results (primarily to demonstrate data recording methods) are presented, and recommendations regarding the design and implementation of arthropod diversity studies in long term ecosystem management in the Ouachita National Forest are offered here.

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METHODS

Study Sites

Four sites were sampled (fig. 1); three representing a range of habitat disturbance and one undisturbed control stand. We had originally envisioned using three New Perspectives Phase I treatment sites, but one of them, a clearcut, was eliminated for logistical reasons. A nearby early succession sapling stand (site 1, compartment 1646) was chosen in its place to represent a high level of disturbance. Two intermediate levels of disturbance were represented by a group selection stand with overstory hardwoods retained in openings (site 2, compartment 143 1, stand 19) and a shelterwood with pines retained (site 3, compartment 1641, stand 17). The unmanaged control was an old-growth pine-hardwood stand located within Crystal Mountain Scenic Area (site 4, compartment 1635).

Collecting Techniques

The arthropod faunas of the study sites were sampled continuously using three trapping methods; pitfall, flight intercept/malaise, and Lindgren. All traps were unbaited and were therefore presumed to be non attractive (but see flight intercept protocol recommendation below). Continuously operating traps were supplemented by weekly substrate sampling and visual censuses. A baited survey for the endangered American burying beetle was also conducted. Weekly ultraviolet light trapping was abandoned due to equipment problems.

Pitfall traps (10 per site at 10-m intervals) consisted of 0.5-l plastic cups sunk into the ground with the rims flush with the surface. Each trap was covered by a small wooden rain shield, which also functioned as a shelter for surface-active organisms. A 1: 1 mixture of ethylene glycol and saturated saline solution with a small amount of liquid soap was used as a preservative. Arthropods were removed by straining the preservative through "no-see-em" netting mesh sewn onto an aquarium net frame.

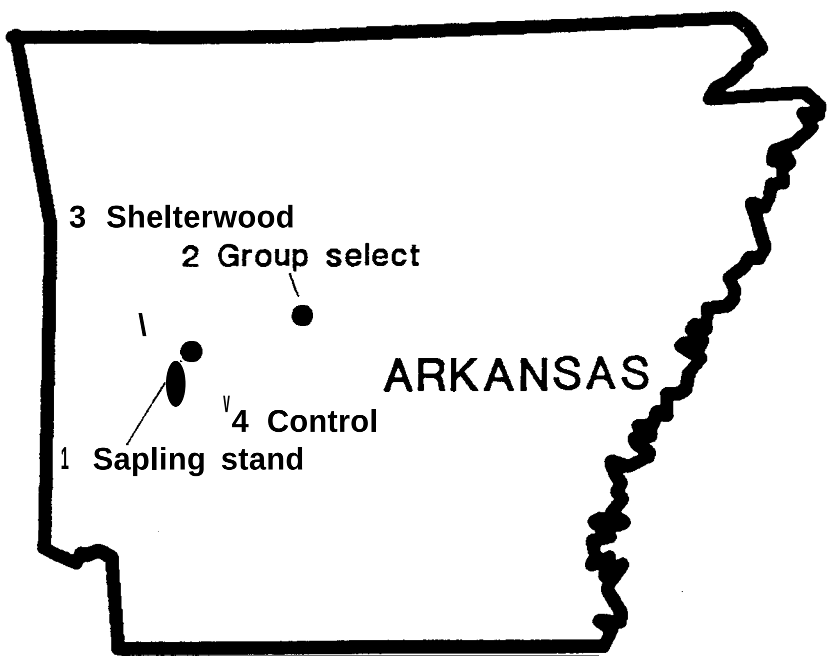

Figure 1 .-*Arthropod biodiversity sampling sites during* 1993 *protocol testing.*

Combination malaise/flight intercept traps were set in pairs at each site at least 20 m apart. The flight intercept component of all but two traps consisted of a 3-m trough cut from 18-cm sewer pipe sealed at the ends (original design by K. Stephan) and located beneath the center vane of the malaise canopy. The flight intercept component of the remaining two traps consisted of a 3-m row of disposable aluminum meatloaf pans. Flight intercept traps were filled with saturated soapy saline solution as a preservative. The collecting heads of the malaise components of the traps were filled with ethylene glycol early in the study. Ethyl alcohol (95%) was used late in the study.

Unbaited 12-unit Lindgren traps (Pherotech, Inc., Delta, British Columbia), two per site, were used as midstory flight intercept traps. Traps were hung from branches approximately 7 m above the ground on all but the sapling site (site 1), where they were hung 3 m high. Traps were lowered and raised during servicing by strings tied at ground level. Ethylene glycol was used as a preservative.

A Berlese sample was taken at each site when continuously operated traps were serviced. Leaf litter, rotting logs and stumps, and flood debris were sifted through 0.7-cm mesh screen until approximately 3 kg of material were obtained. Arthropods were extracted from these samples using Berlese funnels equipped with incandescent lights.

The presence or absence of two species of insects, the American burying beetle (Coleoptera: Silphidae: ***Nicrophorus americanus***) and the Diana fritillary (Lepidoptera: Nymphalidae: ***Speyeria diana***), was of particular interest during the study. The American burying beetle is protected by the Endangered Species Act of the United States; the beetle occurs in nearby counties in eastern Oklahoma and western Arkansas (Raithel 1991). For the American burying beetle survey, the preservative was removed from the pitfall traps and replaced with well-rotted chicken gizzard bait. Trapping was conducted on two consecutive nights, and captured silphids were collected the following mornings.

The Diana fritillary was listed as a candidate for protection under the Endangered Species Act (Anon. 1991) and is known to occur near the study area in Logan County, Arkansas. The Diana fritillary was surveyed by visual censuses of the study sites and surrounding areas during service visits.

Sampling Durations and Service Intervals

Sampling was initiated in late April and continuously operated traps were serviced at weekly intervals during May and June. Weekly Berlese samples were also collected during this period. In early July, flight intercept trapping and Berlese sampling were terminated, and service intervals for malaise, pitfall, and Lindgren traps were decreased to every other week during the remainder of the study (terminated in late September). The American burying beetle survey was conducted during 2-3 June.

RESULTS AND DISCUSSION

Although this study was conducted as a preliminary investigation to test sampling protocols, it generated an impressive volume of specimens and numbers of taxa. Insect activity was most intense and sampling most thorough during May and June. A conservative estimate of the number of specimens collected from each site during this period is 3,000 per week; for four sites during the 8-week period the figure approaches 100,000. Although the last half of the survey may have been affected by a moderate drought and heat wave, the project resulted in the collection of a total of more than 150,000 specimens for the season.

Selected Coleoptera Data

A point-in-time compilation of beetle family abundances and approximate numbers of species collected in flight intercept traps on 25 May is shown in table 1. For comparison, captures from the malaise traps for the same date are given in table 2. These data demonstrate differences in the effectiveness of flight intercept versus malaise trapping as passive methods for sampling aboveground and forest substrate-inhabiting Coleoptera. Flight intercept traps are effective for most Coleoptera (1,033 specimens in 46 families) but are less effective than malaise traps in sampling aboveground herbivores such as Chrysomelidae and Cerambycidae. By contrast, malaise traps provide much poorer sample diversity (696 specimens in 41 families). When trap catches are broken down according to broadly defined habitat and functional group categories, it is evident that the low diversity of malaise trap catches is due.in part to their ineffectiveness in capturing substrate-inhabiting forms (table 3). The difference in effectiveness may be the result of differential geotaxis of substrate-inhabiting versus aboveground-inhabiting insects when encountering obstacles. Beetles in the first group tend to drop (positive geotaxis); those in the latter are about equally likely to drop or crawl up (negative geotaxis).

Table 1 .- *Coleoptera family abundances and species diversity from flight intercept samples on a single sample date, 25 May 1993. Data are expressed as numbers of specimens/numbers of species*

Family	Site 1 (sapling)	Site 2 (group select)	Site 3 (shelterwood)	Site 4 (control)
Aderidae	0/ 0	7/ 3	1/ 1	0/ 0
Alleculidae	0/ 0	0/ 0	010	4/ 1
Anobiidae	1/ 1	3/ 1	1/ 1	2/ 1
Biphyllidae	0/ 0	1/ 1	0/ 0	0/ 0
Bostrichidae	0/ 0	3/ 2	0/ 0	0/ 0
Buprestidae	2/ 2	1/ 1	010	0/ 0
Cantharidae	0/ 0	2/ 2	1/ 1	10/ 1
Catabidae	010	1/ 1	2/ 2	1/ 1
Chrysomelidae	6/ 4	23/ 5	8/ 2	0/ 0
Ciidae	1/ 1	1/ 1	0/ 0	0/ 0
Coccinellidae	2/ 2	2/ 2	2/ 1	0/ 0
Colydiidae	010	3/ 3	0/ 0	0/ 0
Corylophidae	0/ 0	7/ 3	// 1	0/ 0
Cryptophagidae	0/ 0	8/ 1	2/ 1	0/ 0
Cucujidae	// 1	0/ 0	0/ 0	0/ 0
Curculionidae	1/ 1	8/ 7	5/ 4	1/ 1
Dermestidae	0/ 0	2/ 2	0/ 0	010
Elateridae	0/ 0	2/ 2	1013	6/ 3
Endomychidae	010	4/ 1	2/ 1	1/ 1
Erotylidae	5/ 1	3/ 2	2/ 2	1/ 1
Eucinetidae	0/ 0	1/ 1	1/ 1	0/ 0
Histeridae	0/ 0	28/ 3	111	0/ 0
Hydrophilidae	0/ 0	3/ 2	24/2	8/3
Lagriidae	0/ 0	010	0/ 0	1/ 1
Lampyridae	0/ 0	0/ 0	1/ 1	0/ 0
Lathridiidae	0/ 0	6/ 1	1/ 1	0/ 0
Leiodidae	7/ 3	23/ 8	15/ 8	22/ 7
Melandryidae	0/ 0	0/ 0	0/ 0	1/ 1
Melyridae	1/ 1	0/ 0	0/ 0	0/ 0
Mordellidae	010	2/ 2	0/ 0	0/ 0
Mycetophagidae	0/ 0	6/ 1	0/ 0	0/ 0
Mycteridae	0/ 0	0/ 0	0/ 0	5/ 1
Nitidulidae	5/ 3	7/ 4	10/ 2	1/ 1
Phalacridae	0/ 0	1/ 1	1/ 1	0/ 0
Phengodidae	0/ 0	0/ 0	3/ 1	0/ 0
Pselaphidae	32/ 7	22/ 7	4/ 3	53/ 7
Ptiliidae	0/ 0	66/10	6/ 4	8/ 4
Scaphidiidae	0/ 0	2/ 2	2/ 2	0/ 0
Scarabaeidae	6/ 5	0/ 0	28/ 4	0/ 0
Scirtidae	1/ 1	0/ 0	0/ 0	0/ 0
Scolytidae	4/ 2	7114	29/ 5	7/ 5
Scydmaenidae	6/ 4	13/ 6	5/ 3	9/ 4
Sphindidae	2/ 1	3/ 2	1/ 1	2/ 1
Staphylinidae	14/ 8	112/32	54/18	86/19
Throscidae	1/ 1	22/ 3	2/ 1	010
(Unknown)	0/ 0	0/ 0	1/ 1	7/ 1
46 families total	102/47	469/129	226/90	236/65

Table 2.- *Coleoptera family abundances and species diversity from flight intercept samples on a single sample date, 25 May 1993. Data are expressed as numbers of specimens/numbers of species*

Family	Site 1 (sapling)	Site 2 (group select)	Site 3 (shelterwood)	Site 4 (control)
Aderidae	1/ 1	11/ 2	2/ 1	1/ 1
Alleculidae	1/ 1	0/ 0	6/ 1	32/ 1
Anobiidae	010	6/ 1	4/ 2	2/ 1
Apionidae	010	0/ 0	1/ 1	0/ 0
Buprestidae	5/ 2	2/ 2	2/ 1	1/ 1
Byrrhidae	0/ 0	1/ 1	010	1/ 1
Cantharidae	38/ 3	1/ 1	at 2	27/ 4
Carabidae	01 0	0/ 0	1/ 1	2/ 1
Cerambycidae	0/ 0	4/ 3	0/ 0	0/ 0
Chrysomelidae	8/ 7	107/ 6	6/ 4	0/ 0
Cicindelidae	2/ 2	3/ 1	1/ 1	0/ 0
Cleridae	1/ 1	612	010	11/ 1
Coccinellidae	8/ 2	6/ 1	5/ 1	1/ 1
Corylophidae	010	1/ 1	1/ 1	1/ 1
Ctyptophagidae	010	1/ 1	0/ 0	2/ 1
Curculionidae	9/ 4	6/ 4	2/ 2	0/ 0
Dermestidae	3/ 2	010	0/ 0	01 0
Elateridae	5/ 3	6/ 3	16/ 5	30/ 2
Erotylidae	29/ 2	0/ 0	18/ 2	1/ 1
Eucinetidae	01 0	0/ 0	1/ 1	1/ 1
Hydrophilidae	0/ 0	0/ 0	0/ 0	1/ 1
Lampyridae	1/ 1	1/ 1	9/ 1	0/ 0
Lathridiidae	2/ 1	5/ 1	12/ 1	1/ 1
Leiodidae	0/ 0	1/ 1	1/ 1	0/ 0
Lycidae	1/ 1	9/ 4	6/ 2	1/ 1
Melandryidae	010	5/ 1	0/ 0	1512
Melyridae	0/ 0	1/ 1	0/ 0	0/ 0
Mordellidae	1/ 1	7/ 2	10/ 2	1/ 1
Mycetophagidae	010	1/ 1	o/o	1/ 1
Nitidulidae	2/ 1	o/o	2/ 1	010
Phalacridae	3/ 1	0/ 0	2/ 1	0/ 0
Phengodidae	0/ 0	12/ 1	5/ 1	3/ 1
Pselaphidae	1/ 1	0/ 0	1/ 1	1/ 1
Scarabaeidae	7/ 4	21 1	1/ 1	010
Scolytidae	0/ 0	1/ 1	2/ 2	2/ 1
Scraptiidae	1/ 1	0/ 0	0/ 0	0/ 0
Scydmaenidae	0/ 0	010	5/ 4	0/ 0
Silphidae	1/ 1	0/ 0	0/ 0	0/ 0
Sphindidae	1/ 1	0/ 0	0/ 0	0/ 0
Staphylinidae	9/ 4	9/ 3	6/ 6	3/ 1
Throscidae	010	22/ 1	17/ 2	241 1
41 families total	140/48	237/48	153/52	166/30

Table 3.-*Data from Tab les I and 2 ca tegorized by habitats/functional groups. Data are expressed as num ber of specim ens/num bers of species*

Habitat/ functional group	Site 1 (sapling)	Site 2 (group select)	Site 3 (shelterwood)	Site 4 (control)
Flight intercept				
Substrate				
predators	53/15	109/35	41/18	106/20
fungi-herbivores	25/14	230/59	97/38	93/27
Aboveground				
predators	31 3	18/ 5	16/ 6	61 3
fungi-herbivores	21/15	111/28	78/21	31/12
Malaise				
Substrate				
predators	5/ 3	5/ 2	1019	6/ 3
fungi-herbivores	3917	38/ 8	59/14	11/ 9
Aboveground				
predators	121 6	22/ 8	15/ 8	12/ 2
fungi-herbivores	82/30	148/24	42/18	79/11

Diversity data expressed at higher taxonomic categories are particularly useful for establishing priorities for more detailed research aimed at identifying species that are likely to reveal treatment effects of interest to the investigator(s). In this project, the identity and abundance of pselaphid beetle species collected during an 8-week period were determined. The Pselaphidae, with approximately 9,000 described species (Newton and Chandler 1989) is a taxonomically rich family of predatory beetles. Pselaphids are ubiquitous inhabitants of forest substrates worldwide. Many species exhibit high levels of microhabitat fidelity and geographic endemism, and many species are potentially useful as indicators of habitat manipulation and forest quality (Carlton and Chandler in press; Chandler 1987).

The species richness of pselaphid beetles at the four sites (from combined Berlese and flight-intercept samples) is listed in table 4. Overall species richness at the four sites is similar for Pselaphidae, though there is considerable variation in evenness. Evenness is apparently lowest at the undisturbed control site (site 4), but endemism is highest, with four species that were not collected at either of the other sites (table 5). Only one other species was limited to a single site.

Table 4.-*Pselaphid beetle species diversity from Berlese and flight intercept samples 12 May-8 July 1993. Data are expressed as numbers of specimens*

Species	Site 1 (sapling)	Site 2 (group select)	Site 3 (shelterwood)	Site 4 (control)
Arthmius bulbifer	6	1	0	0
Batrisodes denticollis	0	0	0	2
B. furcatus.	0	0	0	5
B. globosus	12	5	10	1
B. sp.	1	2	0	1
Bibloplectus sp.	2	1	3	0
Conoplectus canaliculatus	117	69	40	425
C. susae	13	14	6	1
Custotychus sp.	5	5	0	11
Dalmosella tenuis	2	7	2	1
Decarthron sp.	0	0	0	4
Euplectus duryi	5	4	9	7
E. filiformis	0	14	2	2
E. sp.	3	0	0	0
Leptoplectus pertenuis	0	0	1	2
Melba parvula	5	13	0	1
M. sulcatula	0	10	1	0
M. thoracica	2	9	8	0
M. sp.	29	20	9	1
Pilopius sp.	1	0	0	0
Pycnoplectus sexualis	0	0	1	8
P. interruptus	0	1	0	1
P. sp.	0	0	0	1
Rhexius schmitti	2	0	8	0
R. substriatus	0	0	0	1
R. sp.	0	1	1	0
Tmesiphorus carinatus	2	0	0	0
Thesiastes atratus	3	2	2	0
T. fossulatus	6	8	3	0
T. pumilis	1	2	1	0
T. sp.	3	1	1	0
Trimiomelba dubia	34	69	47	86
Trimioplectus australis	0	0	0	1
Tyrus sp.	0	1	0	0

Table 5.-Summary data from Table 4

Summary category	Site 1 (sapling)	Site 2 (group select)	Site 3 (shelterwood	Site 4 (control)	All sites
Total					
specimens	225	260	155	562	1232
species	17	19	16	17	28
Unique to site	0	1	0	4	5

Annotated Checklist of Selected Species

In addition to the broad questions of ecological interactions and community compositions that are addressed by biodiversity studies, they also contribute a great deal of information to understanding the biologies and distributions of individual species. Studies conducted in poorly surveyed regions inevitably produce records of previously unrecorded taxa or change our perceptions of previously recorded, but poorly understood species. The following entries illustrate the novel findings from the brief survey that was conducted between May and September 1993:

Coleoptera: Byturidae: ***Byturus unicolor***, site 2 (group select), 25 May, two specimens. This is a new State record for the species and family.

Coleqptera: Carabidae: ***Anillinus*** sp., site *2* (group select), 13 May, two specimens, 3 June, one specimen, site 4 (control), 25 May, one specimen. Several undescribed species were regarded by Carlton and Cox (1990) as potential biogeographic indicators of relict faunas.

Coleoptera: Endomychidae: ***Mycetina pulchella***, all localities, various dates. This is a new State record for the species.

Coleoptera: Staphylinidae: ***Megalopinus*** sp., site 1 (sapling stand), 9 June, one specimen. This is a new state record for the genus and subfamily Megalopsidiinae.

Hemiptera: Schizopteridae: ***Glyptocombus saltator,*** site 1 (sapling stand), 25 May, 15 specimens. This species was presumed rare by Allen and Carlton (1989). The recovery of numerous specimens from an early succession habitat suggests otherwise.

Lepidoptera: Nymphalidae: ***Speyeria diana***, site 2, 17 June, two males; site 3, 1 July, one male. This species is a candidate species for threatened/endangered status (Anon. 1991). These are new records for the Ouachita National Forest.

CONCLUSIONS

Constraints

The major constraint to extracting meaningful data from arthropod biodiversity surveys is sorting and counting the specimens, not collecting them. The taxonomic diversity represented in the samples and the difficulties of identifying many of the taxa make it obvious that great selectivity must be exercised if data analysis is to be completed in a timely fashion.

The goal of the sampling effort should be to collect enough specimens through the season to adequately sample the system, but not so many as to render identification and enumeration impractical. The goal of data analysis should be the identification and enumeration of taxa to the highest level of identification possible, ideally to species. Even if many of the species cannot be named,it may be possible to sort them to morphospecies. In cases where the precise identification of all taxa is obviously impractical,priority should be given to taxa for which good identification keys or professional expertise are available and/or those that are of obvious significance to the theoretical goals of the project.

Recommended Protocol and Survey Schedule

The following protocol was developed with the above constraints in mind and from the information gathered during this preliminary study. In addition to the sorting/identification bottleneck in data analysis, factors that are considered include the time required to service traps at each study site, distance between sites and site access, and the effect of service intervals and different preservatives on specimen preservation.

Pitfall trapping is an effective method of capturing ground-active arthropods. A line of 10 traps is the minimum number that should be used. An alternative to the use of separate trapping techniques for crawling and flying arthropods is to modify the flight intercept traps by locating them in a trench with the tops flush with ground level. The trap thus created will serve as an efficient flight intercept/pitfall combination. Also, non target small animals, such as shrews, mice, and various amphibians, are more likely to escape from the troughs, with their slanting sides, than they are from the steep-walled pitfall cups (not to mention the toxic effects of the ethylene glycol in the latter). The volume of material from the Berlese samples will depend on the number of funnels available to process the samples and frequency of sampling. Small samples can be processed more thoroughly, but infrequent sampling intervals argue for larger samples, provided they do not sit around the laboratory long enough to dry out prior to processing. Seasonality is not pronounced in most substrate species in the Southern United States, so a monthly sampling frequency is probably adequate for annual surveys.

The combination flight intercept/malaise trap is the most important device for sampling flying insect diversity. The use of a non-toxic preservative in the flight intercept portion such as saturated saline (NaCl) is necessary to prevent accidental poisoning of animals and local contamination of the ground during spills and rain overflow. One-week service intervals are too lengthy and should be reduced to no more than 3 days. Longer intervals not only affect the quality of preservation of the specimens, but also bias the trap catch by attracting large numbers of carrion feeders to the slightly decayed insects. This need for a short service interval affects the schedule of the entire sampling program, which is discussed below. A further advantage of short service intervals is that it becomes unnecessary to use ethylene glycol in the collecting heads of the malaise canopies. Ethyl alcohol (95%) gives much cleaner samples and is less troublesome to deal with during servicing. Two traps per site, spaced at least 25 m apart and oriented at 90° angles to each other, are adequate.

The use of unbaited Lindgren traps as elevated flight intercept traps is a practical approach if used in sufficient numbers and run contiuously. Numbers of insects produced weekly by a single trap are not impressive, but the diversity represented is good, and, more importantly, there appears to be very little overlap in faunal compositions from the Lindgren traps and the ground-based flight intercept/malaise traps. Five traps per site, perhaps raised to varying heights in the midstory and canopy are recommended. Longer sampling intervals are allowed by the use of ethylene glycol in the collecting cups. Little danger exists in using this chemical in the Lindgren traps because they are elevated and access to the collecting cups is limited.

Timer-operated ultraviolet (UV) light traps have been used effectively by other investigators, but they proved consistently unreliable during the course of this study. Certainly all remotely operated equipment should be rigorously tested prior to being put to use. Since UV light trapping is strongly affected by weather, the phases of the moon, and other variables, comparisons can only be made between study sites sampled simultaneously. Also, if Lepidoptera are being inventoried, they should be hand collected at the light traps. Ideally, microlepidoptera must be mounted immediately following collection.

To adequately assess changes in the diversity patterns of arthropod faunas at several study sites and avoid the quagmire of overcollecting, a monthly sampling cycle is recommended. For 1 week during each month of the insect flight season (March-November), the pitfall/flight intercept/malaise traps should be operated. The investigator should remain in the area and visit each study site at 2- or 3-day intervals during the week. These traps should be deactivated at the end of the sample week and reactivated 3 weeks later.

One large-volume Berlese sample should be collected at each site during the sample week. Berlese samples should be collected at monthly intervals during winter as well. Substrate arthropod diversity is as high during these months as during periods of surface and flight activity.

Light trapping should be conducted at some point in the week when weather conditions are optimal and reasonably consistant at all sites. Large, powerful lights, such as mercury vapor lights, are not recommended because they will pull insects from beyond the study areas.

Because of the low-volume recovery of unbaited Lindgren traps, they should be operated continously throughout the collecting season. The degree of precision desired by the investigator in tracking seasonal activity patterns will determine whether they need to be serviced between normal sampling weeks.

In summary, the scale of effort expended on the field portion of arthropod diversity research in long-term ecosystem studies should be based on the availability of technical and professional personnel to process samples, rough sort taxa, and conduct the laborious process of species identification, rather than the collector's enthusiasm for collecting, though this is a useful adjunct. Such a reality-based collecting protocol allows for a high degree of standardization among field sites, provides sufficient time for sorting samples with even modest committment of personnel, and ensures that rapid, meaningful, and statistically robust results will be generated by the project.

LITERATURE CITED

Allen, Robert T.; Carlton, C.E. 1989. New records of Ceratocombidae and Schizopteridae from Arkansas (Heteroptera: Dipsocoromorpha). Journal of the Kansas Entomological Society. 62: 125- 126.

Anonymous. 1991. Proposed rules. Federal Register. 56 (225): 58,853.

Barbault, R.; Hochberg, M.E. 1992. Population and community level approaches to studying biodiversity in international research programs. Acta Oecologia. 13: 137-146.

Carlton, Christopher E.; Chandler, Donald S. [In press]. Revision of the Nearctic genus ***Pseudactium*** (Coleoptera: Pselaphidae). Coleopterists Bulletin.

Carlton, C.E.; Cox, Randel T. 1990. A new species of *Arianops* from central Arkansas and biogeographic implications of the Interior Highlands *Arianops* species (Coleoptera: Pselaphidae). Coleopterists Bulletin. 44: 365-371.

Chandler, Donald S. 1987. Species richness and abundance of Pselaphidae (Coleoptera) in old-growth and 40-year-old forests in New Hampshire. Canadian Journal of Zoology. 65: 608-615.

Collins, N.M.; Thomas, J.A., eds. 1989. The conservation of insects and their habitats.: New York, Academic Press.

Martin, William. C.; Boyce, Stephen G.; Echtemacht, Arthur C., eds. 1993. Biodiversity of the Southeastern United States. Upland Terrestrial Communities. New York, John Wiley and Sons, Inc.

Newton, Alfred F., Jr.; Chandler, Donald S. 1989. World catalog of the genera of Pselaphidae (Coleoptera). Fieldiana (Zoology) New Series. 53: l-93, + iv.

Raithel, Christopher. 1991. American burying beetle (*Nicrophorus americanus*) recovery plan. Newton Comer, MA: U.S. Department of Interior, Fish and Wildlife Service.

Solbrig, 0. T. 1991. The origin and function of biodiversity. Environment. 33: 16-20, 34-38.

Wilson, Edward O., ed. 1988. Biodiversity. Washington, DC: National Academy of Science Press.

Seed, Cone, Regeneration, and Defoliating Insects in Forest Ecosystem Management[1]

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ABSTRACT

As part of the Phase II Ecosystem Management Research conducted on the Ouachita and Ozark National Forests, the Arthropod and Microbial Communities Study Group completed two studies in 1992: a survey of regeneration and defoliating insects and a study of seed bug damage to shortleaf pine (*Pinus echinata* Mill.) seeds. Pitfall traps collected two species of pine regeneration weevils, *Hylobius pales* (Herbst) and *Pachylobius picivorus* (Germar). The primary defoliators were katydids (*Pterophylla* sp.). A total of 92 shortleaf pine seeds were collected from 22 stands. Of the seeds collected, 40 were viable, 41 were empty, and 11 were damaged by seed bugs, *Leptoglossus corculus* (Say) and *Tetyra bipunctata* (Herrich-Schaffer). Studies initiated in 1993 include the effect of single-tree selection on insect infestation rates of white oak (*Quercus alba* L.) acorns and the impact of coneworm and seed bug infestations on shortleaf pine seed yields in Phase II stands.

INTRODUCTION

The Ecosystem Management Research on the Ouachita and Ozark National Forests is an ambitious program to assess several silvicultural harvesting treatments. The goal is to determine the effects of the various harvesting methods on all aspects of forest biology and use. The research included a study group originally known as the Insect and Disease Study Group. During the past 2 years, as the group developed its research plans, it became apparent that the scope of the research would include far more than insect pests and diseases. Consequently, the group renamed itself as the Arthropod and Microbial Communities Study Group. This new name more accurately describes the broad and complex aspect of ecosystem management that the group has undertaken.

Insects are major components of all forest ecosystems. Many of the pioneering studies of insect population dynamics have concerned themselves with forest insects, for exaniple, epidemic outbreaks of the spruce budworm (Morris 1963). Many forest insect species can undergo phenomenal population changes from generation to generation or from season to season. It is not uncommon to see tenfold increases in population numbers for several generations followed by precipitous declines over the following generations (Varley and others 1973). However, the real importance of insects in forest ecosystems is due to the immense diversity of insect species and the role insects play in forest food webs, energy transfer, pollination of plants, and decomposition processes (Wilson 1992).

This paper will be concerned with the insects that make their living in or on seeds, cones, and seedlings. Additionally, a survey of defoliators will be discussed. The more general surveys of insect biodiversity are discussed separately (Carlton and others 1994).

Entomological Background

Forest insects represent a wide array of species in all insect orders. A good general discussion of forest insects is given by Drooz (1985). Insects that may play an important role in shaping forest communities are those that infest the seeds or fruits of trees or seedlings. Both groups of insects may play an important role in forest community dynamics.

Caterpillars of the genus *Dioryctria* attack and kill cones of conifers throughout the Northern Hemisphere. Commonly called coneworms, the adults are small, gray or brown-orange moths with crossbands on the forewings. Four sympatric species infest pines in the South: the southern pine coneworm, *D. amatella* (Hulst); the blister coneworm, *D. clarioralis* (Walker); the webbing coneworm, *D. disclusa* Heinrich; and the loblolly pine coneworm, *D. merkeli* Mutuura and Monroe. Larval feeding destroys conelets and cones, making coneworms major pests in southern pine seed production areas (Ebel and others 1980).

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[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

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In the South, two species of seed bugs significantly reduce pine seed yields: the leaffooted pine seed bug, ***Leptoglossus corculus*** (Say), and the shieldbacked pine seed bug, ***Tetyra bipunctata*** (Herrich-Schaffer). Both feed by inserting their piercing-sucking mouthparts into the cones or conelets and sucking out the nutritious contents of the developing seeds. Consequently, mature seeds appear normal but fail to germinate (Ebel and others 1980).

Hardwood seeds are subject to predation by a number of insects as well. Insects infesting acorns are of special concern because oaks ***(Quercus*** spp.) make up a significant proportion of the hardwood component of southern forests and acorns are an important source of food for a wide variety of wildlife species.

A great deal of work has been done on estimating the mast production of hardwoods, especially the oaks (Bonner 1992, Downs and McQuilken 1944, Sharp 1958, Sork and others 1993, Tryon and Carve11 1962). Several studies indicate that acorn production varies from year to year and from tree to tree in a given year (Christisen and Kearby 1984, Sharp 1958, Sork and others 1993). Consequently, loss of acorns to insects can be serious in years of poor acorn production. In one study, insects were responsible for the loss of 30 percent of the acorn crop (Tryon and Carve11 1962).

Several species of weevils in the genera ***Curculio*** and ***Conotracheles*** reduce oak mast (Christisen and Kearby 1984, Myers 1978). Species in both genera have similar life histories; adults lay eggs in the developing nuts, and the resulting larvae feed on the contents of the seed, destroying it. Larvae leave the nut and pupate in the soil. Other insect species infesting acorns are the acorn moth, ***Valentinia glandulella*** (Riley), and the filbertworm, ***Melissopus latiferreanus*** (Walsingham). With these two species, as with the weevils, the immature stages feed within and destroy the nut (Myers 1978).

Regeneration insects are those that feed on seedlings and young trees. One of the primary hardwood regeneration insects is the twig girdler, ***Oncideres cingulata*** (Say). This species attacks most of the major hardwood species in the Eastern and Southern States including oaks, hickories, and elms. The adults feed on the tender bark of small trees sometimes causing heavy damage (Drooz 1985). Several weevils cause damage to young pine trees and seedlings. Two species of primary importance in the South are the pales weevil, ***Hylobius pales*** (Herbst), and the pitcheating weevil, ***Pachylobius picivorus*** (Germar). These weevils feed on the stems of small pines frequently killing them. Damage can be extensive in young plantations and Christmas tree farms (Hunt and Raffa 1989, Rieske and Raffa 1993). These weevils breed in recently cut stumps and stump roots and build up substantial populations after logging (Drooz 1985). Consequently, they may affect natural regeneration following silvicultural treatments.

Studies Completed or Initiated

Regeneration Insects and Defoliators - 1992 Survey

The objective of this study was to survey Phase II control stands for pine regeneration weevils, defoliators and the twig girdler. This survey was conducted in 1992 to determine the potential effects of insects on regeneration in the Phase II treatment stands.

Seed Bug Damage to Shortleaf Pine Seeds - Phase I

This study consisted of a radiographic analysis of pine seeds collected in the Ouachita National Forest as part of the Phase I research in 1992. The objectives were to obtain an estimate of damage to seeds of shortleaf pine, ***Pinus echinatu*** Mill., caused by seed bugs and to compare radiographic analysis with the "cut test" as methods for the determination of shortleaf pine seed viability.

Acorn Insects

This study was initiated in September 1993 to determine the effects of the PhaseII single-tree selection treatment on the rate of insect infestation in white oak ***(Quercus alba*** L.) acorns. A second objective will be to determine the effects of canopy conditions or gaps on the rate of insect infestation in acorns.

Coneworm/Seed Bug Damage to Shortleaf Pine Seeds - Phase II

This study was initiated in October 1993 to surveyconeworm and seed bug damage on shortleaf pines in or near selected Phase II stands in the Ouachita National Forest. A second objective will be to determine the extent of seed bug damage to shortleaf pine seeds collected from seedtraps placed in the Phase II treatment stands.

METHODS

Regeneration Insects and Defoliators - 1992 Survey

Pine Regeneration Weevil Survey

Turpentine/ethanol-baited pitfall traps described by Hunt and Raffa (1989) were used to collect pine regeneration insects. Traps were modified slightly by suspending the bait vials from the lids using soft wire harnesses held in place by passing the ends through holes in the lids and bending the ends outward. At each of the 4 study sites, 20 traps were placed at approximately 6-m intervals and checked, cleaned, and rebaited weekly.

Weevils were kept live in cardboard mailing tubes or individually in small petri dishes for 5 days after collection to check for parasitoid emergence. The weevils were then killed and preserved in 70 percent ethanol. Subsequently, they were dried, identified, and sexed. Voucher specimens were pinned and deposited in the University of Arkansas Arthropod Museum.

Defoliator Survey

Frass traps identical to those described by Haack and Blank (1991) were used with slight modification. Twenty-four traps, divided equally between pine and hardwood canopies in groups of four, were placed at each site. Collections were made weekly. Frass collections were combined for pine and hardwood samples for each site each week. The material was air-dried for several days; then, nonfrass debris was separated by hand and discarded. Frass was weighed to 0.1 mg, sorted, and identified.

Mercury-vapor Light Traps

Mercury-vapor light traps were used to survey for twig girdlers although all insects captured in the traps were sorted and identified. Light traps were rotated among the four sample sites during weekly trap runs if the weather was satisfactory. Insects were collected into soapy water screened by 6.35 mm wire mesh to exclude large moths.

Study Sites

The study sites used control stands established for the Phase II research on the Ouachita and Ozark National Forests (Baker 1993). Study-site numbers and locations were: Site 1 - Yell County, 4.8 km northeast of Blue Ball; Site 2 - Yell County, 4.8 km northeast of Aly; Site 3 - Montgomery County, 12.8 km northeast of Glenwood; Site 4 - Polk County, 16 km west of Mena.

Seed Bug Damage to Shortleaf Pine Seeds - Phase I

In 1992, seed traps were placed in six randomly selected plots per stand in 22 of the 25 Phase I pilot study stands (clear-cut stands were excluded). At each plot, seed traps were placed at a distance of 6.7 m along azimuths of 0”, 120°, and 240” from the plot center. Seeds were collected twice per seedfall season (early December and late February/early March). Seeds from all the traps in one plot were cornposited into one sample. Consequently, each stand produced six cornposited samples. Seed samples were cleaned, sorted, and tallied.[3] The seed samples were collected primarily to estimate regeneration potential but also provided information on seed bug damage. Traditionally, seed bug damage is determined by examination of radiographs (X-rays) of seeds (Bramlett and others 1977). Radiography allows determination of seed viability, i.e. full (healthy), empty (aborted seeds or “pops”), or insect damaged. As part of the survey of seeds collected from the Phase I plots, we compared the radiographic method of seed analysis with the “cut test” method of testing seed viability. The cut test involves slicing the seed open with a knife to examine the condition of the seed contents.

[3] Guldin, James M.; Shelton, Michael G.; Wittwer, Robert F. [and others]. 1993. Study plan: New Perspectives/Ecosystem Management research on the Ouachita/Ozark National Forests: Phase II - Silviculture Research. 67p. Monticello, AR: Southern Forest Experiment Station, Forestry Sciences Laboratory, administrative report 4 110 FS-SO-4 106-8 1 (problem 3).

Acorn Insects

A control[4] and a single-tree selection treatment in the Phase II south zone, and a control and a single-tree selection in the Phase II north zone (Baker 1994) of the Ouachita Mountains (Ouachita and Ozark National Forests) were selected to determine insect infestation of acorns. All stands were primarily pine with a 60-80 year old hardwood component and were previously unmanaged.

Twenty-five acorn traps consisting of a metal trash can with a 0.325-m diameter opening and a chicken-wire mesh top were placed in each area. Each trap was placed under a separate tree unless 25 trees were not available, then several traps were placed under a single tree. Trees were selected on the basis of acorn production determined by ground observations. Only white oaks were selected due to their abundance in all stands. Traps were placed under the canopy of the tree midway between the trunk and the canopy edge and in random orientation to the trunk. Trees used in single-tree selection stands were located outside green belts and trees had been removed from at least one side of the canopy. Codominant trees were selected because of their overall abundance in all areas and tendency to produce more acorns than subdominants and because dominant oaks were rare or nonexistent in several stands. Acorn production in each tree was estimated visually from the ground and recorded as low, medium, or high.

Samples will be collected every 2 weeks. For each sampling, traps will be checked and the acorns removed and placed in labeled paper bags. Acorns will also be collected from the ground in a 1.0-m radius around the traps. Acorns collected from the ground will be kept separately from trap-collected acorns. Differences in insect infestation rates between the ground and trap-collected acorns will be determined, as well as infestation rates.

Basal areas of pines and hardwoods surrounding the selected trees will be estimated using a IO-basal area factor (BAF); and canopy height of trees will be estimated using a metric clinometer to determine if infestation rates are related to canopy conditions surrounding individual sample trees.

Coneworm/Seed Bug Damage to Shortleaf Pine Seeds - Phase II

The 10 wildlife/biodiversity stands in the Phase II south and east zones will be used for this study (Baker 1993). At each stand, at least 25 mature, unopened cones of shortleaf pine will be collected. Trees that are readily accessible will be sampled by one of two methods. When possible, an aerial lift truck belonging to the Ouachita Seed Orchard will be used to get to the tops of the trees where most cones are located. The cones will be pulled by hand or clipped with pruning shears. Based on the total number of shortleaf pines remaining in the stands, it may be necessary to collect from trees near, rather than within, the stands. When access by the aerial lift truck is not possible, cones will be collected by shooting cone-bearing branches from the tops of the trees with a 22-caliber rifle. Cones will be examined in the field for coneworm damage and other damage.

Following field examination, cones will be returned to the Stuart Seed Orchard in the Catahoula Ranger District of the Kisatchie National Forest, Pollock, LA, where they will be air-dried in open sheds for several weeks and then oven dried for 24 hr to open the cones. Seeds will be extracted, dewinged, and radiographed to determine the proportion damaged by seed bugs. Estimates of seed bug damage in seeds collected will be compared with damage to shortleaf pine seeds collected during the 1993-94 season from the seed traps placed in Phase II stands.

RESULTS AND DISCUSSION

Regeneration Insects and Defoliators - 1992 Survey

Pine Regeneration Weevil Survey

A total of 467 regeneration weevils were collected from the baited pitfall traps; 116 pales weevil (52 males, 64 females) and 35 1 pitcheating weevil (137 males, 2 14 females). Some seasonal differences in weevil numbers were obvious including a dramatic decline in weevil abundance in late August. Although only two species of Hylobiini were collected during this survey, the possibility that other species are present cannot be discounted because distributional information is incomplete for this area.

Other insects attracted to the turpentine/ethanol bait included several ***Drosophila*** spp., two specimens representing two genera of Scolytidae, and large numbers of a single species of carpophiline Nitidulidae. Ground-dwelling arthropods that entered the traps included carabid beetles (mainly ***Evarthrus*** spp.), centipedes, spiders, and crickets.

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[4] This control was not the previously established Phase II control stand. This new control stand was established near the single-tree selection stand in order to more closely match stand and edaphic conditions.

On 20 July 1992, 15 hymenopterous parasitoid larvae emerged from a female ***P. picivorus***. Unfortunately, all died before pupation. These larvae were likely the braconid ***Microctonus pachylobii*** (Rieske and others 1989). No additional parasitoids were recovered during the survey.

Baited pitfall traps proved excellent for the two weevils of primary concern. Given the effectiveness of the technique, adequate sampling could probably be achieved using lines of 10 traps per site rather than 20, especially if the treatments are replicated at least 3 times. If 10 traps are used, they could be spaced further apart reducing the time spent at each site and lessening the possibility that the traps themselves might reduce local weevil populations. Since live insects are involved, the weekly sampling schedule is desirable. Specimens should be kept alive between sample runs to monitor for parasitoid emergence because this may be an important density-dependent control for weevil populations.

Defoliator Survey

Both pine and hardwood frass samples were dominated by orthopteran frass, mainly from tettigoniids. Katydids (***Pterophylla*** sp.), as large nymphs in July and as adults in August and September, were present in large numbers at all sites. Second in abundance was a mixture of fine powdery frass and minute pellets. The powdery material was likely derived from orthopteran pellets. A distant third in abundance was caterpillar frass. There were no obvious qualitative differences between pine and hardwood samples.

Cross-contamination was a serious problem of this method of estimating relative defoliator abundance. It was difficult to set up the traps in locations where drift from nontarget trees did not contaminate the samples. Deciduous frass samples contained pine needles, and all the pine samples contained deciduous tree leaves. The pine samples also contained substantial amounts of katydid frass, which evidently drifted into the pine frass traps. In a number of cases, katydids were actually resting inside the pine frass traps. This is obviously a potential source of sample bias. The problem of contamination from nontarget canopies will probably continue in the relatively closed canopies of the control plots but might be reduced in treatment plots where trees are removed. To be more meaningful, deciduous trees should be sampled by species or genera. However, in addition to the detailed sorting of the frass samples this will dramatically increase time and personnel requirements.

Mercury-vapor Light Traps

Although no twig girdlers were collected during the'light-trap survey period, the occurrence of girdlers in northwest Arkansas in October suggests that a brief period of sampling at the sites during this time might yield results.

Seed Bug Damage to Shortleaf Pine Seeds - Phase I

A total of 92 shortleaf pine seeds were collected from the seed traps in the 22 Phase I stands. This may seem to be a small number of seeds; however, it must be remembered that the seed traps represent only a very small percentage of area in which seeds are dispersed. Seeds were not expected to be collected in large numbers. Of the seeds collected, 40 were viable (full), 4 1 were empty (pops) and 11 were classified as damaged (due to feeding by seed bugs).

Comparison of the two methods for determining seed viability-radiographic examination and the cut test-revealed that the two methods yielded very similar results. Only two seeds were classified differently by the two methods. However, the cut method does not provide information on the causes of seed damage.

Acorn Insects

Traps were placed in the study plots in late September 1993. At this time, two collections have been made. However, inspection of the acorns for insect damage has not been completed.

Coneworms/Seed Bugs - Shortleaf Pine - Phase II

Cones will be collected during the week of 24 October 1993 so no data are presently available.

CONCLUSIONS

The frass sampling for defoliating insects was discontinued because of cross contamination between the pine and hardwood traps and because it required large amounts of time and manpower to be done correctly. The pitfall traps will be continued as a part of the arthropod biodiversity studies rather than as part of the seed, cone, and regeneration studies. The collection of acorns in the single-tree selection stands and controls will be supplemented by acorns collected in **seedfall** traps placed in all Phase II stands by the silviculture study group. All acorns collected will be inspected for insect damage. Additionally, the shortleaf seeds collected in the **seedfall** traps will be radiographed for seed bug damage. It is hoped that these collections and analyses can be conducted for the next several years in order to establish a detailed data base on insect influences on natural forest regeneration.

LITERATURE CITATIONS

Baker, James. 1994. Overview of Phase 11 Stand-level Research. In: Pretreatment conditions and preliminary findings: Proceedings of the symposium on ecosystem management research in the Ouachita Mountains; 1993 October 26-27; Hot Springs, AR. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Bonner, F.T. 1992. Hardwood seed. In: Proceedings of the Southern Forest Nursery Association Conference; 1992 July 20-23; Callaway Gardens, Pine Mountain, GA. [place of publication unknown]: 67-90.

Bramlett, D.L.; DeBarr, G.L.; Yates, H.O., III [and others]. 1977. Cone analysis of southern pines - a guidebook. Gen. Tech. Rep. SE-13. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station and Southeastern Area, State and Private Forestry. 28 p.

Carlton, C.E.; Bollinger, J.; Thompson, L.C. 1994. Arthropod biodiversity-sampling protocol development. In: Pretreatment conditions and preliminary fmdings: Proceedings of the symposium on ecosystem management research in the Ouachita Mountains; 1993 October 26-27; Hot Springs, AR. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Christisen, Donald M.; Kearby, William H. 1984. Mast measurement and production in Missouri (with special reference to acorns). The Missouri Department of Conservation Terrestrial Series No. 13. Missouri Department of Conservation, Jefferson City, MO. 36 p.

Downs, A.A.; McQuilken, W.E. 1944. Seed production of southern Appalachian oaks. Journal of Forestry. 42: 913-920.

Drooz, Arnold T., ed. 1985. Insects of eastern forests. Misc. Publ. 1426. Washington DC: U.S. Department of Agriculture, Forest Service. 608 p.

Ebel, Bernard H.; Flavell, Thomas H.; Drake, Loyd E. [and others]. 1980. Seed and cone insects of southern pines. Gen. Tech. Rep. SE-8. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 43 p.

Haack, R.A.; Blank, R.W. 1991. A simple ground-based trap for estimating densities of arboreal leaf-eating insects. Research Note NC-354. Radnor, PA: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station.

Hunt, D.W.A.; Raffa, K.H. 1989. Attraction of ***Hylobius radicis*** and ***Pachylobius picivorus*** (Coleoptera:Curculionidae) to ethanol and turpentine in pitfall traps. Environmental Entomology. 18(3): 35 l-355.

Morris, R.F. 1963. The dynamics of epidemic spruce budworm populations. Memoirs of the Entomological Society of Canada. 3 1: l-332.

Myers, Steven A. 1978. Insect impact on acorn production in Missouri. Columbia, MO: University of Missouri-Columbia. 246 p. Ph.D. thesis.

Rieske, L.K.; Hunt, D.W.A.; Raffa, K.F. 1989. ***Microctonus pachylobii*** (Hymenoptera:Braconidae) parasitizes ***Hylobius*** weevils in Wisconsin: new host genus and geographic records. Entomological News. 100: 153-154.

Rieske, L.K.; Raffa, K.F. 1993. Potential use of baited pitfall traps in monitoring pine root weevil, ***Hylobius pales, Pachylobius piscivorus,*** and ***Hylobius radicis*** (Coleoptera:Curculionidae) populations and infestation levels. Journal of Economic Entomology. 86(2): 475-485.

Sharp, Ward M. 1958. Evaluating mast yields in the oaks. Bulletin 635. University Park, PA: Pennsylvania State University College of Agriculture Agricultural Experiment Station. 22 p.

Sork, Victoria L.; Bramble, Judy; Sexton, Owen. 1993. Ecology of mast-fruiting in three species of North American deciduous oaks. Ecology. 74(2): 528-541.

Tryon, E.H.; Carvell, K.L. 1962. Acorn production and damage. Bull. 466T. Morgantown, WV: West Virginia University Agricultural Experiment Station; 18 p.

Varley, G.C.; Gradwell, G.R.; Hassell, M.P. 1973. Insect population ecology - an analytical approach. Berkeley,CA: University of California Press. 212 p.

Wilson, Edward 0. 1992. The diversity of life. Cambridge, MA: Belknap Press of Harvard University Press. 424 p.

Southern Pine Beetle Risk Ratings[1]

Peter L. Lorio, Jr.[2]

ABSTRACT

A preliminary assessment of stand risk rating for the southern pine beetle (SPB), ***Dendrocronus frontalis*** Zimmermann, indicated that the 52 Phase II research stands range from medium to high risk. The risk rating considers the relative susceptibility of trees and stands to attack, the potential for SPB reproduction, and the potential loss of valuable resources. An abundance of food and habitat, required to produce large SPB populations, is considered paramount.

INTRODUCTION

The purpose of this paper is to describe the approach taken to assess the risk of loss to the southern pine beetle (SPB), ***Dendrocronus frontalis*** Zimmermarm, in 52 stands (pretreatment conditions), which are part of the Ecosystem Management Research Phase II Program, and to present some preliminary results. Factors considered are (1) relative susceptibility or resistance of stands to beetle attack, (2) the potential for SPB reproduction in those stands, and (3) the potential loss of valuable resources in the event of successful attacks (Lorio 1978, Lorio and Sommers 1981, Lorio and others 1982). The approach differs from hazard ratings based solely on the relative susceptibility of trees and stands to SPB attack or the combined consideration of tree susceptibility and SPB population level at some point in time (Paine and others 1984). Abundant food and habitat, required to produce large SPB populations, is considered paramount.

METHODS

As indicated above, the assessment procedure used here includes factors apart from the relative susceptibility of trees and stands to SPB attack. Also, because detailed plot and stand data were collected in connection with other objectives of Phase II, those data are used instead of resource data contained in the Continuous Inventory of Stand Conditions (CISC) data base (Lorio and Sommers 1981, Lorio and others 1982).

The approach involves procedures described in Lorio (1980) in which data are plotted on a stocking chart requiring only average basal area per acre and number of trees per acre. This is similar to a widely used upland hardwoods chart (Gingrich 1967) to compare existing stand conditions with concepts of understocked, fully stocked, and overstocked stands. For convenience, the chart used is one developed for loblolly pine, ***Pinus taeda*** L., by Westvaco Corporation, which was used previously for a similar purpose (Lorio 1980). Any number of other standards, such as Meyer (1942), Schumacher and Coile (1960), and USDA FS (1976), could be useful for comparisons of actual stand densities with convenient points of reference. On the Westvaco chart, 100-percent stocking represents the average condition existing when the maximum number of well-spaced trees of a given size occupy an acre of land without overcrowding. Full stocking may or may not mean optimum stocking, correct stocking, or even adequate stocking for any specific product (Lorio 1980).

With the lack of an historical data base for SPB infestations on the Ouachita National Forest, stand densities and stocking of stands at the points of origin of 217 infestations, which occurred in stands on the Kisatchie National Forest in Louisiana from June 1975 through June 1977, are presented for comparison with existing stocking in Phase II stands.

RESULTS AND DISCUSSION

Data from two stands included in Phase II research were plotted to illustrate the approach being taken. Data for 14 plots in stand 5, compartment 1658, are shown in figure 1 (pine and pine plus hardwoods 19.6 inches in d.b.h.) and in figure 2 for trees 13.6 inches in d.b.h. For clarity, only the 50- and 100-percent stocking lines from the Westvaco stocking chart are shown. Looking only at the overstory (fig. 1), one sees quite a wide range in number of trees per acre, but quite uniform

[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

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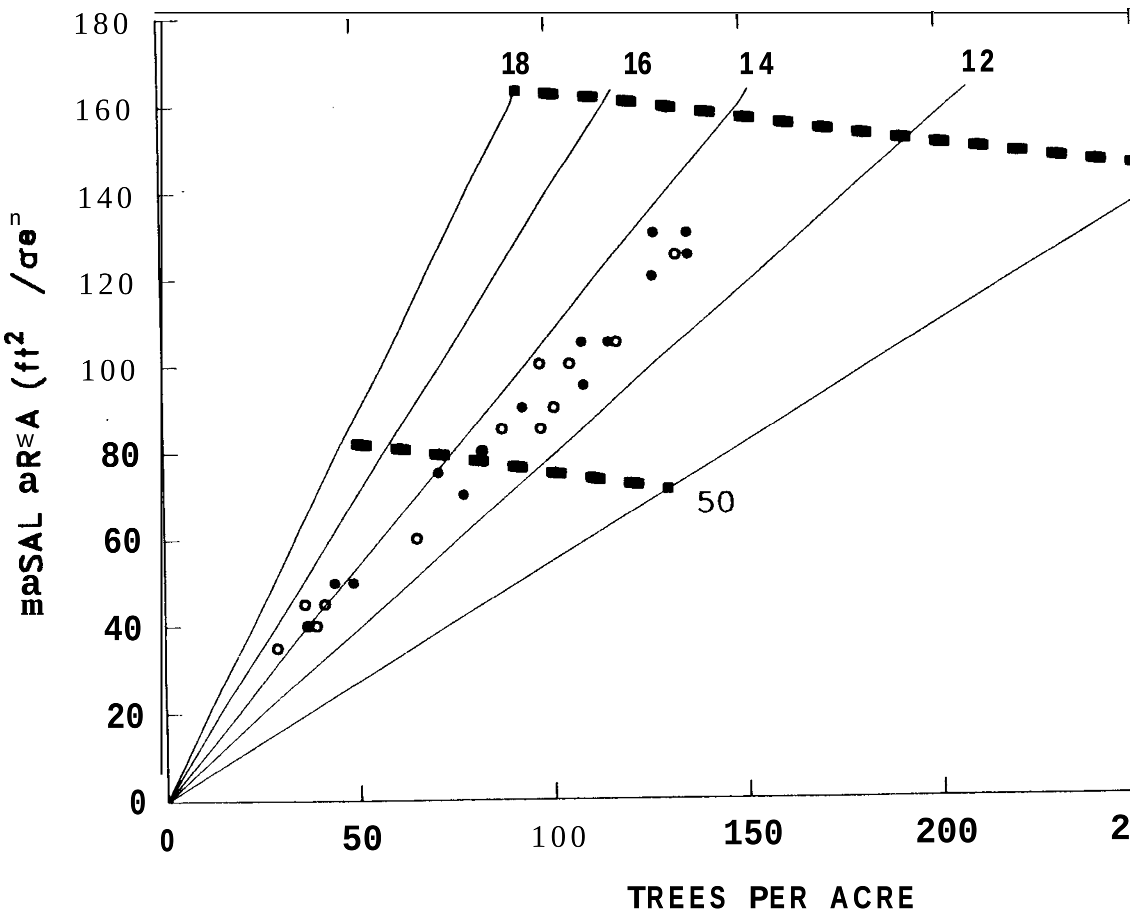

Figure 1.— Stand density and relative stocking of trees ≥ 9.6 inches in d.b.h. in 14 plots wi 1658, on the Ouachita National Forest (pine, open circles; pine plus hardwoo from Westvaco Corp. stocking chart). Here, and in all other figures, the labe are quadratic mean diameters, and the dashed lines, labeled 50 and 100, a extracted from the Westvaco stocking chart (see Lorio 1980).

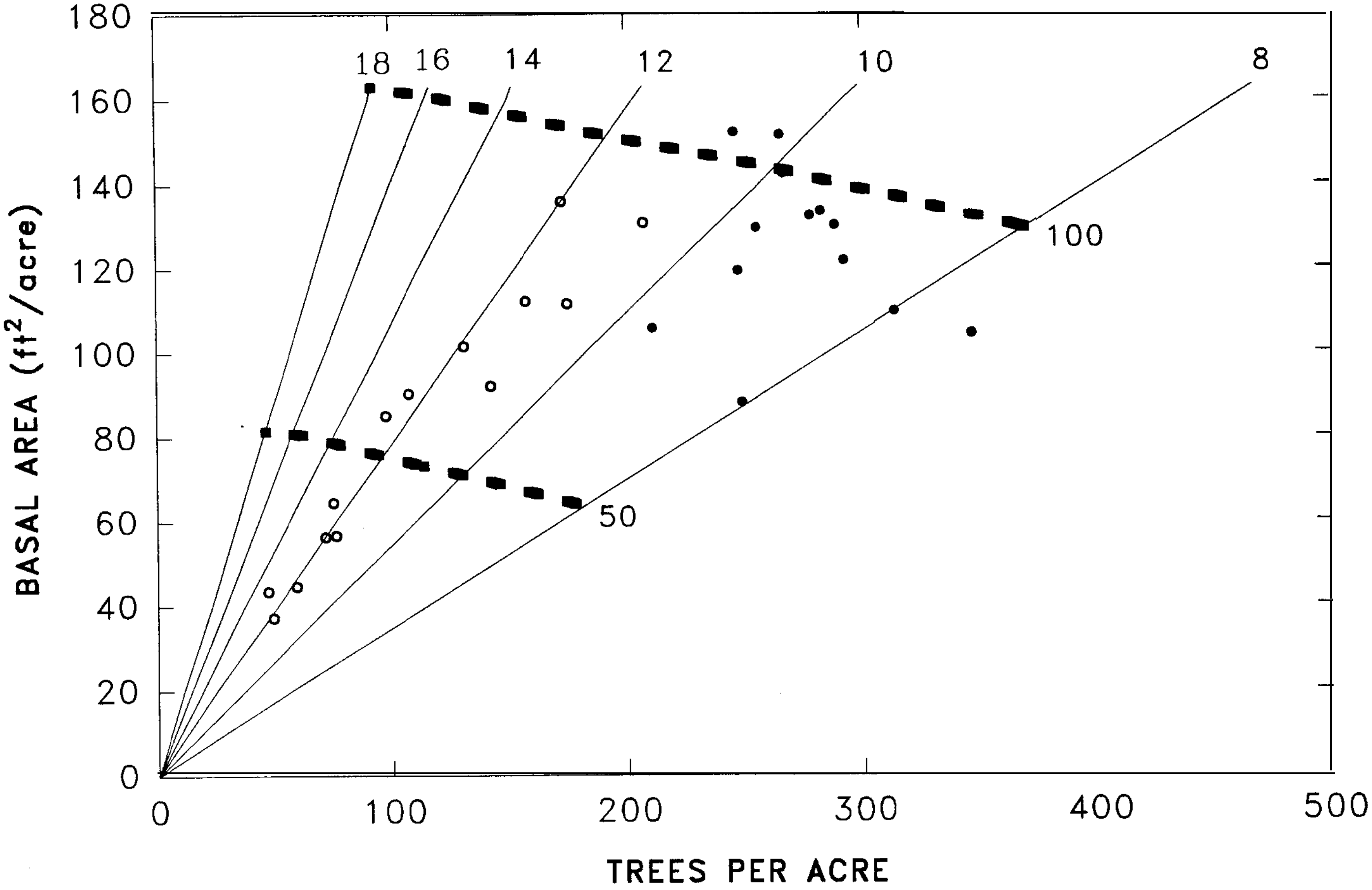

Figure 2.— Stand density and relative stocking of trees ≥3.6 inches in d.b.h. in 14 plots within stand 5, compartment 1658, on the Ouachita National Forest (pine, open circles; pine plus hardwood, filled circles).

tree diameters, both for pine only and for pine and hardwood combined, with stocking ranging from low to moderately high. As expected, when the midstory trees are added to the data, average diameters range widely, generally decreasing, and stocking levels are shifted upward.

Similar data are shown for stand 1, compartment 833, in figures 3 and 4. In the overstory (fig. 3), there is considerable variation in stocking and average diameter, but average diameter is considerably larger than that found in stand 5, compartment 1658 (fig. 1). Similar data available for one SPB infestation are also plotted (square symbols). Lightning was apparently associated with initiation of the infestation, but stocking was at the high end of the range for the sample plots. When data are plotted for all trees ≥ 3.6 inches in d.b.h., several plots exceed 100-percent stocking, and the range in d.b.h. is greatly increased.

The average stocking for the 52 stands included in the Phase II study is shown in figure 5, in which, if one considers only pines, stands do not appear to be excessively stocked. If the hardwood component is included, stocking level shifts toward and over 100 percent. If hardwoods are ignored, one may get a misleading indication of competition for water, nutrients, and space in stands typed as pure pine.

Figures 6 and 7 are provided to show the ranges of density and stocking found in 217 SPB-infested stands over a period of 2 years in the Kisatchie National Forest in Louisiana. In figure 6, considering pines only, most stands exceed the loo-percent stocking level, but there are many near SO-percent stocked, and more than a few less than 50-percent stocked. When the hardwood component is added (fig. 7), the great majority of stands fall in the 100-percent and over range, and the few below 50 percent are in the larger diameter classes.

it would be helpful to have a record of SPB infestations over time in the Guachita National Forest for which data could be plotted as shown in figures 6 and 7. However, the density and stocking of the 52 Phase II stands shown in figure 5, especially considering the pine-plus-hardwood data, does indicate a probability of high risk based on comparisons with data for SPB-infestations on the Kisatchie National Forest (fig. 6 and 7). There are aspects other than assessment of stocking that support the probability. For example, as stands mature, age and size of mature and overmature trees become increasingly important, and site quality less so. Stands composed of such trees, but apparently only modestly stocked, may still provide considerable food and habitat for the SPB. As trees age and their physiological state declines (e.g., root systems no longer meet the demands of crowns for water and nutrients, and crowns supply less than adequate food to maintain root systems), not only does growth decline, but secondary metabolism, which includes synthesis of oleoresin, also declines. Consequently, because oleoresin is a major factor in pine resistance to beetle attack, tree resistance to attack decreases.

The average age of the 52 stands in the Phase II study is 61.5' years, with a quite narrow distribution. Thirty-one stands range between ages 60 and 70, and 17 range between 50 and 60, with three stands over age 70 and only one stand under age 50. A similarly flat distribution exists for site index (height in feet at base age 50 years), which averages 62 and ranges from 50 to 71. The mature ages of these stands, in spite of low productivity indicated by the site indices, combined with the densities and stocking indicated in figure 5, suggest that in the absence of silvicultural treatment, SPB could become a serious problem over the next 5 to 10 years. This would be especially true if these stands are representative of a large proportion of the surrounding forest areas.

Considerable resource losses can accumulate from small infestations (less than 10 trees) in stands with characteristics representative of those in the Phase II study, in stands of large, mature trees (Lorio 1984). In addition, such trees are capable of producing large SPB populations and likely serve as refuges in which SPB reproduce during endemic periods (low populations).

Based on this preliminary assessment of risk rating for the SPB, it appears that the 52 Phase II research stands range from medium to high risk of losses and production of SPB populations. It is not possible to predict when and where infestations will occur, and many biological and abiotic factors not considered here may limit the potential for SPB activity in the Ouachita Mountains.

ACKNOWLEDGMENTS

Sincere appreciation is extended to Tim Mersmann, USDA Forest Service, Guachita National Forest, for guidance, assistance, and orientation concerning the Ecosystem Management Research Program. James M. Guldin, USDA Forest Service, Southern Forest Experiment Station, provided guidance and data in the form of computer files for the Phase II research stands without which even this very preliminary assessment would have been impossible.

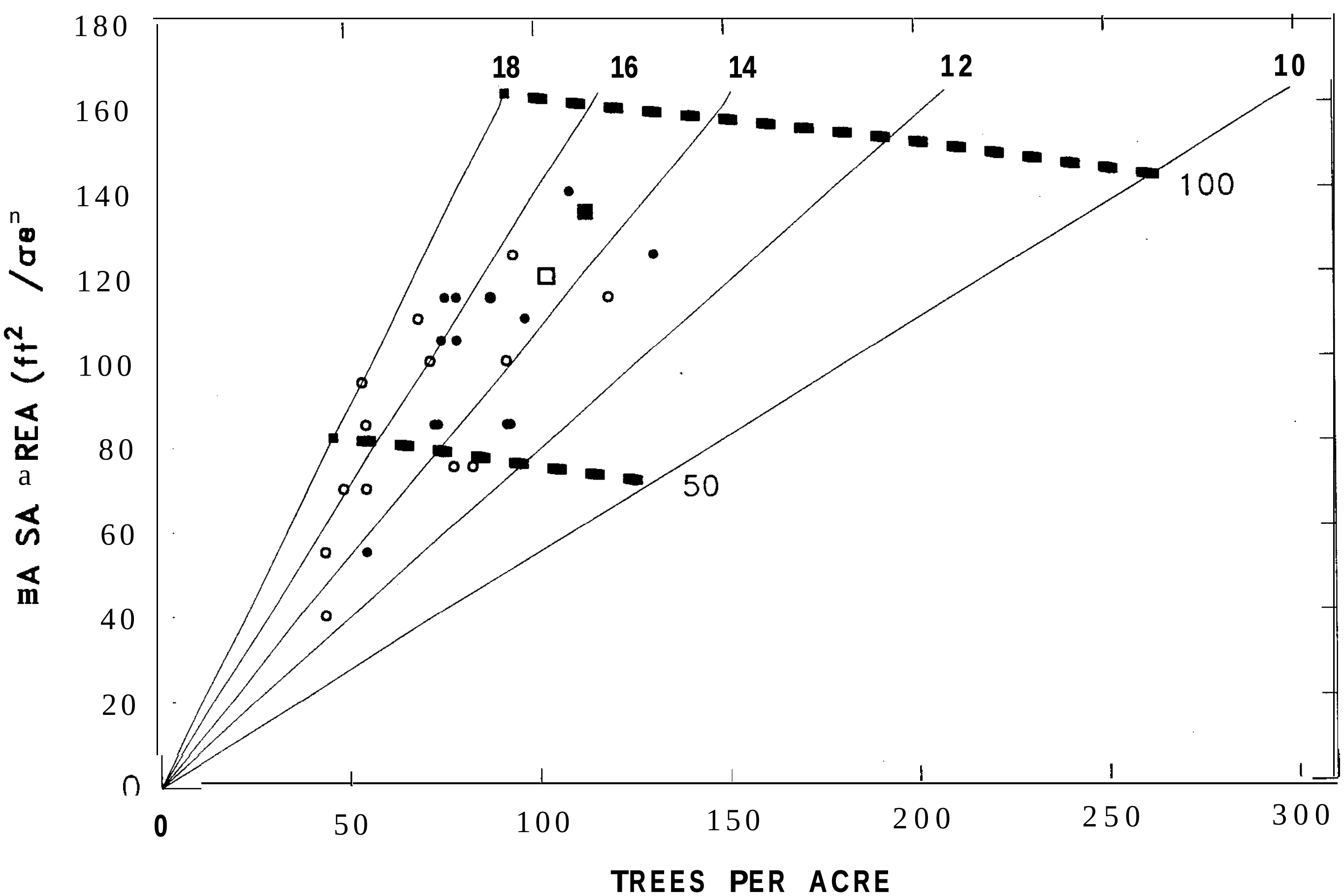

Figure 3.- Stand density and relative stocking of trees ≥ 9.6 inches in d. b. h. in 14 plots within stand 1, compartment 833, on the Ouachita National Forest (pine, open circles; pine plus hardwood, filled circles). Note the density and stocking (square symbols) at the origin of an SPB infestation.

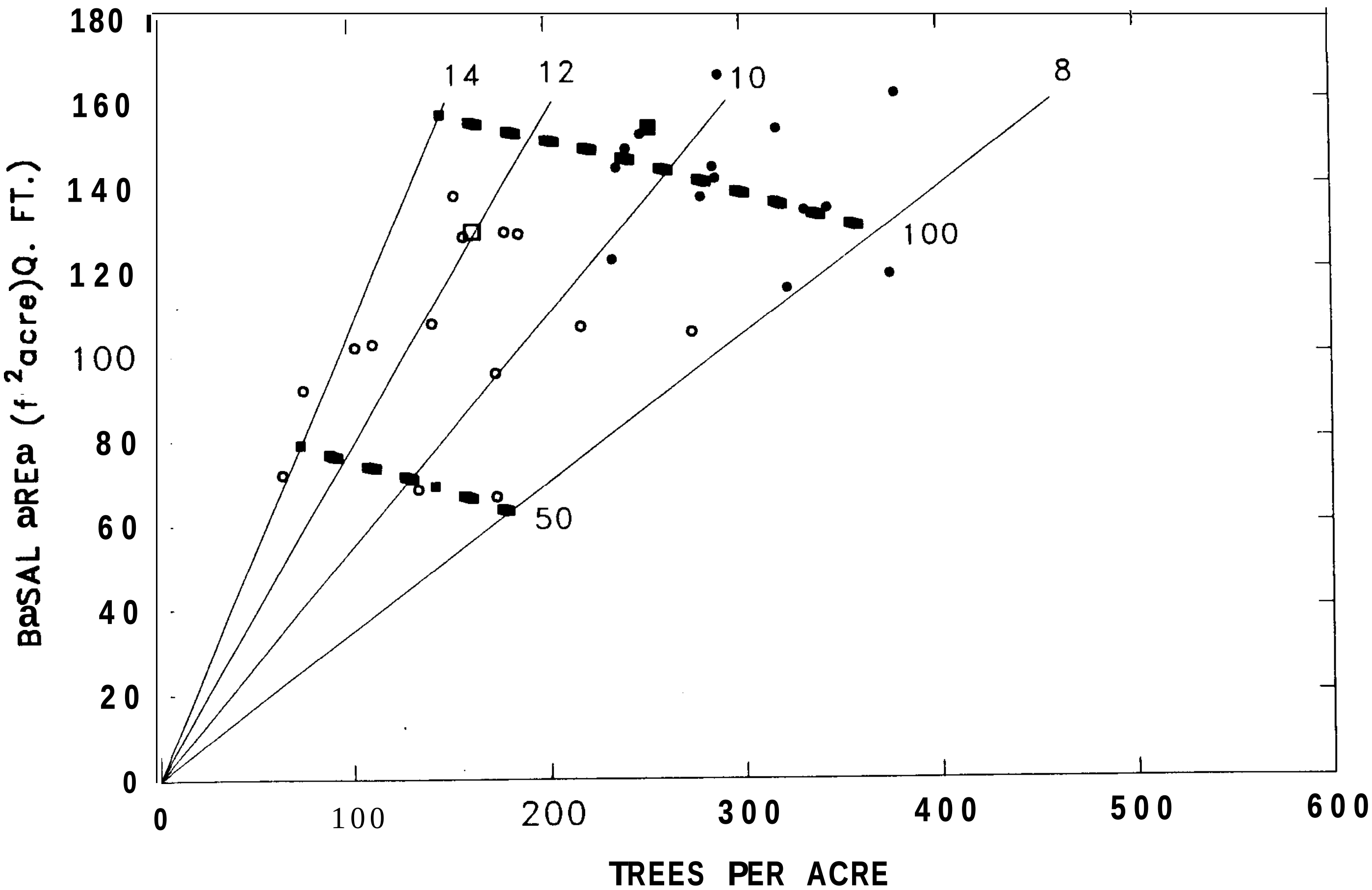

Figure 4.— Stand density and relative stocking of trees ≥3.6 inches in d. b. h. in 14 plots within stand 1, compartment 833, on the Ouachita National Forest (pine, open circles; pine plus hardwood, filled circles). Note the density and stocking (square symbols) at the origin of an SPB infestation.

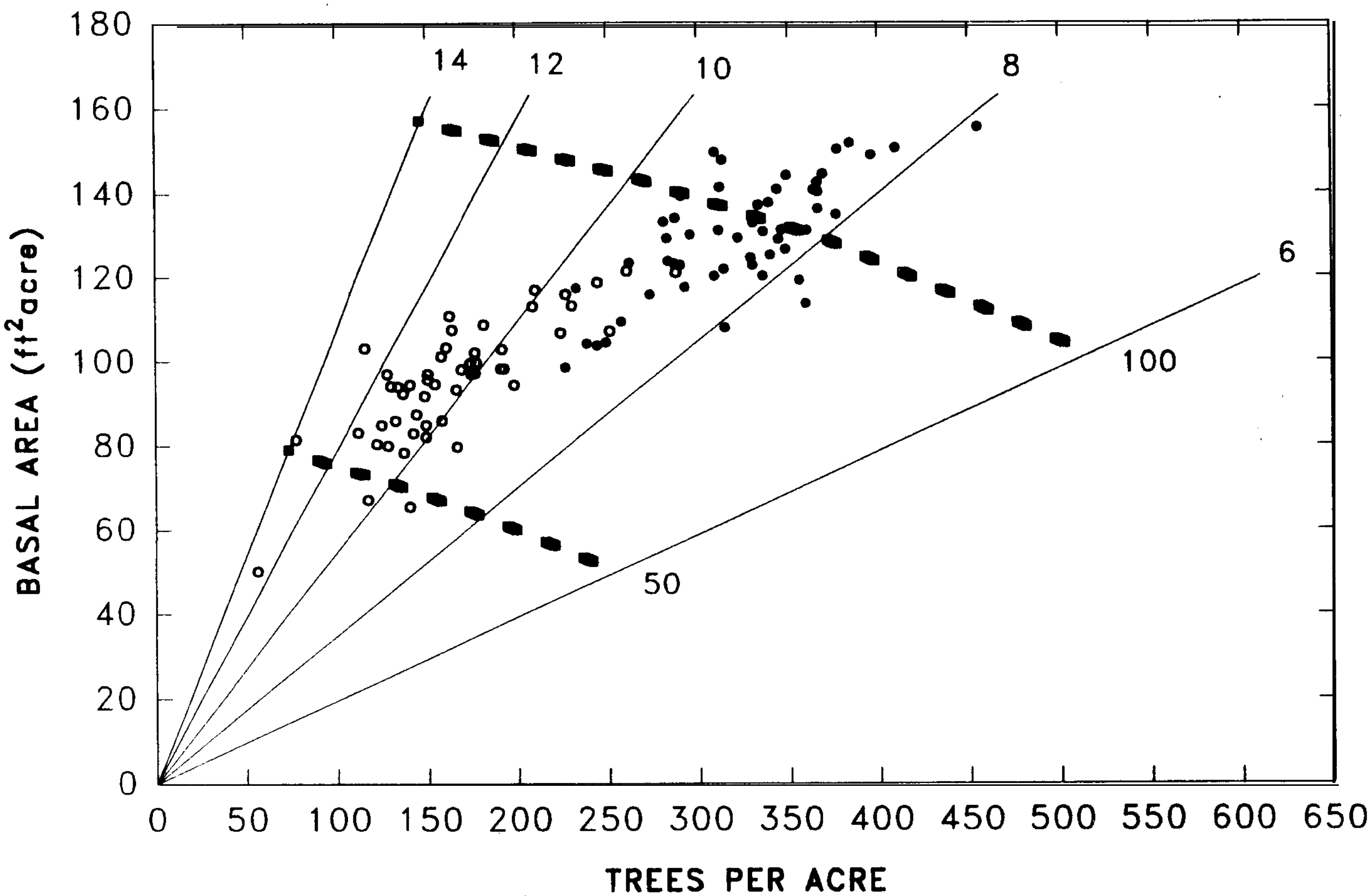

Figure 5.— Stand density and relative stocking of trees ≥ 3.6 inches in d.b.h. in 52 Phase II stands on the Ouachita National Forest (pine, open circles; pine plus hardwood, filled circles).

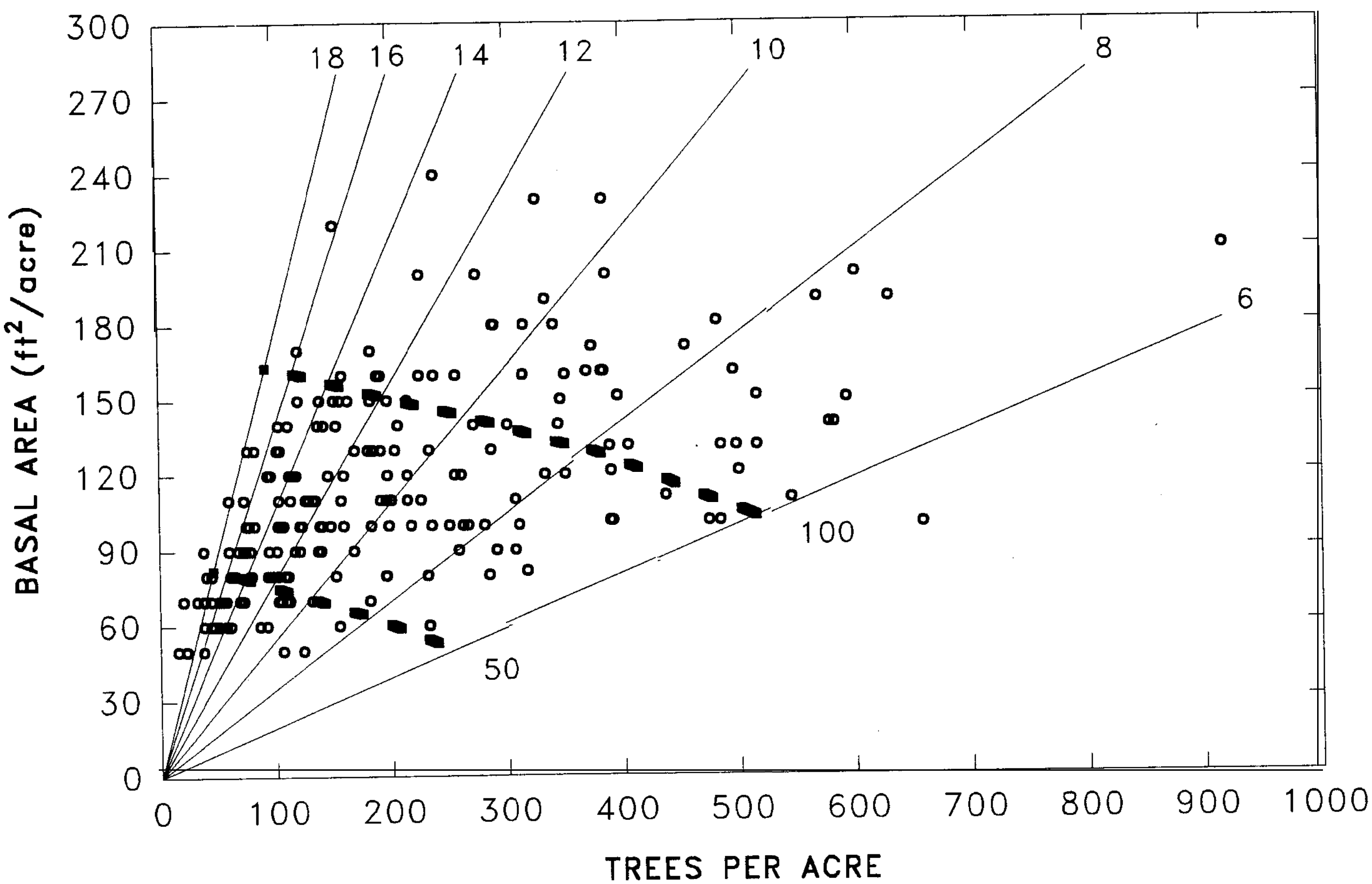

Figure 6.— Stand density and relative stocking of pines ≥3.6 inches in d.b.h. at the origin of 217 SPB infestations on the Kisatchie National Forest in Louisiana (June 1975 through June 1977).

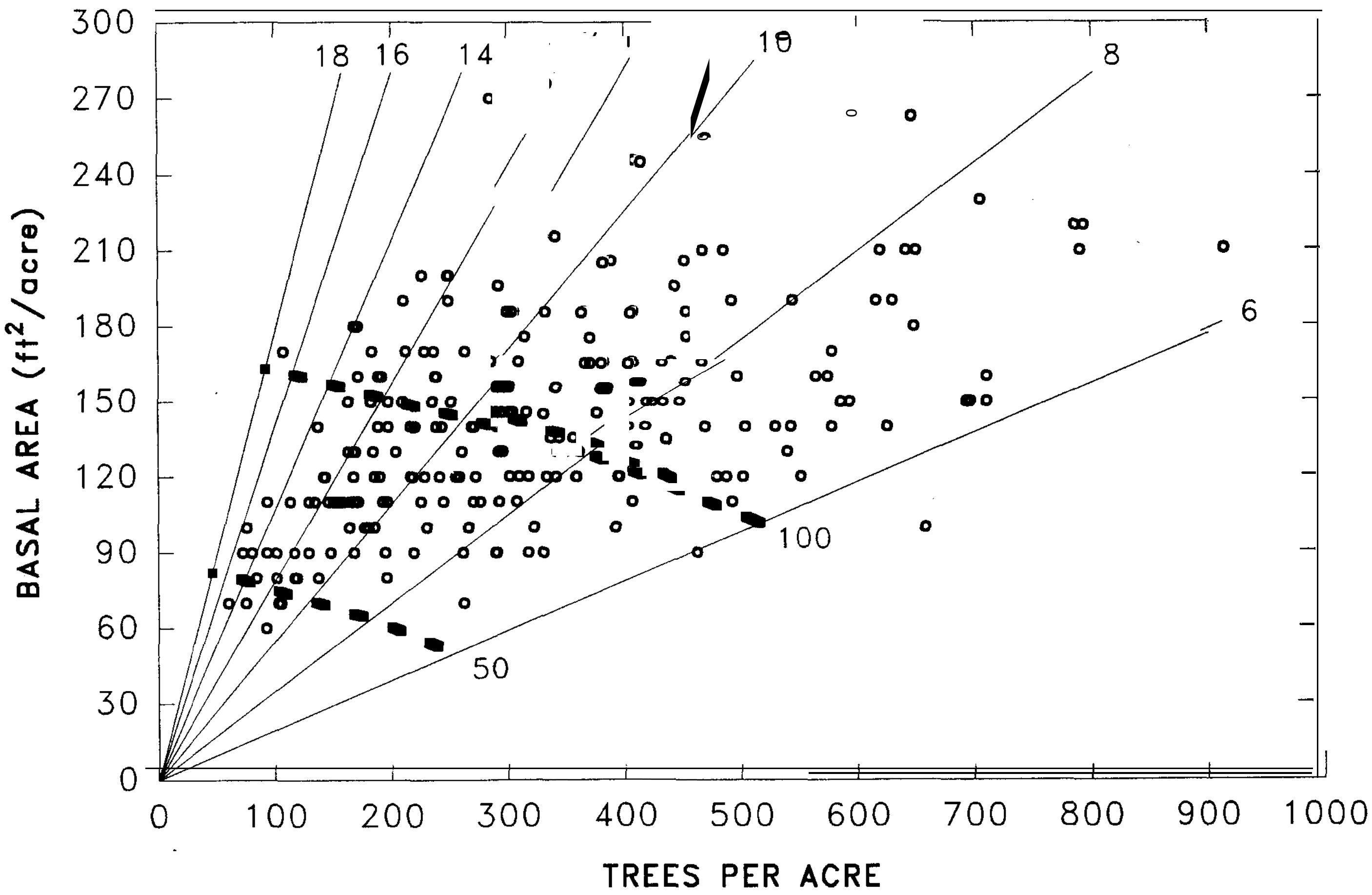

Figure 7.— Stand density and relative stocking of pines plus hardwoods ≥3.6 inches in d.b.h. at the origin of 217 SPB infestations on the Kisatchie National Forest in Louisiana (June 1975 through June 1977).

LITERATURE CITATIONS

Gingrich, S.F. 1967. Measuring and evaluating stocking and stand density in upland hardwood forests in the central states. Forest Science. 13: 38-53.

Lorio, P.L., Jr. 1978. Developing stand risk classes for the southern pine beetle. Res. Pap. SO-144. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 9 p.

Lorio, P.L., Jr. 1980. Loblolly pine stocking levels affect potential for southern pine beetle infestation. Southern Journal of Applied Forestry. 4: 162-165.

Lorio, P.L., Jr. 1984. Should small infestations of southern pine beetle receive control priority? Southern Journal of Applied Forestry. 8: 201-204.

Lorio, P.L., Jr.; Mason, G.N.; Autry, G.L. 1982. Stand risk rating for the southern pine beetle: integrating pest management with forest management. Journal of Forestry. 80: 212-214.

Lorio, P.L., Jr.; Sommers, R.A. 1981. Use of available resource data to rate stands for southern pine beetle risk. In: Hedden, Roy L.; Barras, Stanley J.; Coster, Jack E., tech. coords. Hazard-rating systems in forest pest management: Proceedings symposium. Gen. Tech. Rep. WO-27. Washington, DC: U.S. Department of Agriculture: 75-78.

Meyer, W.H. 1942. Yield of even-aged stands of loblolly pine in northern Louisiana. Yale University School of Forestry Bull. 51. New Haven, CT: Yale University School of Forestry. 39 p.

Paine, T.D.; Stephen, F.M.; Taha, H.A. 1984. Conceptual model of infestation probability based on bark beetle abundance and host tree susceptibility. Environmental Entomology. 13: 6 19-624.

Schumacher, F.X.; Coile, T.S. 1960. Growth and yields of natural stands of the southern pines. Durham, NC: T. S. Coile, Inc. 115 p.

U.S. Department of Agriculture. 1976. Volume, yield, and stand tables for second-growth southern pines. Misc. Publ. WO-50. Washington, DC: U.S. Department of Agriculture. 202 p.

Crow n Health of Overstory Hardwoods [1]

Dale A. Starkey [2]

ABSTRACT

Monitoring the health of reserve hardwood trees is being performed as part of the Ecosystem Management Research Project for shortleaf pine-oak forest types on the Ouachita and Ozark National Forests in Arkansas. Results will provide information about the success of retaining such trees and to provide guidelines for selecting reserve trees in future operational harvests. Reserve trees are mostly 10 to 12 inch d.b.h. codominant and intermediate oaks. A suite of crown measurements (diameter, live crown ratio, density, dieback, and foliage transparency) is being used to detect significant changes in reserve tree health over time. Average ratings for these indicators before harvest appear to be within normal ranges for each species. Immediately after harvest, 16 to 62 percent of reserve trees had logging injury to the base, crown, or both. Injury frequency generally increased with the intensity of harvest cutting. Most injury was judged slight or moderate in severity.

INTRODUCTION

The Ecosystem Management Research Project in the Ouachita Mountains is being conducted to investigate the utility of a wide range of silvicultural practices in meeting a variety of ecosystem management goals for the Ouachita and Ozark-St. Francis National Forests. A complete description of the project can be found in Guldin and others (1994) and Baker and others (1991). In about half of the harvest treatments, overstory and midstory hardwoods are being retained in order to meet ecosystem management objectives such as improved wildlife habitat, greater biodiversity, reduced visual impact of harvesting, and perpetuation of the pine-hardwood forest type. These treatments are (and hereafter referred to as): low impact single-tree selection (LISTS), pine-hardwood single-tree selection (PHSTS), pine-hardwood group selection (PHGS), pine-hardwood shelterwood (PHSW), pine-hardwood seed-tree (PHST), clearcut (CC), control, i.e. uncut (CONT).

Retained trees generally meet the recently proposed definition of "reserve trees" (Society of American Foresters 1993) for the clearcutting, seed-tree, shelterwood, or coppice regeneration methods. Reserve trees are defined as pole-sized or larger and are retained after the regeneration period. Retained trees within groups in the group selection treatments of this study may also fit the definition of reserve trees because they will be retained after the regeneration period. However, in the single-tree selection treatments, trees retained in this study cannot truly be considered reserve trees; they are more appropriately considered as a normal component of the pine-hardwood forest types being studied in this project. Nonetheless, it seems expedient when describing this study to use the term "reserve trees" throughout.

The health and longevity of reserve trees are important if ecosystem management objectives are to be realized. In addition, information about the health and fate of these trees can be used to develop guidelines for the selection of reserve trees in future operational harvests under an ecosystem management regime. This portion of the ecosystem management research project was implemented to monitor changes in crown condition and health of hardwood reserve trees.

The major concern for the health and fate of reserve hardwoods is due to oak (*Quercus* spp.) or hardwood decline (Starkey and others 1989, Wargo and others 1983). Decline can generally be described as a complex disease syndrome resulting from the interaction of a variety of host, site, and stand factors with biotic and ahiotic agents and stress factors. It is expressed by a progressive dieback of the crown from the upper and outer portions downward, usually resulting in mortality. Manion (1991) describes decline as "an interaction of interchangeable, specifically ordered abiotic and biotic

[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

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factors to produce a gradual general deterioration, often ending in death of trees"; decline is depicted as a spiral of one or more predisposing factors, followed by one or more inciting factors, which are then followed by one or more contributing factors. Figure 1 displays some of the factors that can be responsible for decline according to their type, i.e. abiotic, biotic, site/stand, or anthropogenic. Figure 2 shows these same factors in categories reflecting the sequence and function in the decline syndrome of host trees. Most reports of decline occurrences in the Eastern United States (Millers and others 1989, Starkey and others 1989) attribute decline to climatic events and stand/site factors (predisposing), defoliation, drought, or frost (inciting); and root rots and borers (contributing). In the ecosystem management study stands, the factors most likely to he operative are stand/site factors (predisposing), stand disturbance from harvesting (inciting), and root rot/borers (contributing).

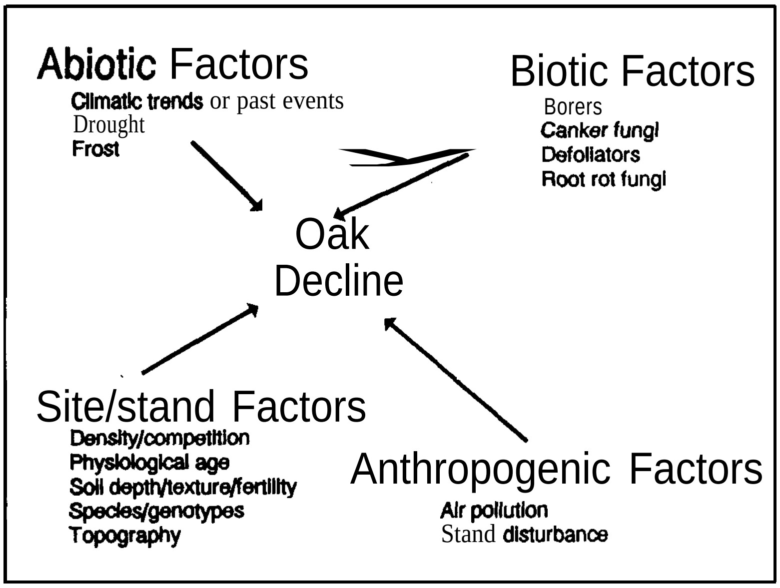


Figure l.--*Causal factors of oak decline organized by type.*

METHODS

The silviculture research plots were used as the basic sampling units for this part of the study (Guldin and others 1994). At each of the 14 plots installed in each study stand, 3 to 5 of the largest and nearest hardwoods were identified for monitoring. These constituted the trees most likely to be designated as reserves during marking and harvesting operations. Preference was given to trees already marked as reserves, to oaks of any species, hickories (*Carya* spp.), and finally, other hardwoods.

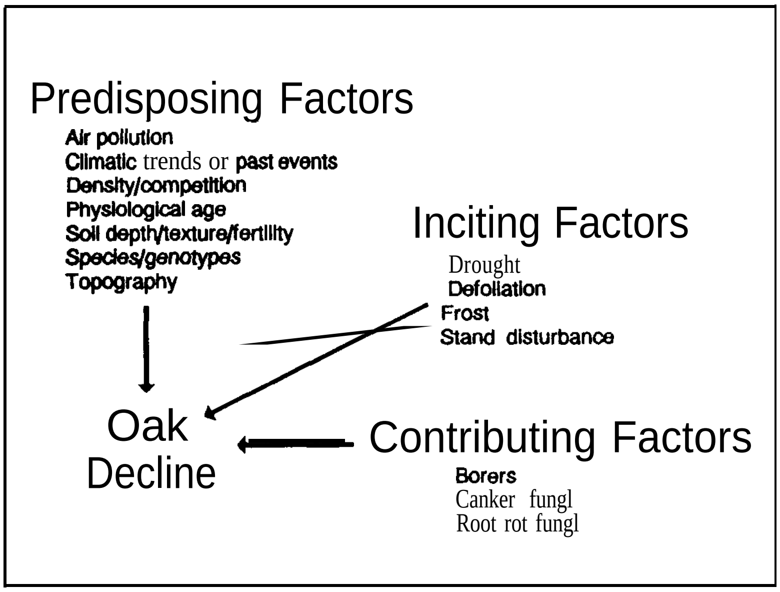


Figure 2.--*Causal factors of oak decline organized by their function in the decline syndrome.*

Azimuth and distance from plot center were recorded for each tree as well as species and d.b.h. (diameter at breast height). A suite of crown measurements was utilized to describe the current condition (i.e. health) of tree crowns--a procedure currently being used in the National Forest Health Monitoring Program (USDA Forest Service 1992). The suite consists of six measurements (tahle I), each requiring two crew members to acquire. Crown diameter was measured on two axes at 90" to one another by projecting the crown perimeter onto the ground. The other five indicators were each visually estimated by two observers standing on opposite sides of the tree about one-half to one tree length away. Estimates are made by each crew member, and a concensus or average of both is used as the final estimate.

In addition, a damage coding system (table 2) was used for describing obvious damages due to physical injury, insect or disease problems; particularly those that may not influence the crown indicators described above. Up to three damages par tree could he recorded along with the location and probable cause of the damage.

Table l.--Crown *health indicators for monitoring reserve hardwood trees*

Indicator	Definition and units
Crown diameter	Measured on ground in 2 directions at 90°; in feet to the nearest foot; average of measurements.
Crown position	Standard forestry definitions; dominant, codominant, intermediate, or suppressed.
Live crown ratio	Ratio (in percent) of live crown length to total tree height; visually estimated in S-percent increments.
Crown density	Estimated percentage of foliage, twigs, branches, and reproductive structures blocking light through the *crown;* visually estimated in 5-percent increments.
Crown dicback	Estimated percentage of recent dieback (tine twigs remaining) in upper and outer portions of the crown compared to entire crown; visually estimated in S-percent increments.
Foliage transparency	Estimated percentage of light being transmitted through the foliated portions of the crown; visually estimated in S-percent increments.

Table ***2--Obvious damages recorded for reserve trees selected for monitoring***

Code	Definition
Conditions that can occur in multiple locations:	
00	None
01	Dead (describes part of a living tree)
02	Open wound; (>4.0 square inches, inner wood exposed)
03	Closed wound; healed, cankers; lesions (inner wood not exposed)
04	Small holes or pinholes (>0.5 inch diameter; e.g., bark beetle attack/emergence holes)
05	Broken
06	Removed; missing (other than defoliation by insects; branches of foliage (i.e. pruning)
07	Rotten branch stubs; excessive swelling at base of dead branches
0X	Resinosis; bleeding
09	Deformed, twisted, curled (woody stems only)
10	Galls (abnormal swellings on main stem or branches)
II	Imbedded foreign objects (nail, fence, etc.)
12	Other than described above (needs explanation in notes)
Conditions that occur on trunk only:	
20	Crook or sweep (severe enough to impede growth or affect survival)
21	Crack of seam
22	Swelling (greater than one-half diameter of tree above the swelling)
23	Leaning (from partial windthrow or root spring)
24	Ahundancr of epicormic branches or water sprouts on trunk or base

Table *2--Obvious damages recorded for reserve trees selected for monitoring (continued)*

Code	Definition
Conditions that occur on branches only:	
40	Excessive branching (indicator of past injury such as top kill)
41	Abundance of seeds or cones (may cause dieback)
42,	Stunted, dwarfed (woody stems only, short internodes, chlorotic dwarfs)
Conditions that occur on foliage only:	
60	Defoliation (from insect feeding)
61	General discoloration (mixed colors; >30 percent of the crown with leaves having >50 percent of foliage affected; includes necrotic foliage)
62	Pale-green foliage (> 30 percent of the crown with leaves having > 50 percent of foliage affected)
63	Yellow-green foliage (> 30 percent of the crown with leaves having > 50 percent of foliage affected)
64	Leaves spotted (> 30 percent of the crown with leaves having >50 percent of foliage affected)
65	Damaged leaves (> 30 percent of the crown with foliage shredded, with holes, or otherwise mechanically damaged)
66	Distorted foliage (>30 percent of the crown with wrinkled, shrivelled, galled, or otherwise distorted leaves)
67	Stunted foliage (>30 percent of the crown with stunted or dwarfed foliage, less than one-half normal size)
Location codes:	
	Crown stem (main trunk or bole within the crown)
2	Upper bole (upper half of the trunk between roots and crown)
3	Lower bole (lower half of the trunk between roots and crown)
4	Roots (exposed) and stump (12 inches in height)
5	Whole trunk (includes codes 1 to 4)
6	Branches (woody stems other then the main stem)
7	Buds and shoots (the most recent year's growth)
8	Foliage
9	Whole crown (includes codes 6 to 8)
Probable cause:	
100	Insect
200	Disease
300	Fire
400	Animal
500	Weather
600	Plant competition/suppression
700	Logging and related; human damage
800	Unknown
900	True mistletoe
999	Other than described above; needs explanation in notes
Up to 3 damages **can be coded** per tree	

Crown health and damage data were collected in conjunction with all other silvicultal data collection. Silviculture field crews were trained to collect crown health and damage data during a l-day session. Classroom training and field practice were followed by field testing and evaluation in order to meet quality assurance goals (USDA Forest Service 1992). For all visual crown indicators, a goal of ± 10 percent (i.e. two 5 percent classes, see table 1), 90 percent of the time, (when compared to estimates of the trainers) was used. For crown diameter, average diameter was required to be ±10 percent of the trainers result, 90 percent of the time. For the damage indicator, obvious damage was required to be correctly recorded 90 percent of the time.

Because logging injury was likely to occur on some reserve trees, a survey of a portion of harvest& stands was conducted soon after logging was completed. Two stands of each treatment were visited, and ***reserve*** trees on five to six plots in the treated area (plots 1 to 12) examined. Logging injury was recorded as either crown or basal, and rated slight, moderate, or severe (table 3).

Table **3.**--***Logging damage* severity *rating used in postharvest tree evaluation***

Intensity	Basal Injury	Crown Injury
Slight	Open wound <20 percent of circumference	One broken limb, not the top
Moderate	Open wound 20 to 40 percent of circumference	Two broken limbs, not the the top
Severe	Open wound >40 percent of circumference	Three broken limbs, or top broken out
Dead	N/A	Tree broken off mid-bole or knocked over. Severe enough to preclude any recovery

Future evaluations of reserve trees are planned 2 and 4 years after harvesting (1995 and 1997) in conjunction with silviculture plot remeasurements (Guldin and others 1994). Significant changes in tree health should be reflected in large changes in one or more crown indicators.

RESULTS AND DISCUSSION

The sample population consisted mostly of oaks (about 84 percent, fig. 3). Hickories and all other species comprised 8 percent each. The proportion of oaks, hickories, and other species varied somewhat among treatments, but the oak component was always above 75 percent and populations were quite similar (fig.4). White (Q. *alba* L.) and post oak (Q. ***stellata*** Wangenh.) were the most prevalent among oaks in all treatments (fig. 5), ranging from 62 to 93 percent. Black oak (Q. *velutina* Lam.), southern red oak (Q. ***falcata*** Michx.), northern red oak (Q. ***rubra*** L.), and blackjack oak (Q. ***marilandica*** Muenchh.) comprised 11, 6, 5, and 2 percent, respectively, overall; in only one treatment was any of these over 20 percent (group selection, 23 percent for black oak).

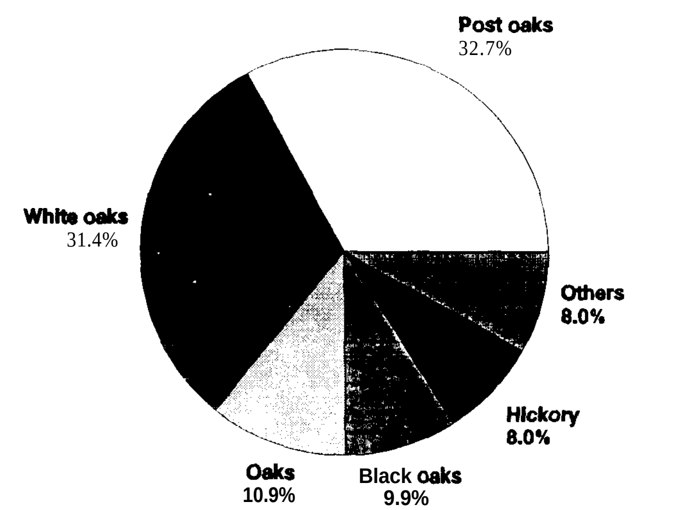


Figure **3.**--***Sample population of reserve hardwoods monitored for tree health changes.***

Most trees were in either codominant or intermediate crown positions (fig. 6; 40 and 54 percent, respectively, overall). Northern red oak had the highest proportion of dominant trees (9 percent) and, along with southern red oak, the highest proportion of codominant trees (58 and 64 percent, respectively). Blackjack oak and hickory had the highest proportions of intermediate and suppressed crown classes. Average d.b.h. varied only slightly among species and ranged from 10 to 12 inches (fig. 7).

Crown health indicators varied somewhat by species but were similar to those collected in other areas of the South (Bechtold and others 1992; fig. 8). Crown diameters averaged 22 to 29 feet, live crown ratios, 47 to 60 percent, crown density, 48 to 61 percent, dieback, 2 to 6 percent, and foliage transparency, 12 to 16 percent. Differences between species are probably not significant in terms of tree health. They just reflect species differences.

'Obvious damage was coded on 80 percent or more of trees of each species (fig. 9). Trees with two or more damages comprised less than 10 percent of trees of each species except in one case (post oak). In most cases, damage was not significantly impacting tree health at the time of evaluation, but the damage 'may contribute to decline in tree health in the future.

Logging in-jury after harvesting was common (fig. 10). Overall, 38 percent of trees had basal damage, crown damage, or both. Crown damage was the most prevalent overall, but basal injury was most prevalent in the shelterwood and single-tree selection treatments where the number of reserve hardwoods was highest. Crown injury was usually judged slight (62 percent; fig. 11) while basal injuries were more evenly divided among slight (42 percent) and moderate (53 percent). Four percent of crown injuries were so severe that form was totally destroy& or mortality was the likely result. Logging injury generally increased in frequency as the intensity of tree harvest increased (fig. 10).

These preharvest crown health measurements and post-harvest logging injury assessments provide baseline data to which future crown and tree damage measurements can be compared. After all harvest and site-preparation work is completed, reserve tree conditions will probably change and then stabilize with time. Future evaluations of these trees will provide valuable information about the contributions of reserve trees to ecosystem management objectives and provide data for the development of guidelines for selecting *reserve* trees in future harvests.

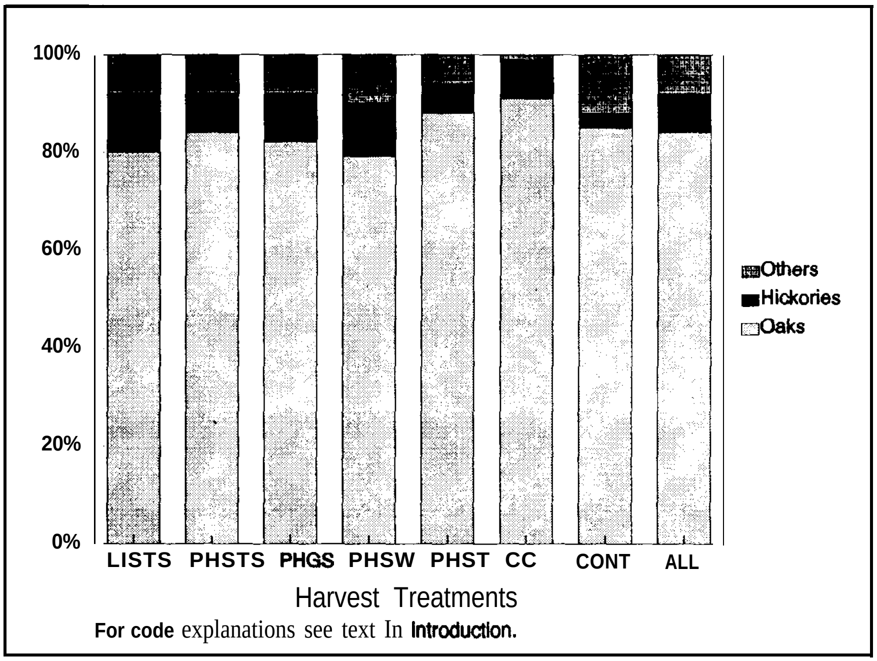


Figure 4.--*Sample population of reserve hardwood trees by species and treatment.*

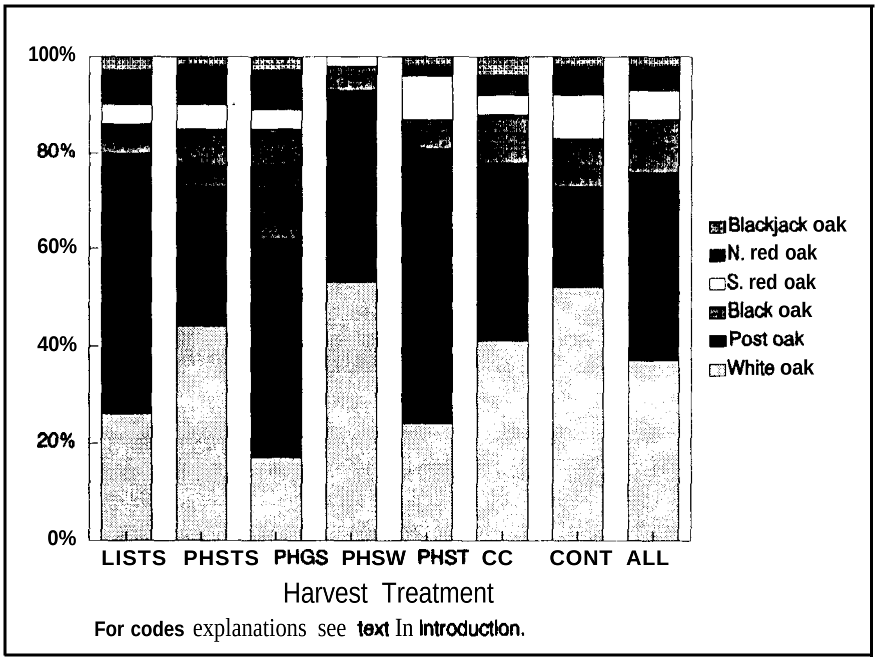
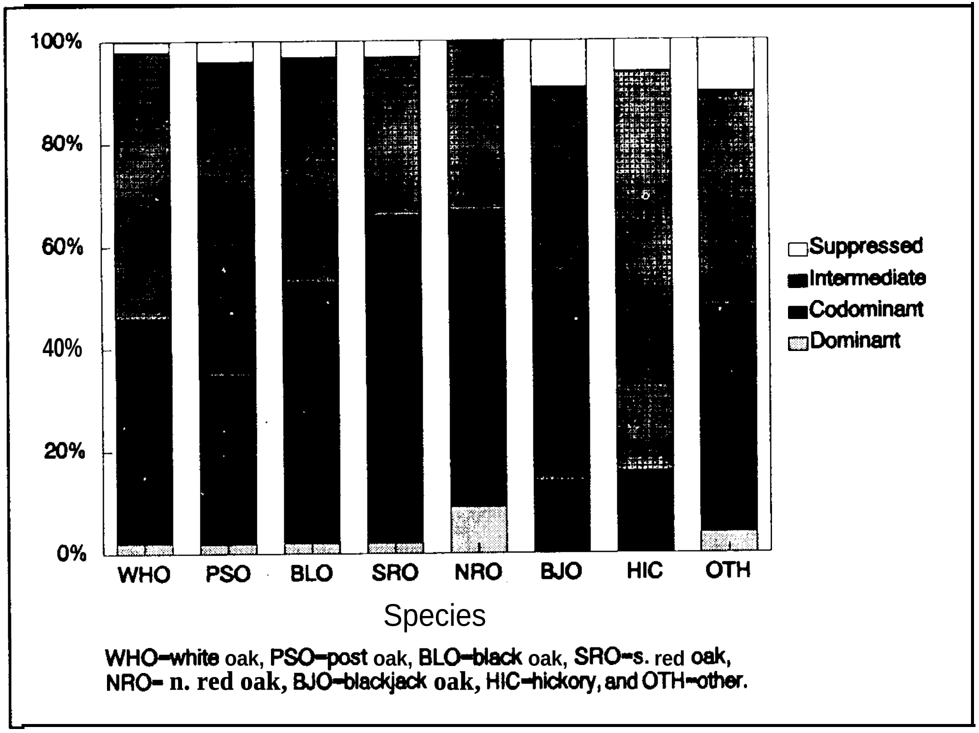


Figure *S.--Sample population of reserve oaks by species and treatment.*



igure 6.--*Percentage of reserve hardwoods by crown position and species.*

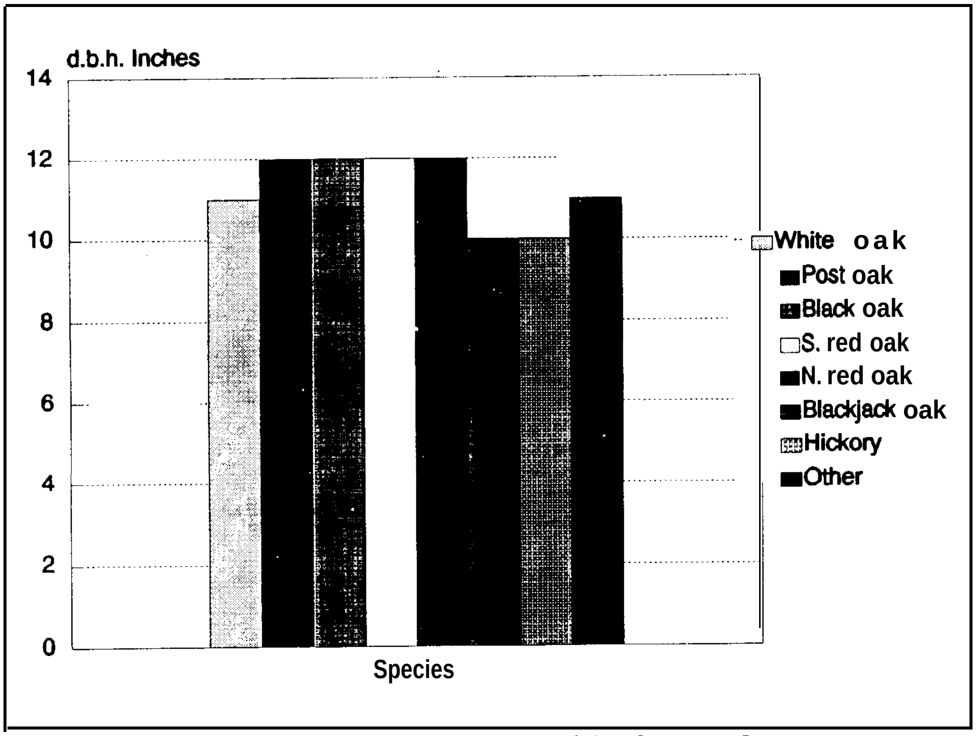


Figure 7.--*Average diameter at breast height (d.b.h.) of reserve trees by species.*

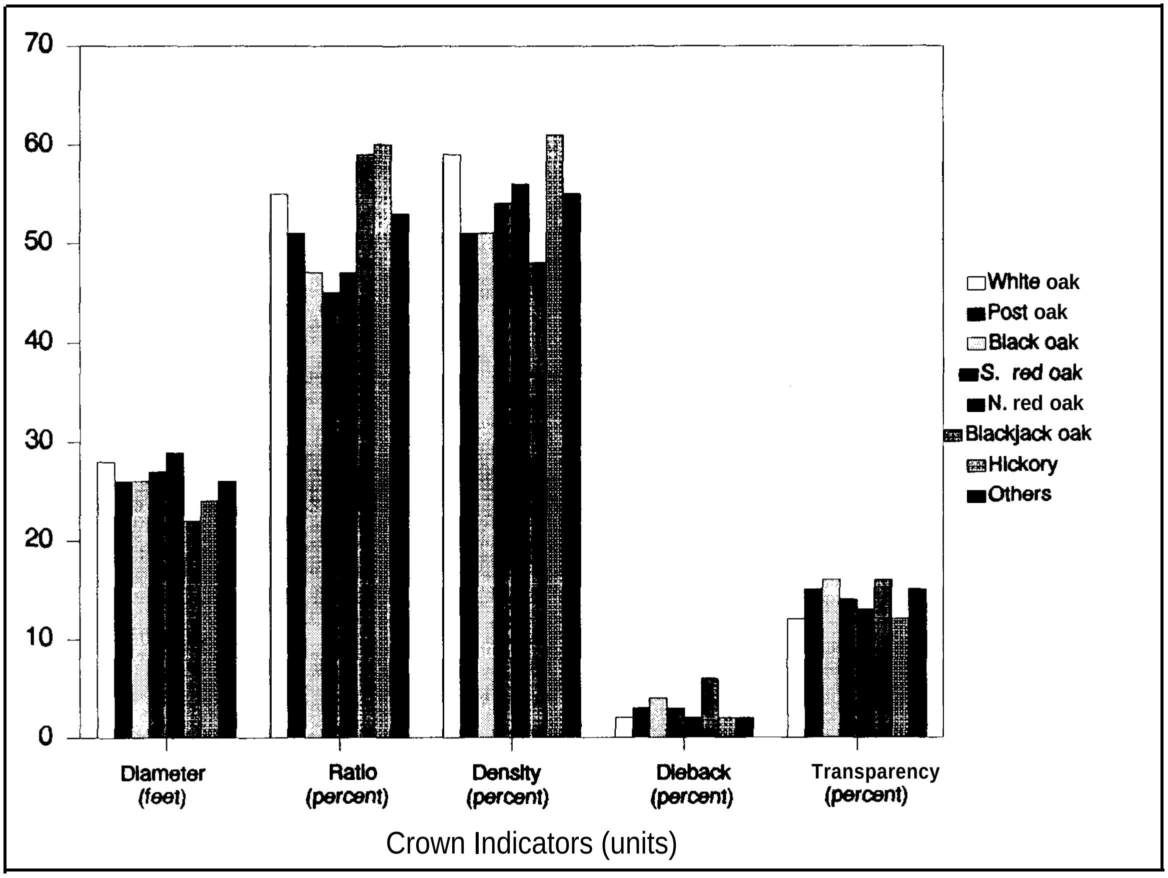


Figure 8.--*Average crown-indicator ratings for reserve hardwoods by species.*

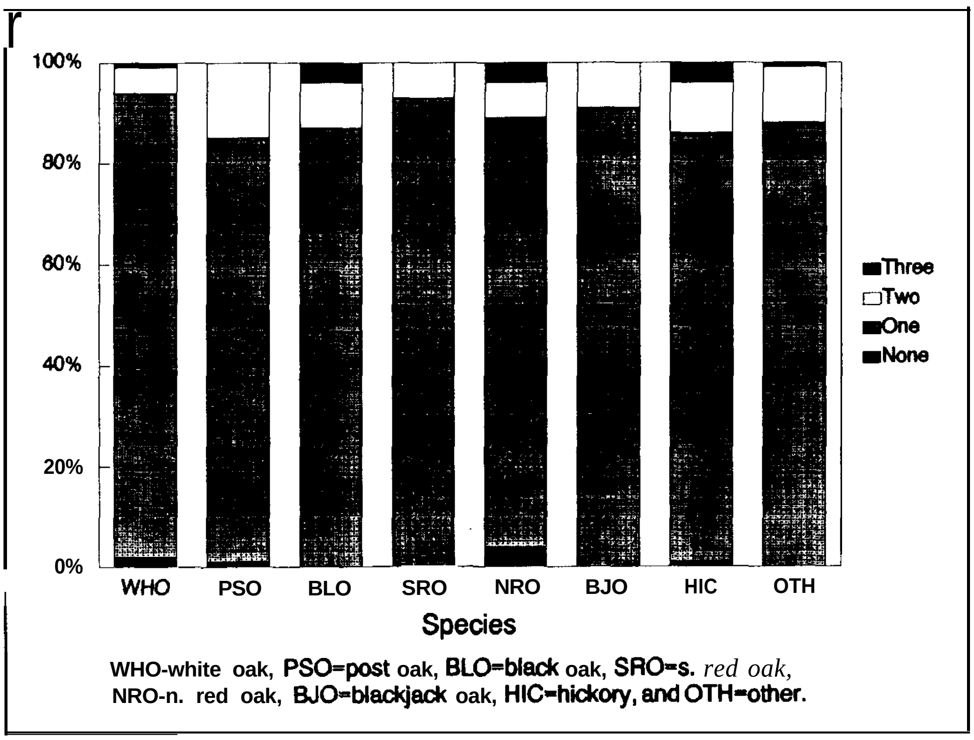


Figure 9.--*Percentage of reserve trees with one, two, or three damages by species.*

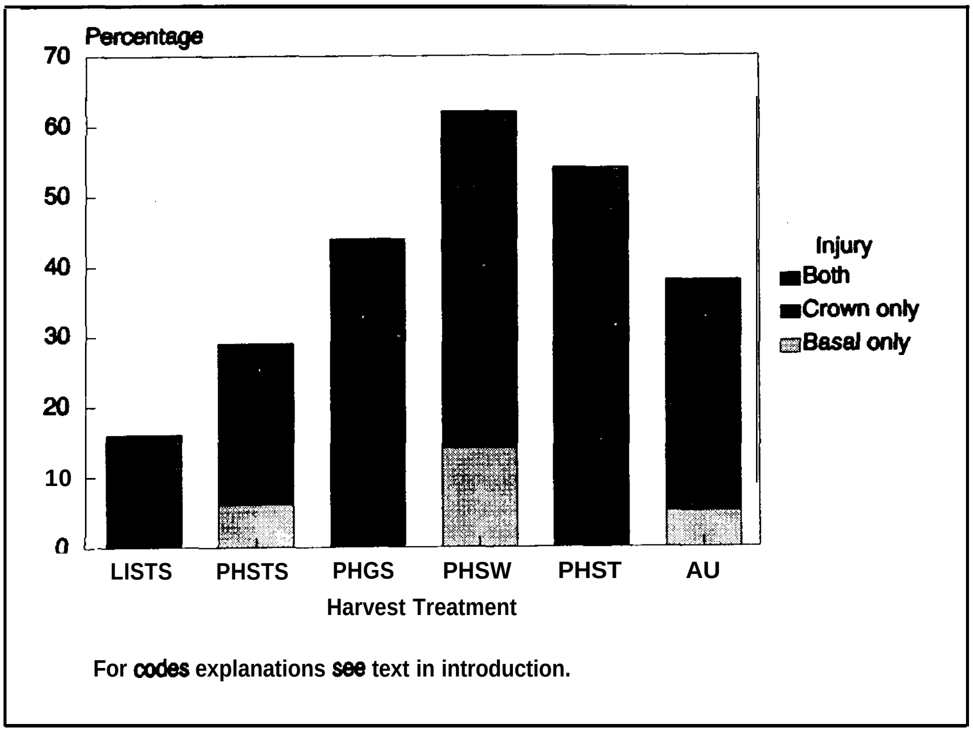


Figure 10.--Proportion of reserve trees with logging injury by location and treatment.

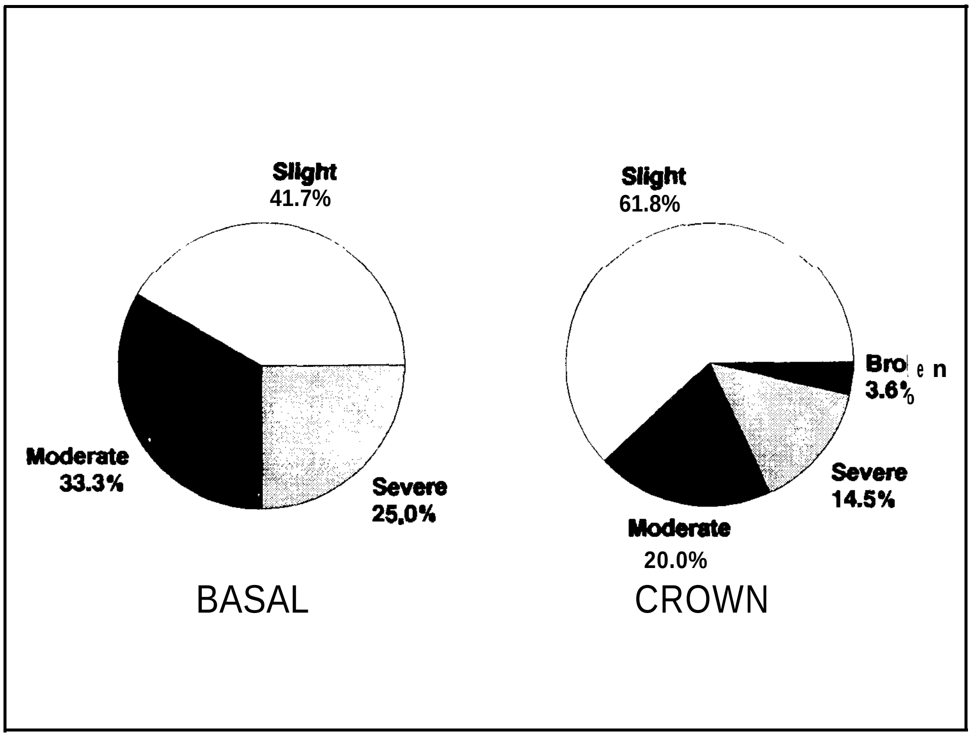


Figure *Il.--Proportion of reserve trees with logging injury by location and severity.*

LITERATURE CITED

Baker, J.E. 1991. Study plan: New perspectives research and forest management on the Ouachita/Ozark National Forests. FS-SO-4106-81. Monticello, AR: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 31 p.

Bechtold, William A.; Hoffard, William H.; Anderson, Robert L. 1992. Summary report: Forest health monitoring in the South, 1991. Gen. Tech. Rep. SE-81. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station. 40 p.

Guldin, James, M.; Baker, James B.; Shelton, Michael G. 1994. Pretreatment conditions in mature pine/hardwood stands on south-facing slopes of the Ouachita/Ozark National Forests: midstory and overstory plants. In: Proceedings of the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings. 1993 October 26-27; Hot Springs, AR. New Orleans, LA: U.S. Department of Agriculture, Forest Service, ‘Southern Forest Experiment Station.

Manion, P.D. 1991. Tree disease concepts. Prentice-Hall, Inc. Englewood Cliffs, NJ. 399 p.

Millers, I; Shriner, D.S.; Rizzo, D. 1989. History of hardwood decline in the eastern United States. Gen. Tech. Rep. NE-126. Broomall, PA: U.S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station; 75 p.

Society of American Foresters. 1993. Silviculture Terminology - September 1993. Silviculture Working Group Newsletter (D-2). October 1993. Bethesda, MD: Society of American Foresters. 4 p.

Starkey, Dale A.; Oak, Steven W.; Ryan, George W.; and others. 1989. Evaluation of oak decline areas in the South. Protection Rep. R8-PR17. Atlanta, GA: U.S. Department of Agriculture, Forest Service, Southern Region. 36 p.

USDA Forest Service. 1992. Forest health monitoring field methods guide (eastern guide). Research Triangle Park, NC: U.S. Department of Agriculture, Forest Service, Forest Health Monitoring Program.

Wargo, P.M.; Houston, D.R.; LeMadeleine, L.A. 1983, Oak decline. Forest Insect and Disease Leaflet 165. Washington, DC: U.S. Department of Agriculture, Forest Service. 8 p.

Woody Debris Dynamics in Zero Order Streams of the Ouachita National Forest: Preliminary Findings[1]

Wm. Patrick Fowler[2]

ABSTRACT

The importance of woody debris within zero order stream channels of the Ouachita National Forest is unclear. Basic processes of recruitment, occurrence and movement of woody debris are largely unexplored. The occurrence and abundance of woody debris dams may prove to be a useful indicator for aquatic macroinvertebrate habitat. If so, woody debris may be used as an indirect biological indicator for the ephemeral portions of aquatic ecosystems. This study was conducted to map the location and estimate the biomass of woody debris in forested ephemeral channels. The effects of reproductive timber harvest methods on these debris dams are estimated by remeasurement of the location and biomass of the debris. Ratios of debris dams per 100m are determined and will be compared for untreated and treated drainages. Additionally, the basic processes of recruitment and movement are examined.

INTRODUCTION

Woody debris plays an important role in channel formation and function of aquatic ecosystems (Bilby and Likens 1980, Galay 1983, Harmon and others 1986, Heede 1985, Keller and Swanson 1979, Potts and Anderson 1990). Some of the functions of woody debris include instream structure to dissipate flow energy, detain sediment, and provide refugia for fish. Plus, woody debris is a nutrient source/sink, as well as habitat for benthics.

Knowledge of the function of woody debris in the aquatic ecosystems of southeastern watersheds is lacking (Hedman and Van Lear 1991). In particular, the functions of woody debris in the aquatic ecosystems of the Arkansas highlands are largely unexplored. The occurrence and abundance of woody debris dams may prove to be a useful indicator for macroinvertabrate habitat and therefore useful as an indirect biological indicator for the ephemeral portions of these aquatic ecosystems.

Additionally, the effects, if any, of forest management activities on this debris have yet to be fully quantified or understood.[3] Traditional methods of studying direct and indirect effects of forest activities upon aquatic ecosystems have focused on water flow and water chemistry studies. These studies are expensive, require long timespans for results, and do not allow for assessment of biophysical stream characteristics. Therefore, in this study the use of small woody debris and detritus to assess potential effects of forest activities on the biological component of streams is examined. Accordingly, biomass is estimated and locations are mapped for woody debris in forested ephemeral channels. Furthermore, the effect of reproductive cutting methods on these debris dams will be estimated by remeasurement of the location and biomass of the debris.

[1] Paper presented at the Symposium on Ecosystem Managemnt Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

[2] Research hydrologist, Oxford Hydrology Laboratory, Oxford, MS 38655, USDA Forest Service, Southern Station.

[3] Studies by Golladay and Webster (1988) and Golladay, Webster, Benfield, and Swank (1992) at Coweeta, North Carolina showed decreases in organic debris dams after clearcutting.

SCOPE

Five reproductive cutting methods and a control are applied to the study areas. They are: clearcut, shelterwood, seedtree, group selection, single-tree selection, and uncut. These treatments occur on 52 stands of approximately **16ha** each. Ephemeral zero order drains occur within these stands. While small in nature, these streams may reflect direct and indirect impacts resulting from silvicultural activities.

Objectives

The objectives of the study are:

(1) to describe the natural occurrence of debris dams in small ephemeral channels.
(2) to track the movement of woody debris in small ephemeral channels.
(3) to determine the effects, if any, of various silvicultural treatments on the presence and movement of woody debris in small ephemeral channels.

Methods

Drainages and local controls within the units were surveyed to identify small woody debris locations and estimate the amount of woody debris. An arbitrarily selected ***zero*** station is established at the beginning of each channel survey. This station is marked O+OOO. Then the 100-m tape is extended along the thalweg. Each 100 meters a station is designated by a wooden stake marked with the station number (e.g., 1 +OOO). Each woody debris dam occurrence is flagged, and the distance to the nearest tenth of a meter is noted on the flagging and recorded on the data form. For example, if a debris dam occurred at **78.3m** the distance of **0+783** is recorded on both the flagging and the data form.

Debris Typing

Next, these debris dams are typed in one of the following categories:
1 = Large woody debris, full
2 = Large woody debris, partial
3 = Small woody debris, full
4 = Small woody debris, partial
5 = Detritus, full
6 = Detritus, partial
7 = Slash, full
8 = Slash, partial

Characteristics of the variuos types of debris dans are: large woody debris is 15 cm or greater in diameter, small woody debris is less than 15 cm in diameter, detritus is comprised of leaves and needles, and slash is recently deposited tree tops resulting from **blowdown** or harvest. If a debris dam occupies 70 percent or more of the channel width, then it is classified as a full dam. If it occupies less than 70 percent of the channel width, it is classified as a partial dam.

Biomass Estimate

Biomass was determined by adapting Brown's (1974) techniques for estimating downed woody material to the woody debris. Biomass is estimated by measuring, to the nearest **tenthof** a meter, the length of the debris across the channel. The width of the debris is measured at the midpoint of the debris dam, and the height of the debris is also taken at the midpoint of the dam but on the downstream side. These measurements are then recorded. Drainages are to be resurveyed annually for 3 years after the treatment.

PRELIMINARY FINDINGS

Initial measurements were taken in the fall of 1992. The harvesting occurred during the summer of 1993. The first remeasurements were taken in the fall of 1993. While it is premature to ascertain the effects of forest management activities upon woody debris, it is possible to characterize debris occurrence on the study sites.

The overall distribution of debris dam types is presented in Figure 1. As can be seen in this figure, small woody debris and detritus are more common than either large woody debris or slash. Preliminary characterization of debris occurrences is listed in table 1. by drainage, frequency per 100m, and estimated biomass per 100m. Twenty-seven zero order drainages were surveyed. A total length of 8778m of drainages were surveyed and 2399 debris dams were counted. Debris-dam frequency appears to be a relatively consistent parameter.

An average of approximately 26 debris dams per 100m were encountered in zero order drainages of the study areas. Both the Cold Water Creek and Gaffords Creek study areas averaged approximately 30 debris dams per 100m. Both Harvey Creek and the South Fork of the Guachita River study areas

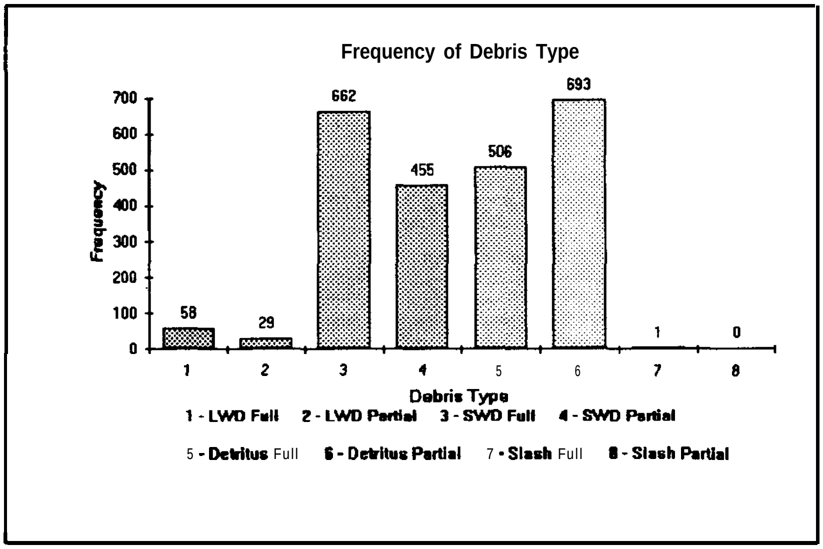


Figure 1. Frequency of Woody Debris Type

Table 1. Preliminary charaterization of debris on study sites

Drainage number	Tributary of	Length m	Frequency *number/100m*	Biomass *m^3/100m*
1035-l	Cold Water Creek	300	33	1.2
1035-2	Cold Water Creek	124	39	4.3
1035-3	Cold Water Creek	399	33	4.7
1035-4	Cold Water Creek	341	31	5.0
1035-5	Cold Water Creek	195	28	1.1
1035-6	Cold Water Creek	155	21	1.4
1035-7	Cold Water Creek	668	30	1.7
1035-a	Cold Water Creek	274	26	2.0
1035-9	Cold Water Creek	249	24	2.2
1035-10	Cold Water Creek	398	25	3.6
1035-11	Co!d Water Creek	300	31	2.8
1035-12	Cold Water Creek	319	27	2.6
1044-l	Gaffords Creek	400	36	2.3
1044-2	Gaffords Creek	254	34	2.1
1044-3	Gaffords Creek	464	28	1.6
1044-4	Gaffords Creek	427	30	1.5
1044-5	Gaffords Creek	407	28	1.7
1044-6	Gaffords Creek	264	23	1.2
1651-I	Harvey Creek	119	21	2.4
1651-2	Harvey Creek	317	16	1.2
1651-3	Harvey Creek	291	19	1.3
1651-4	Harvey Creek	241	20	1.3
1651-5	Harvey Creek	488	22	2.5
1658-l	Ouachita River*	247	19	2.2
1658-2	Ouachita River	357	20	1.2
1658-3	Ouachita River	---	--	
1658-4	Ouachita River	137	23	0.7
1658-5	Ouachita River	642	19	2.5

* -The south fork of the Ouachita River.

averaged approximately 20 debris dams per 100m. Although this is a **limited preliminary data** set, the differences in average frequency may imply ecoregional differences in debris occurrence.

CONCLUSION

This study is underway to map the location and estimate the biomass of woody debris in zero order forested ephemeral channels and to determine the effects, if any, of reproductive timber harvest methods on these debris dams. Preliminary data indicate a ratio of 26 debris dams per 100 m. Ecoregional differences in debris-dam frequency may occur.

LITERATURE CITED

Bilby, R.E.; Likens. G. 1980. Importance of organic debris dams in the structure and function of stream ecosystems. Ecology. 61: 1107-1113.

Brown, J.K. 1974. Handbook for inventorying downed woody material. Gen. Tech. Rep. INT-16. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Research Experiment Station. 24p.

Galay, V.J. 1983. Causes of river bed degradation. Water Resources Research. 19(5):1,057-1,090.

Golladay, S.W.; Webster, J.R. 1988. Effects of clearcut logging on wood breakdown in Appalachian Mountain Streams. American Midland Naturalist. 119: 143-155.

Golladay, S.W.; Webster, J.R.; Benfield, E.F.; Swank, W.T. 1992. Changes in stream stability following forest clearing as indicated by storm nutrient budgets. Archiv fur Hydrobiologie. Suppl.-BD. 90: l-33

Harmon, M.E.; Franklin, J.F.; Swanson, F.J.; and others. 1986. Ecology of course woody debris in temperate ecosystems. Advances in Ecological Research. 15: 133-302.

Hedman, C.W.; Van Lear, D.H. 1991. Riparian zone vegetation and large woody debris dynamics: preliminary findings for the Southern Appalachians. Society of American Foresters National Convention, San Francisco, CA.

Heede, B.H. 1985. Channel adjustments to the removal of log steps: An experiment in a mountain stream. Environmental Management. 9(5): 427-432.

Keller, E. A. ; Swanson, F.J. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Process. 4:361-380.

Potts, D. F.; Anderson, B. K. M. 1990. Organic debris and the management of small stream channels. Western Journal of Applied Forestry: vol (1): 25-28.

Water Chemistry of Ephemeral Streams[1]

J.L. Michael, W.P. Fowler, H.L. Gibbs, and J.B. Fischer[2]

ABSTRACT

Four individual, but related, studies are currently being conducted to determine the effects of clearcut and seed tree reproduction cutting methods on stream chemistry, sedimentation, and bedload movement by monitoring herbicide and nutrient movement in stemflow, overland flow, streamflow, and zonal subsurface flow. Sediment movement is being quantified for stormflow water samples. Comparative rates of movement are also being studied for imazapyr, hexazinone, and triclopyr. Analytical chemistry methods have been developed to permit detection of triclopyr at 0.5 micrograms per liter (parts per billion, ppb). Freezer storage studies are underway to demonstrate the suitability of frozen storage of water samples for herbicide analysis. Studies conducted on the epoxy paint, used throughout to protect wood and concrete surfaces during study installation, show a coeluting coextractable compound that interferes with triclopyr analysis. This compound does not appear after a 2-week curing period for the epoxy paint. Curing was complete long before triclopyr was applied to the site. Therefore, the coeluting coextractable compound will not confound any of the triclopyr analyses.

INTRODUCTION

The job of managing and protecting National Forest System land is constantly growing in complexity. Pressures are increasing for forest lands to produce greater amounts of goods and services while maintaining or enhancing water quality and site productivity. Accordingly, there is a continuing need to evaluate and monitor the effects of alternative silvicultural and forest management activities on the forest environment. Evaluating and monitoring the impacts of these activities on water yield, water quality, ecosystem functioning, and site productivity are essential to sound forest land management. Research has provided much information, which may be used to evaluate management activities, but there is little integrated research involving the myriad interactions in the environment.

Herbicides have been used in forest management with generally good results. The movement of forestry herbicides offsite and the potential impacts on nontarget organisms or ecosystems are a concern. Several studies have been summarized that report fate and movement of herbicides from forest sites (Michael and Neary 1990, 1993; Neary and others 1993). None of the reported studies monitored movement of triclopyr from injected sites. Where injection of other forestry herbicides was the mode of application, peak observed streamflow concentrations did not exceed 21 micrograms per liter (ppb) (table 1). A similar, low-intensity application method known as spot treatment resulted in a maximum observed concentration of 37 ppb in streamflow (table 1). Neary and others (1986) point out that sediment is the single greatest nonpoint source pollution problem created by forestry and that use of herbicides in forestry improves water quality by decreasing sediment loads to levels much lower than observed with other management tools. Thus, there is the question of ecosystem impacts and the relative impairment of water quality from herbicide use versus use of other tools in forest management.

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[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

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Table 1 .-*Maximum observedherbicide residues in streamflow from herbicide injection end spot treatments in the Southern United States*

Herbicide'	Location	Application Method'	Application Rate*	Surface Source'	Water'
Picloram	Georgia	INJ	0.3	M	ND
Picloram	Georgia	INJ	0.3	M	ND
Picloram	Georgia	INJ	0.3	M	6
Picloram	Kentucky	INJ	1.3	M	21
Picloram	Kentucky	INJ	0.3	M	10
Picloram	Tennessee	INJ	0.6	M	4
Hexazinone	Arkansas	SPOT	2.0	B	8
Hexazinone	Alabama	SPOT	2.9	M	24
Hexazinone	Alabama	SPOT	2.9	M	37
Hexazinone	Alabama	SPOT	2.9	M	23
Hexazinone	Georgia	SPOT	1.6	M	6
Hexazinone	Georgia	SPOT	1.6	M	9

• Hexazinone - E.I. duPont deNemours & Company, Wilmington, DE; Picloram - DowElanco, Indianapolis, IN.

'Stem injection (INJ), application directly to the ground in a grid network (SPOT).

‡ Active ingredient (ai) applied in kg/ha.

§ *Bouchard and* others 1985, Michael and Neary 1993.

¶ Expressed as µg/L, detection limits of analytical method are 1 µg/L.

This study centers on the impacts that changes in ephemeral stream water quality may have on water quality and quantity at the landscape scale. Specifically, objectives are:

1. Investigate offsite movement of herbicides through water movement:
   (a) to estimate total offsite movement of triclopyr injected for operational herbicide application,
   (b) to estimate relative importance of different routes of offsite movement of triclopyr applied as single stem injection for vegetation management (stemflow, overland flow, and zonal subsurface flow); and
   (c) to compare relative rate of movement of imazapyr, triclopyr, and hexazinone through subsurface routes following surface application.
2. Determine the effects of clearcut and seedtree reproduction cutting methods on stream chemistry, sedimentation, and bedload movement.

METHODS

Study Plans

This study is covered by four study plans. The need for multiple study plans arises from the complexity of each phase of the research:

FS-SO-4351-92-1 Effects of reproduction cutting methods on streamflow, water quality, soil, and cultural resource characteristics (Clearcut Study or CCS)

FS-SO-4105-1.25 (FS-SO-4351-93-1) Effects of seed tree cutting and site preparation on streamflow chemistry, sedimentation, and water yield in the Ouachita Mountains (Seed Tree Study or STS)

FS-SO-4105-1.26 Development and validation of an analytical and freezer-storage method for triclopyr in water samples (Analytical Methods Study or AMS)

FS-SO-4105-1.27 (FS-SO-4351-94-l) Subsurface flow of injected and ground-applied herbicides on a typical Ouachita National Forest mixed pine/hardwood site (Subsurface Flow Study or SFS)

Sites

A total of six study sites are divided among the four study plans. The sites are typical of the Ouachita National Forest shortleaf pine/hardwood mixed stands. Topographic relief is variable depending on the length of watershed under consideration, but slope is typically 10 to 25 percent with loamy surface soils ranging from moderate to well drained.

The CCS includes four ephemeral watersheds located on the clearcut stands in Compartment (Cpt) 1658 Stand (St) 05 (Womble Ranger District) and Cpt 458 St 16 (Fourche Ranger District). Each stand includes two small watersheds. These watersheds were clearcut in July and August 1993.

The STS site is a 32.5-acre watershed on the Alum Creek Experimental Forest. It was harvested in August 1993 by removal of all merchantable stems except 10 to 15 seed trees per acre and approximately 5 ft^2/acre of hardwood basal area.

The SFS site is also located on the Aim Creek Experimental Forest. Soils here are shallow to moderately deep (6 ft), well drained, with slow to moderate permeability. Existing mature pines will not be harvested from this site, which includes several very small drainages of which two are instrumented. The small drainage to be used in this study is approximately 0.25 acres.

Instrumentation

All sites include H-flumes of the appropriate size. The CCS sites were instrumented in the fall/winter of 1992. Control sections are constructed from plywood and protected from the elements with a coat of epoxy paint. The output from control sections passes through 2-ft H-flumes. Each control section is covered with a fiberglass roof extending over the H-flume output. Instrument huts are also constructed of plywood and contain all sampling instrumentation. Sampling instruments for collection of water samples are Isco® automatic samplers connected to Isco flow meters and plotters. Control sections for the STS site and below the SFS site are constructed of concrete coated with epoxy paint for 4.5-ft and 3-ft H-flumes, respectively.

All sites are, fitted with tipping bucket and weighing bucket rain gauges. The tipping bucket rain gauges are connected to electronic data loggers, which store precipitation data until it is downloaded and processed by the Oxford Laboratory.

Sample Handling

All samples are removed on a per-storm basis from the Isco samplers, double labeled with preprinted, stick-on labels, and stored in freezers at the appropriate work centers. Chest-type freezers are located at each work center and are for the exclusive storage of these samples. When freezers approach full capacity, a team from the Auburn Laboratory travels to the work centers in Arkansas carrying empty freezers. Samples are transferred to the empty freezers and returned to the Auburn Laboratory in a frozen state. All personnel involved in the study have received training in the collection, labeling, handling, and logging-in of samples, in the programming of Isco sampling device, and in the maintenance of samplers and rain gauges.

Chemical Analysis

Triclopyr

An analytical method for triclopyr has been developed at the Auburn Laboratory. It is an HPLC method utilizing UV detection. This method is undergoing final validation. Triclopyr is first extracted and concentrated using solid phase extraction technology, then cleaned-up and eluted for HPLC analysis. The method is capable of quantitation at the 0.5 to 1 part per billion level, depending on the initial sample size. A second method for more rapid analysis is being tested. Utilizing enzyme-linked immunosorbent assay technology, this method (ELISA) permits analysis of approximately 80 to 100 samples in a day with very good reliability. Some problems with interfering substances (a problem with all analytical methods) still exist, and solutions are being investigated.

Freezer storage stability studies are being conducted to determine the recovery of triclopyr from samples fortified with known amounts of triclopyr and stored in the frozen state for up to 1 year. Triclopyr has a water solubility of 430 parts per million (ppm) at 77 °F. Frozen samples thawed for analysis will be at room temperature when extracted (approximately 72 °F) and are not expected to contain more than about 0.04 ppm, so solubility should not be a concern in this study. Any decreased recovery would be attributable to surface sorption on the container wall or due to hydrolysis.

Studies have been conducted to determine whether any coextractable coeluting substances elute from the epoxy paint (used throughout these studies), which might interfere with triclopyr analysis. Prior to complete curing, a single compound appears to elute from the paint, but use of a two-stage gradient mobile phase elution technique completely separates this compound from triclopyr. Subsequent to curing, which takes about a week, no additional compounds elute to interfere with the triclopyr analysis. In addition, studies were conducted to determine whether triclopyr would preferentially sorb onto the epoxy paint surface. No triclopyr sorbtion was detected.

Sediment

Aliquots (500 ml) of the water samples collected by Isco automatic samplers are filtered through prewashed, dried, and weighed Whatman® GF/B glass fiber filters to remove all suspended sediment. Subsequent to filtration, each filter is again dried to constant weight at 105 °C and then weighed. The difference in weight-suspended sediment-is related to flow measured with the Isco flow meters to calculate total suspended sediment transported offsite.

Nutrients

Anions and cations are analyzed using a Dionex® ion chromatograph. Concentrations will be related to storm flow and treatment. The pH of all samples is also checked and recorded.

Stem Injection

Injection of hardwood stems began during the week of 18 October 1993. Auburn and Oxford Laboratories, as well as National Forest System personnel, were on site to record the exact amount of triclopyr used on each watershed. The two watersheds on the Womble were treated 21 October 1993; site 1 received a total of 3,885 ml undiluted Garlon® 3A with blue dye added to this mixture; site 2 received 3,610 ml with blue dye added to this mixture. The Fourche watersheds were treated 22 October 1993; site 3 received 6,630 ml with no dye added, and site 4 received 5,330 ml with no dye added. And the Alum Creek watershed was treated 23 October 1993; the total area received 30,530 ml whereas the watershed drainage monitored by the H-flume received 26,280 ml. Monitoring of offsite movement began with the first precipitation event following the application.

The application method was not a classical injection treatment. Classical injection is application via some instrument like a tubular type injector (e.g., Jim-Gem" or Cran-jector®). This type of injection equipment ensures insertion of the herbicide into cuts usually at the rate of 1 or 2 ml per cut. A modification of the injection technique, which reduces the back strain common with tubular injectors, is the Hypo-Hatchet@ . Hypo-hatchets are hatchets with narrow bits specially hollowed to allow delivery of the herbicide on impact with the injected stem. The method used in this study is more aptly described as a hack-and-squirt method. In hack-and-squirt, as it was used on the Fourche, Womble, and Alum Creek watersheds, a machete, hatchet, or other cutting device was used to essentially girdle each stem and remove bark, often down to the xylem. A spray bottle was then used to spray either a steady stream or a spray mist onto each tree around the girdle. During this process, some splashing was observed, which frequently went directly onto the ground. Because of this, values of offsite movement will likely be intermediate between the values observed in spot and injection treatments (table 1).

RESULTS AND DISCUSSION

All sites have been completely instrumented except the SFS site. Sampling equipment is present on the SFS site, but stem collars for the monitoring of stemflow from injected sites have not been installed.

Some baseline sampling has been conducted on these sites. Precipitation data and stream stage data have been correlated to produce hydrographs indicating stream response to precipitation events of different magnitudes. Early results produced atypical hydrographs in which flow began and then appeared to remain constant for a long time, instead of decreasing in an orderly and predictable fashion. The problem was identified and determined to be the result of incident precipitation received in the flumes. Because H-flumes are designed to have a small dip at the gauging point, incident precipitation pooled over the pressure transducers used to record stream stage. Identification of this problem led to covering the entire length of control section and the H-flume to preclude interception by the control section and the resulting false flow. Subsequent hydrographs have been more typical. Flow from the Fourche watersheds typically lasts much longer (3 to 5 days) than that observed for the Womble (1 to 3 days). The STS site on Alum Creek may flow for weeks after a rain event.

Preliminary surveys indicate the Fourche watersheds are approximately 8 and 13 acres while the Womble watersheds are approximately 3 acres (2.8 and 2.7). The Alum Creek STS is approximately 32.5 acres. The Alum Creek SFS is approximately 14 acres, with 0.25 acres instrumented for subsurface flow sampling. Additional surveys will be conducted to more completely identify the area of the treated watersheds.

LITERATURE CITATIONS

Bouchard, D.C.; Lavy, T.L.; Lawson, E.R. 1985. Mobility and persistence of hexazinone in a forested watershed. Journal of Environmental Quality. 14: 229-233.

Michael, Jerry L.; Neary, Daniel G. 1990. Fate and transport of forestry herbicides in the South: research knowledge and needs. In: Coleman, Sandra S.; Neary, Daniel G., comps., eds. Proceedings of the 6th biennial southern silvicultural research conference; 1990 October 30-November 1; Memphis, TN. Gen. Tech. Rep. 70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 641-649. Vol. 2.

Michael, J.L.; Neary, D.G. 1993. Herbicide dissipation studies in southern forest ecosystems. Environmental Toxicology and Chemistry. 12: 405-410.

Neary, D.G.; Bush, P.B.; Michael, J.L. 1986. Herbicides in southern forestry: improving water quality. In: Proceedings of the 39th annual meeting of the Southern Weed Science Society; 1986 January 20-22; Nashville, TN. Champaign, IL: Southern Weed Science Society. 39: 335-341.

Neat-y, D.G., Bush, P.B.; Michael, J.L. 1993. Fate, dissipation and environmental effects of pesticides in southern forests: a review of a decade of research progress. Environmental Toxicology and Chemistry. 12: 41 l-428.

Forest Floor Characteristics in Mature Pine-Hardwood Stands in the Ouachita Mountains*

Michael G. Shelton and Edwin R. Lawson[2]

ABSTRACT

The forest floor was characterized in 24 mature, shortleaf pine (*Pinus echinata* Mill.)-hardwood stands located in the Ouachita Mountains before implementation of 6 overstory treatments that were replicated 4 times in a randomized complete block design. Within each stand, five 0.1-m^2 samples of the forest floor were collected from each of three permanent locations representing lower, middle, and upper slope positions. No significant differences were observed among overstory treatments, topographic positions, or blocks for any of the forest floor characteristics evaluated. The weight of the forest floor averaged 19.3 t/ha, and its mean depth was 3.1 cm. Twenty-seven percent of the total weight was in the litter layer and 73 percent was in the fermentation layer. The litter layer was composed of nearly equal weights of pine foliage, hardwood foliage, and woody material. Total weight of the forest floor was positively correlated with forest floor depth (fit index = 0.34) and percentage of pine foliage in the L layer, an expression of composition (fit index = 0.18).

Key words: Decomposition, litter production, nutrient cycling, organic matter, forest soils.

INTRODUCTION

The forest floor is one of the most distinctive features of a forest ecosystem. It consists mainly of shed vegetative parts, such as leaves, branches, bark, and stems, existing in various stages of decomposition above the soil surface. Although composed principally of dead organic material, the forest floor also teems with a wide variety of fauna and flora. In fact, it is one of the richest components of the ecosystem from a biodiversity standpoint (Dickinson and Pugh 1974). The major compartments for the storage of organic matter and nutrients within forest ecosystems are plant biomass, forest floor, and soil. The forest floor serves as a bridge between the aboveground biomass and the soil, and it is a crucial component in nutrient transfer via biogeochemical cycling. Much of the energy and carbon fixed by forests is annually added to the forest floor through litterfall (Hinesley and others 1991), and a substantial portion of the annual nutrient requirement of forested ecosystems is supplied by mineralization of organic matter in the forest floor and soil surface (Jorgensen and others 1975, Switzer and Nelson 1972). The sustained productivity of forests is closely linked with the turnover of shed plant parts, particularly the nutrient-rich foliage (Witkamp 1971).

Forest floor characteristics are also of considerable interest from a stand-regeneration standpoint because they affect the seedbed conditions existing after the regeneration cut (Shelton and Wittwer 1992). Pine germination is best on a mineral soil seedbed. However, the nutritional and protective roles of the forest floor should be fully considered before managers prescribe site preparation treatments that create favorable seedbed conditions through its destruction (Bengtson 1981, Switzer and Shelton 1984). Disturbance of the forest floor is also closely linked with water quality (McClurkin and others 1987).

The preharvest character of the forest floor within the study area are described in this paper. Results are restricted to forest floor physical characteristics because the chemical analyses have not been completed.

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METHODS

Study Area, Treatments, and Sampling Design

Relatively undisturbed, mature, shortleaf pine (*Pinus echinata* Mill.)-hardwood stands were selected for study on generally south- facing slopes in the Ouachita Mountains of Arkansas and Oklahoma. A detailed description of the study area and its vegetation is provided in Baker (1994) and Guldin and others (1994).

Baker (1994) describes the selection criteria for stands and provides an overview of the full array of 13 overstory treatments. A subset of the full complement of treatments was selected for forest floor and soil sampling because of limited available resources. The six selected treatments were: clearcut, pine shelterwood, pine-hardwood shelterwood, pine single-tree selection, pine-hardwood single-tree selection, and unharvested control. These treatments will provide a broad range of disturbance effects and also allow evaluating the effects of different levels of hardwood retention. Treatments were randomly assigned within each of the four ecoregions that serve as blocks, providing a total of 24 stands. Each 16-ha stand was subdivided into quarters to facilitate establishing 12 randomly located, permanent subplots that were used for sampling vegetation. These quarters were oriented perpendicular to the dominant slope within the stand. In stands receiving a uniform manual site-preparation treatment, one quarter, with its three subplots, was randomly selected for sampling the forest floor and soils. In stands receiving different site-preparation treatments, forest floor and soil sampling were restricted to the quarter randomly assigned to the manual site-preparation treatment. This assured that the site-preparation treatment would be the same in all areas used for sampling the forest floor. Each subplot within a quarter represented either the lower, middle, or upper topographic positions. In total, 72 subplots were sampled in 24 stands.

Field Sampling

Sampling was conducted during February and March of 1993. Five sampling locations were systematically located 11.4 m from each subplot center. Sampling locations were relocated if abnormal conditions occurred, such as large surface rocks, woody debris more than 9 cm in diameter, or previous manmade disturbance (e.g., old roads, etc.). The forest floor was collected within a 0.1-m^2 square frame at each sampling location. Two layers or stages of decomposition were recognized: (1) a litter (L) layer, which included the uppermost, relatively undecomposed material that was mostly deposited in the autumn pulse of litterfall and (2) a fermentation (F) layer consisting of partially decomposed, older material located between the soil surface and the L layer. The L and F layers are also referred to as Oi and Oe horizons, respectively. The color, texture, and level of fragmentation of foliage (especially the hardwoods) were used to define the boundary between the L and F layers. The boundary between the bottom of the F layer and the soil surface was also based on decomposition stage--the source of F layer material was apparent, such as a fragment of a pine needle or a piece of bark. By contrast, the soil surface was either mineral matter or dark, amorphous organic matter, representing the humus (H) layer or the Oa horizon. A well-defined H layer rarely exists in the forest floors of southern forests because of rapid decomposition rates and incorporation of organic matter within the soil by fauna (Switzer and others 1979). Thus, any H-layer material present was included within the surface soil sample. Forest floor depth was evaluated at the midpoint of each side of the sampled area.

Laboratory Procedures

Forest floor samples were dried to a constant weight at 75 °C and weighed. Each L-layer sample was separated into woody and foliar components. The woody component included branches, bark, small stems, and reproductive material (e.g., pine cones). The foliar component of three of the five samples for each subplot was separated into pine and hardwood foliage and weighed. Thus, the L layer was represented by pine foliage, hardwood foliage, and woody components. The F layer was not separated because of its high fragmentation.

Forest floor components were composited for a subplot and were ground to pass a 20-mesh sieve. Weight loss on ignition at 500 °C for 4 hours was determined, and reported weights were for volatile matter. This is a frequently used approximation of organic matter, although a small error occurs because some nutrients in organic matter are left in the ash. Ash content was expressed as a percentage of oven-dried weight.

Data Analysis

Forest floor data were analyzed using analysis of variance for a two factorial, randomized complete block design. Overstory treatment and topographic position were the two factors. Means for ash content of forest floor components were separated by the Ryan-Einot-Gabriel-Welsch multiple-range test at the 0.05 probability level using the GLM procedure of SAS Institute (1990). In addition, forest floor weight was regressed with depth and pine percentage in the L layer's foliage, which is an expression of **forest floor** composition. The following function, which accommodates a wide range of data patterns, was used:

$$Y = b_0 + b_1 X^{b2} \quad (1)$$

Coefficients were determined by nonlinear, least squares regression, using the MODEL procedure (SAS Institute 1988). Data for regression were the mean values for the 72 subplots. One outlier for forest floor depth was dropped from the data.

RESULTS AND DISCUSSION

Ash Content

i-he forest floor principally consists of shed plant parts in various stages of decomposition. Since deposition mainly comes from the canopy, the freshest material is in the uppermost portion of the forest floor (the L layer), whereas the oldest and most highly decomposed material is at the bottom (the F layer). Ash content in the forest floor components reflects the type' of material and its stage of decomposition (fig. 1). The fresh material making up the L layer is very low in ash, ranging from 2 percent in woody material to 6 percent in hardwood foliage. These differences reflect the characteristic chemical makeup of each type of material since some nutrients in organic matter are left in the ash. For example, Hinesley and others (1991) found that nutrient concentrations in the litter produced in mature pine-hardwood stands in Mississippi are generally greatest in the hardwood foliage and least in the woody material.

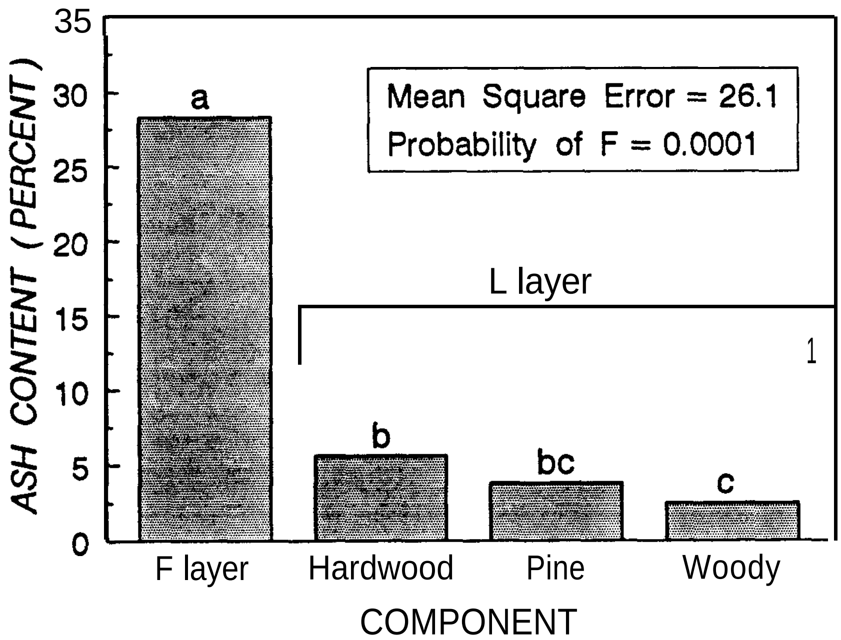

Figure 1.-Ash *content in forest floor components. Bars with differerent letters are significantly different by the Ryan-Einot-Gabriel-Welsch multiple-range test at the 0.05 probability level.*

Ash contents increase as the L-layer material decomposes, and the more highly decomposed F layer averaged 28 percent ash. This increase principally reflects the mixing of mineral soil within the decomposing material. Shelton (1984), for example, reported a large increase in mineral matter in decomposing pine stems that was attributed to termite activity. Mechanisms of mineral matter incorporation include the burrowing and foraging activity of a wide assortment of animals, such as earthworms (Lofty 1974), arthropods (Edwards 1974), and small mammals (Pritchett and Fisher 1987).

The Typical Ouachita Forest Floor

The L layer of the 24 sampled stands averaged 5.2 t/ha and was composed of approximately equal weights of pine foliage, hardwood foliage, and woody material (table 1). The woody material was the most highly variable of these components, with a coefficient of variation (CV) of 44 percent compared to 23 percent for pine foliage and 32 percent for hardwood foliage. The L layer is principally the organic material deposited in the pulse of litter during autumn, and thus, it approximates annual litter production. For example, the foliar portion of the L layer averaged 3.3 t/ha, which is close to the 3.6 t/ha/yr of foliar litter collected in similar stand and site conditions in Perry County, Arkansas[3]. These values for the Ouachita Mountains are close to the 3.9 t/ha/yr of foliar litter reported by Metz (1952) for similar stand conditions in the Piedmont of South Carolina. In contrast, Hinesley and others (1991) reported foliar litter was 7.5 t/ha/yr for mature pine stands growing on average sites in the Coastal Plain of Mississippi.

Table 1 .-*Mean forest floor weights of the 24 sampled stands by component*

Component	Mean	Standard deviation	Range	
			Minimum	Maximum
		t/ha-------------------------		
L layer				
Pine foliage	1.7	0.40	1.1	2.9
Hardwood foliage	1.6	0.51	0.5	2.6
Total foliage	3.3	0.60	2.2	4.9
Woody material	1.9	0.82	0.8	3.6
Total L layer	5.2	1.20	3.7	7.8
F layer	14.1	1.93	10.4	17.6
Total forest floor	19.3	2.01	16.2	23.5

The F layer averaged 14.1 t/ha (CV = 14 percent) and accounted for 73 percent of the total forest floor weight. Thus, the F layer represents the accumulation of several years of litter production. Decomposition rates for the forest floor can be calculated from the annual litter inputs and the steady state of the forest floor (Olson 1963). Because the L layer approximates annual litterfall and the F layer approximates the steady state of the forest floor, their ratio is an expression of decomposition rate. The ratio of the L and F layers averaged 0.37. Similar decomposition rates have been reported for natural pine stands (Switzer and others 1979) and pine plantations (Shepard 1985) in the Coastal Plain of Mississippi.

The total forest floor averaged 19.3 t/ha, with a CV of 10 percent. The surprisingly narrow range in values (16.2 to 23.5 t/ha) points to the uniform stand and site conditions existing in the stands before implementation of overstory treatments. Forest floor weights in the Ouachita Mountains are typical of those reported elsewhere in the South and worldwide for a similar climate and species composition. In a literature review, Vogt and others (1986) reports an average of 20 t/ha for the warm, temperate coniferous forest type. Crosby (1961) reported that forest floor weights in shortleaf pine stands in the Ozark Mountains of Missouri varied with stand basal area; values ranged from 23 t/ha for a basal area of 14 m^2/ha to 30 t/ha for a basal area of 46 m^2/ha. Metz (1954) reported that the forest floor of a 40-year old, natural shortleaf pine stand in the Piedmont of South Carolina weighed 18 t/ha; forest floors for mixed shortleaf pine and hardwoods averaged 12 t/ha.

Forest floor depth is also of interest because it is easily determined in the field and is correlated with weight. Depth averaged 3.1 cm (standard deviation = 0.51 cm; CV = 17 percent) in the 24 sampled stands and ranged from 2.4 to 4.4 cm. In old-field pine stands on the North Carolina Piedmont, Coile (1940) reported an average depth of 3.8 cm at 20 years, which increased to 7.1 cm at 80 years. Coile's depths for mature pine stands are considerably greater than those reported here for mature pine stands of the Ouachita Mountains or the 3.3 cm reported for similar stand compositions in the Coastal Plain of both Mississippi (Shelton 1975) and Arkansas (Grano 1949).

Factors Affecting Forest Floor Characteristics

No significant differences were observed among the forest floor weights of assigned overstory treatments, topographic positions within stands, or blocks (table 2). Similar results, not shown, were observed for depth and weight of L-Iayer

[3] Unpublished USDA Forest Service data on file with the Southern Forest Experiment Station, Monticello, AR 71656-3516.

components. This was expected because of the random assignment of overstory treatments and selection criteria used to assure uniform stand conditions before treatment implementation. Apparently, differences in environmental conditions associated with topographic positions within stands or blocks were too minor to affect forest floor characteristics.

Table 2. -*Results of the analysis of variance for forest floor weights*

Source	Degrees of freedom	L layer	F layer	Total
		---------Mean square error---------		
Block	3	1.50 (0.78)'	6.26 (0.67)	3.96 (0.86)
Overstory treatments	5	3.27 (0.57)	0.83 (1.00)	3.40 (0.96)
Topographic position	2	1.63 (0.68)	10.68 (0.41)	16.64 (0.36)
Treatment x position	10	0.37 (1.00)	8.05 (0.74)	9.12 (0.83)
Error	51	4.18	11.86	16.00

* The number in parentheses is the probability of F.

Site quality apparently has little influence on forest floor weight within a climatic region and forest type. This is shown by comparing the values for poor sites in the Ouachita Mountains (this study) to those for better sites in the Coastal Plain of Mississippi (Switzer and others 1979): values were 19 t/ha for stands on poor sites (pine site index of 18 m at 50 years) compared to 21 t/ha for stands of a similar composition but on better sites (pine site index of 26 m at 50 years). In addition, Shepard (1985) found no significant affect of site index on forest floor weights averaging 18 t/ha in a series of loblolly pine (*Pinus taeda* L.) plantations with site indices ranging from 15 to 28 m at 25 years. This uniformity in forest floor weights for a forest type over a wide range of sites undoubtedly reflects the balance between inputs from litter-fall and outputs from decomposition. Good sites have higher rates of input than poorer sites but also typically have higher rates of decomposition. These two opposing processes tend to equalize forest floor weights.

Despite little stand-to-stand variability in forest floor weights, some within-stand variation was observed. For example, total weight of the forest floor increased with an increasing pine composition, as indicated by the following equation:

$$W = 1.07 + 6.82\, P^{0.250} \qquad (2)$$
$$df = 69 \quad RMSE = 3.39 \quad \text{fit index} = 0.18$$

where: W = total weight in t/ha and P is the pine percentage in the L layer's foliage, which is a relative expression of the forest floor's species composition. Pine foliage averaged 52 percent of the total foliage weight in the L layer and ranged from 12 to 87 percent among the 72 subplots. Thus, forest floors in individual subplots varied from nearly all hardwoods to nearly all shortleaf pine. Weights calculated from equation (2) are 15, 19, and 22 t/ha for forest floors composed of 15, 50, and 85 percent pine, respectively. Switzer and others (1979) reported a similar range in forest floor weights for a series of stands representing secondary succession in the Coastal Plain of Mississippi. Forest floor weights maximized at 21 t/ha, whereas pines dominated middle succession and then declined to 14 t/ha as the hardwoods dominated late succession. Such differences reflect the well-known influence of litter characteristics, particularly lignin content, on decomposition rates (Vogt and others 1986).

Total weight of the forest floor increased with increasing depth, as indicated by the following equation:

$$W = 6.54 + 5.75\, D^{0.720} \qquad (3)$$
$$df = 68 \quad RMSE = 3.06 \quad \text{fit index} = 0.34$$

where: W = total weight in t/ha and D = depth in cm. Forest floor depth only accounted for 34 percent of the variation in weight, indicating that numerous other variables affect this relationship. Such variables include the type of material (e.g., woody versus foliar) and its stage of decomposition. Variation in microtopography and surface rocks are also sources of variability. A similar level of fit for the weight to depth relationship of the forest floor was reported in another study (Shelton 1975).

CONCLUSIONS

The forest floor is an important component of forest ecosystems; it functions in stand nutrition, biodiversity, water quality, site protection, soil-water relations, and stand regeneration. Forest floor characteristics depend on a stand's disturbance history and the balance between inputs from litterfall and outputs from decomposition. Any factor that affects either of these two opposing processes, such as the character of the vegetation (age, composition, and density) and the site (climate, soils, aspect, and topographic position) will be reflected in the accumulation of organic matter in the forest floor. However, stands evaluated in this study were selected to conform to specific criteria (namely, relatively undisturbed, mature pine-hardwood stands on generally south-facing slopes). This uniformity in stand conditions was reflected in fairly uniform forest floor characteristics. Thus, variation observed in this study may not be representative of the entire Ouachita Mountains. Of the variables evaluated in this study, within-stand variation in vegetative composition had the greatest effect on forest floor weights. Forest floor weights increased as the pine component increased, a trend that reflects the slower decomposition rate of pine litter when compared to that of hardwoods. The forest floor's nutrient status and its role in nutrient cycling will be reported when chemical analyses are completed.

LITERATURE CITED

Baker, James B. 1994. An overview of stand-level ecosystem management research on the Ouachita/Ozark National Forests. In: Proceedings of the symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Bengtson, G.W. 1981. Nutrient conservation in forestry: a perspective. Southern Journal of Applied Forestry. 5(2):50-58.

Coile, T.S. 1940. Soil changes associated with loblolly pine succession on abandoned agricultural land of the Piedmont Plateau. Bull. 5. Durham, NC: Duke University, School of Forestry. 85 p.

Crosby, John S. 1961. Litter and duff fuel in shortleaf pine stands in southeast Missouri. Tech. Pap. 178. Columbus, OH: U.S. Department of Agriculture, Forest Service, Central States Forest Experiment Station. 10 p.

Dickinson, C.H.; Pugh, G.J.F., eds. 1974. Biology of plant litter decomposition. New York: Academic Press. 775 p. Vol. 2.

Edwards, C.A. 1974. Marcoarthropods. In: Dickinson, C.H.; Pugh, G.J.F., eds. Biology of plant litter decomposition. New York: Academic Press: 533-554. Vol. 2.

Grano, C.X. 1949. Is litter a barrier to the initial establishment of loblolly and shortleaf pine seedlings? Journal of Forestry. 47: 544-548.

Guldin, James M.; Baker, James B; Shelton, Michael G. 1994. Midstory and overstory plants of mature pine/hardwood stands on south-facing slopes in the Ouachita/Ozark National Forests. In: Proceedings of the symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Hinesley, L.E.; Nelson, L.E.; Switzer, G.L. 1991. Weight and nutrient content of litter during secondary succession on well-drained uplands of the East Gulf Coastal Plain in Mississippi. Canadian Journal of Forest Research. 21: 848-857.

Jorgensen, J.R.; Wells, C.G.; Metz, L.J. 1975. The nutrient cycle: key to continuous forest production. Journal of Forestry. 73: 400-403.

Lofty, J.R. 1974. Oligochaetes. In: Dickinson, C.H.; Pugh, G.J.F., eds. Biology of plant litter decomposition. New York: Academic Press: 467-488. Vol. 2.

McClurkin, D.C.; Duffy, P.D.; Nelson, N.S. 1987. Changes in forest floor and water quality following thinning and clearcutting of 20-year-old pine. Journal of Environmental Quality. 16: 237-241.

Metz, Louis J. 1952. Weight and nitrogen and calcium content of the annual litter fall of forests in the South Carolina Piedmont. Soil Science Society of America Proceedings. 16: 38-41.

Metz, Louis J. 1954. Forest floor in the Piedmont region of South Carolina. Soil Science Society of America Proceedings. 18: 335-338.

Olson, Jerry S. 1963. Energy storage and the balance of producers and decomposers in ecological systems. Ecology. 44: 322-331.

Pritchett, William L.; Fisher, Richard L. 1987. Properties and management of forest soils. 2nd ed. New York: John Wiley and Sons. 494 p.

SAS Institute. 1988. SAS/ETS user's guide. Version 6, 1st ed. Cary, NC: SAS Institute Inc. 560 p.

SAS Institute. 1990. SAS/STAT user's guide. GLM-VARCOMP. Version 6, 4th ed. Cary, NC: SAS Institute Inc. 1,686 p. Vol. 2

Shelton, Michael G. 1975. The successional development of the forest floor and vegetation on uplands of the Upper Coastal Plain of Mississippi. Mississippi State, MS: Mississippi State University. 84 p. M.S. thesis.

Shelton, Michael G. 1984. Effects of the initial spacing of loblolly pine plantations on production and nutrition during the first 25 years. Mississippi State, MS: Mississippi State University. 161 p. Ph.D. dissertation.

Shelton, Michael G.; Wittwer, Robert F. 1992. Effects of seedbed condition on natural shortleaf pine regeneration. In: Brissette, John C.; Bamett, James P., comps. Proceedings of the shortleaf pine regeneration workshop; 1991 October 29-31; Little Rock, AR. Gen. Tech. Rep. SO-90. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station: 124-139.

Shepard, James P. 1985. Relationships between nutrient cycling and net primary productivity in loblolly pine plantation ecosystems of the East Gulf Coastal Plain. Mississippi State, MS: Mississippi State University. 195 p. Ph.D. dissertation.

Switzer, G.L.; Nelson, L.E. 1972. Nutrient accumulations and cycling in loblolly pine (*Pinus taeda*) plantation ecosystems: the first twenty years. Soil Science Society of America Proceedings. 36: 143-147.

Switzer, G. L.; Shelton M.G.; Nelson, L.E. 1979. Successional development of the forest floor and soil surface on upland sites of the East Gulf Coastal Plain. Ecology. 60: 1162-1171.

Switzer, G.L.; Shelton, M.G. 1984. Maintenance of productivity: some considerations. In: Karr, Bob L.; Baker, James B.; Monaghan, Tom, eds. Proceedings of the symposium of the loblolly pine ecosystem (West Region); 1984 March 20-22; Jackson, MS. Mississippi State, MS: Mississippi Cooperative Extension Service: 201-216.

Vogt; K.A.; Grier, C.C.; Vogt, D.J. 1986. Production, turnover, and nutrient dynamics of above- and belowground detritus of world forests. Advances in Ecological Research. 15: 303-377.

Witkamp, Martin. 1971. Soils as components of ecosystems. Annual Review of Ecology and Systematics. 2: 85-110.

New Perspectives In Heritage Resources Management On The Ouachita National Forest[1]

Roger E. Coleman[2]

ABSTRACT

This research project is designed to assess the effects of Forest Service timber management practices on cultural resources or heritage resource sites. The research was undertaken in conjunction with Phase II of the ecosystem management project, a replicated stand-level study that considers the effects that 13 different cutting treatments may have on multiple forest resources. This two-part research project focuses on the identification and assessment of heritage resource sites within the 52-stand project area. Following imposition of the cutting treatments, selected heritage sites will be monitored to assess relative impacts. These data will be used to select cutting treatments that are sensitive to heritage resource preservation needs. Furthermore, the avoidance of significant heritage resources during the experiment will make it possible evaluate the success of this forest-wide site protection strategy.

INTRODUCTION

The Ecosystem Management research project, formerly called "New Perspectives," is an experiment in forest management designed to analyze the effects of timber harvest strategies on an array of forest resources (Baker 1994). Specifically, this discussion is concerned with the potential effects of timber cutting methods on one particular resource--cultural properties or heritage sites.

Phase II of ecosystem management research is a replicated stand-level study that is being implemented in fifty-two 40-acre stands in Garland, Montgomery, Polk, Scott, and Yell Counties, Arkansas, and in LeFlore County, Oklahoma. Four replications of thirteen timber cutting methods have been randomly assigned to these stands, and the treatments are being imposed during the summer and fall of 1993. Timber harvests have varying potential to impact heritage resources. Generally, in terms of predicted level of effect, the cutting treatments can be quantified by percentage of ground disturbance sustained and then ranked by relative order of impact. The resulting scale of effect will be an asset to forest land managers who seek to minimize damage to forest resources caused by timber harvests.

Whether by natural forces or human alteration of the landscape, the destruction of archeological sites has been a subject of professional inquiry among archeologists who seek to explicate the processes that affect sites to better interpret the archeological record. Sites are adversely affected when: (1) horizontal displacement or redeposition of artifacts occur with resulting loss of contextual information, (2) vertical mixing of site deposits causes loss of temporally sensitive data, and (3) artifact breakage and deterioration biases composition of the archeological record. However, the study of site destruction, or site taphonomy, is a "gray-area" in the archeological literature. Although such studies have been recommended in Arkansas (Padgett 1978 Klinger 1982), none have been brought to fruition (Harcourt 1993). Ecosystem management, therefore, provides a unique opportunity to study the effects of timber-cutting practices on heritage resources. In fact, if forest managers are to select harvest options sensitive to the preservation of heritage resources, this experiment is essential.

Efforts to document preharvest conditions within the ecosystem management study areas as well as the development of strategies for monitoring and assessing postharvest effects are described here. During the course of this project, the potential effects of other selected management practices will be examined as well. The suitability of forestwide survey methodology for site identification will be tested, and the success of site avoidance as a widespread protective measure used during timber harvests will be explored.

These activities are being undertaken in two stages. The first stage was an archeological survey by USDA Forest Service personnel to identify and document heritage resources within the study areas. This effort has been completed. The second, ongoing stage of analysis--monitoring sites and evaluating postharvest conditions--is being conducted by archeologists of the Arkansas Archeological Survey under the direction of Dr. Charles Ewen.

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[1] Paper presented at the Symposium on Ecosystem Management Research in the Ouachita Mountains: Pretreatment Conditions and Preliminary Findings, Hot Springs, AR, October 26-27, 1993.

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METHODS

Fieldwork to document preharvest conditions was undertaken by Ouachita National Forest Heritage Resource Technicians (HRT's), who are USDA Forest Service personnel trained in the identification and documentation of archeological sites. The HRT's follow a standard survey methodology designed by the forest archeologist to maximize site recognition in forested environments (Etchieson 1990). An archeological survey is conducted by placing parallel transect lines at 30-m intervals across a project area. All transects are subjected to intensive investigation. Areas in slopes of 10 percent or less are shovel tested at 30-m intervals. Other high-site probability areas including benches, terraces, ridgespurs, ridgetops, rock outcrops, alluvial fans, etc., receive additional emphasis. Such locations, as encountered, are shovel tested. To promote artifact recognition, till from each shovel test is screened through 1/4-inch (0.63-cm) mesh hardware cloth, and tests are excavated to a depth of 30 cm *or* until sterile subsoil is encountered. When an archeological site is identified, additional shovel testing is conducted to assess the depth of cultural deposits and artifact content and to establish site boundaries.

Postharvest assessment of heritage sites is currently being conducted under a challenge cost-share agreement with the Ouachita National Forest by archeologists from the Arkansas Archeological Survey (AAS). Survey archeologists shall revisit each of the sample sites and verify the initial baseline data wllected by Forest Service HRT's, including definition of site boundaries and depth of cultural remains. Additional information will be collected, through further shovel testing, for comparison during subsequent postharvest monitoring. Artifact wncentrations within site boundaries, preharvest site disturbances, and the presence of cultural features will be recorded. Datum points and permanent camera stations will be established on each site, and these data will be photographically and planimetrically documented. The survey archeologists shall develop a comprehensive monitoring plan to guide data collection during postharvest inspections and to assess the degree of horizontal and vertical artifact displacement, artifact breakage and deterioration, and the destruction of cultural features. The monitoring plan shall be broadly applicable to all Forest Service projects and will be implemented forestwide. Survey archeologists will conduct the first monitoring inspection to assess the effects of cutting strategies on the site sample. The results of Phase II monitoring shall be formally reported to the Forest Service by June 15, 1994.

As part of the Phase. II research project, the effectiveness of site-protection measures used during timber harvests will be assessed. Those archeological sites that are considered potentially eligible for nomination to the National Register of Historic Places shall be protected during the cutting treatments. Significant sites shall be fl agged and avoided--a Forest Service strategy employed in all timber harvests. The success of this protective measure will be gauged by the Survey archeologists during Phase II monitoring. Furthermore, the suitability of the forestwide survey strategy will be tested through the selective resurvey of research stands following the cutting treatments. At least four clearcut stands will be surveyed, and to avoid bias in site recognition, the resurveys shall not be conducted by the same personnel.

RESULTS AND DISCUSSION

Documenting Preharvest Conditions

Archeological surveys were conducted sporadically from September 25, 1991, to January 14, 1992, for the proposed Phase II Research Project (Coleman and others 1992). Fifty timber stands comprising 2,755 acres were archeologically investigated. Only two unmanaged control units, where archeological sites will not be impacted, were not surveyed. Cumulatively, 1 ,159 hours were invested in these surveys by 16 HRT's, resulting in the identification and description of 26 archeological properties. These sites occur in 16 research stands encompassing the full range of proposed cutting treatments.

Sample Selection

A sample of archeological properties were then selected for monitoring during Phase II of the experiment. Several site types have little potential to contribute to our understanding of site taphonomy including isolated artifacts, sites without associated cultural remains (e.g., mineral test pits and agricultural fields), and sites situated within protected riparian zones where timber eutting is not permitted. Such sites were omitted from the study population. An effort was made in compiling the site sample to include a range of typical Ouachita Mountain site types and 13 cultural properties were selected for inclusion in Phase II of the experiment (tab. 1). These include five late 1 9th-and early 20th-century homesteads, a sixth late historic homestead with a prehistoric component, one whiskey-still site, an historic surface trash midden, a cattle-dipping vat site; and prehistoric lithic scatters. Prehistoric sites include four lithic workshops for production of stone tools, a butchering station, and one short-term hunting camp.

Table I.--The archeological site sample taken from Phase II stands on Ouachita National Forest

Site number	Diiict	Component/function
3MN649	Caddo	Historic/homestead
3MN650	Caddo	Prehistoric/lithic workshop
34LF796	Kiamichi	Prehistoric/lithic workshop
34LF798	Kiamichi	Prehistoric/lithic workshop
34LF797	Kiamichi	Prehistoric/lithic workshop
3PL304	Mena	Historic/homestead
3MN652/3MN653	Oden	Historic/homestead
3YE431	Oden	Historic/homestead
3SC312/3SC313	Poteau	Prehistoric/lithic workshop
3MN707	Womble	Historic/homestead
3MN708	Womble	Historic/cattle dipping vat
3MN645	Womble	Historic/homestead
		Prehistoric/butchering station
3MN710	Womble	Historic/Trash Midden

Documenting Postharvest Conditions

In a preliminary report on the Arkansas Archeological Survey activities, archeologist James Harcourt concludes that the site detection skills of the HRT's are "outstanding." He further notes that Survey archeologists almost always concurred with their findings (Harcourt 1993). The combined efforts of USDA Forest Service personnel and the Arkansas Archeological Survey have resulted in a powerful synthesis of fieldwork and site documentation, leading to Phase II of the ecosystem management project. Postharvest monitoring, however, has not been undertaken and there are, as yet, no conclusions regarding timber-cutting strategies and their effects on cultural resources or the viability of Forest Service site-protection measures. Furthermore, selective resurvey of research stands to determine the effectiveness of Forest Service field methodology has not been initiated. These data, however, are forthcoming. The survey results will prove to be invaluable to forest planning and will provide new directions to heritage resource management on the Ouachita National Forest.

FUTURE PERSPECTIVES

An ecosystem is the product of past events including human alteration of the landscape. Humans have affected the environment in Arkansas for over 10 millenia--perhaps nominally at first, but this is a subject of debate. A popular theory attributes the extinction of pleistocene megafauna to Paleoindian hunters, and the human role in the frequency of fire is widely acknowledged in other regions. In the Ouachitas archeologists are just beginning to understand that late-prehistoric Indians altered floodplain ecosystems through agricultural production, although the effects of novaculite quarrying on the environment have been evident for some time. Some extensive quarries stretch for miles on mountain ridges where human activity has removed or deflated topsoil, exposing novaculite rock on the surface. Fire reddened novaculite exposures suggest that prehistoric Indians may have burned these outcrops to facilitate their mining activities. Generations of such activity could have denuded these ridges of forest vegetation. In any event, drastic environmental changes have occurred in the past 150 years with widespread commercial logging; various mining booms that have pitted the landscape in some locations; homesteading with development of pastures and agricultural fields; and finally, by creation of the Ouachita National Forest in which a period of intensive forest management--notably through tree planting and the supression of natural fire--was initiated. The magnitude of human alterations, especially those of the Forest Service has resulted in an anthropogenic forest.

Now, with adoption of the ecosystem management approach, there is an increasing need to study environmental issues in historic context and to apply the results of these studies to restoration and management of forest ecosystems (Fomey 1993). Heritage resources contain data sensitive to environmental change, and, with C-l 4 dating, dendrochronology and archeomagnetic dating, these data can provide a time-sensitive record of forest evolution. The uses of heritage resources in environmental research have been summarized by Forest Service Archeologist Sandra Fomey who lists some archeological data sets and their potential applications (Fomey 1993). Fossil pollen and opal phytoliths can reveal plant species composition and, in deeply stratified sites, provide a continuous record of plant succession and ecosystem change. Zooarcheological or fauna1 data from excavated sites can reveal past species composition and former abundance of both terrestrial and aquatic species. These data could be decisive in issues concerning endangered species designation, species reintroduction, and wildlife habitat enhancement.

More recent data sources exist that chronicle historic change in the forest environment and are frequently used by heritage resource managers. Government land office records, compiled in the 1840's in west-central Arkansas, contain detailed notes describing plant communities that surveyors encountered while traversing section lines. These data were graphically depicted in color-coded maps. Forest Service land acquisition maps from the 1930's document evidence of human alteration of the environment in that decade including roads, pastures, agricultural fields, and cutover forest land. Another rich source of information yet untapped by ecosystem researchers are the meteorological records of the U.S. Signal Service Corps. This 176-year-old record collection began in 18 17 at the observation station at Fort Smith near the northern boundary of the Ouachita National Forest. It presents a daily record concerning plant species, growing season, precipitation, wind direction, and incidence of fire.

Heritage sites and the data they contain have direct applications to issues of land management and resource planning in the national forests. Heritage resource managers offer a cultural/historical perspective to Ecosystem Management and integrated multidisciplinary studies involving heritage resource data are critical to future forest planning.

REFERENCES

Baker, James B. 1994. An overview of stand-level ecosystem management research in the Ouachita/Ozark National Forests. In: Proceedings of the symposium on ecosystem management research in the Ouachita Mountains: pretreatment conditions and. preliminary findings; 1993 October 26-27; Hot Springs, AR Gen. Tech. Rep. New Orleans LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Coleman Roger E.; Avery, Sherri; Haikey, Larry D. 1992. Cultural resources survey for Phase II New Perspectives research stands, Ouachita National Forest, Montgomery, Garland, Polk, Scott, and Yell Counties, AR, and LeFlore County, OK. Hot Springs, AR: U.S. Department of Agriculture, Forest Service, Ouachita Cultural Resources Report No. 23. 88 p.

Etchieson, Meeks. 1990. Guidelines for completing cultural resource surveys on the Ouachita National Forest. Hot Springs, AR: U.S. Department of Agriculture, Forest Service, Ouachita National Forest. 92 p.

Fomey, Sandra Jo. 1993. Heritage Resources:Tools for Ecosystems Management. 26th annual conference of Society for Historical Archeology, 1993, January 9, Kansas City. Not paged. On file with: U.S. Department of Agriculture, Forest Service, Ouachita National Forest, Supervisor's Office, Hot Springs, AR.

Harcourt, James P. 1993. New Perspectives on recent work in the Ouachitas:the Thirteen Sites Project (Draft). Fayetteville, AR: Arkansas Archeological Survey, Sponsored Research Program. On file with: U.S. Department of Agriculture, Forest Service, Ouachita National Forest, Supervisor's Office, Hot Springs, AR. 4 p.

Klinger, Timothy C. 1982. Mangrum: mitigation through excavation and preservation. Fayetteville, AR: Arkansas Archeological Survey Res. Series No. 20. 125 p.

Padgett, T. J. 1978. Blue Mountain Lake: an archeological survey and an experimental study of inundation impacts. Fayetteville, AR: Arkansas Archeological Survey Res. Series No. 13. 150 p.

Esthetics Evaluation[1]

Victor A. Rudis, James H. Gramann, and Theresa A. Herrick[2]

ABSTRACT

An analysis of summer visual attributes and an overview of ongoing scenic quality research within selected shortleaf pine (*Pinus echinata* Mill.)-hardwood stands in the Ouachita and Ozark National forests are presented. Within-stand visual attributes were reported prior to even-aged stand-level (Phase II) treatment for twelve 40-acre stands in the north, east, and south regions and for plot-level (pre-Phase I) visual attributes for twenty OS-acre plots examined two growing seasons after disturbance. No differences in visual attributes before treatment were apparent between 0.0 to 2.8 feet and 2.9 to 5.5 feet aboveground. From the stand-level study, there were no significant differences among regions but there were significant differences among stands and sample points. The plot-level study, a randomized complete block design with four blocks or landform positions and uneven-aged treatments, revealed differences by distance zone aboveground for disturbed plots. Greater foliage and twig screening and reduced visual penetration in lower zone views were associated with increased overstory removal. Visual penetration was lower and foliage and twig screening was higher in low elevation landform positions compared with high elevation landform positions. Insight from both studies suggests that a significant difference between viewing zones in summer may be suitable as an index of recent stand disturbance.

INTRODUCTION AND OVERVIEW

Public agencies and private owners are increasingly confronted with public reaction to timber harvest and reproduction cutting activities. One frequent issue revolves around the loss of esthetics caused by disturbances. Maintaining and enhancing the visual quality of forests are also becoming more important as competing uses for forest land intensify, particularly on public forest land.

Methods to measure esthetics have been successful in quantifying public perception of a forest's scenic beauty (Ribe 1989, Rudis and others 1988). Stands with limited screening and limited downed woody material and a moderate amount of sawtimber-sized trees are rated higher on a scenic beauty rating scale than those with extensive screening, small-diameter trees, or large amounts of downed woody material.

Many scenic quality studies have suggested silvicultural treatments that alter esthetics, but few have directly tested the effect of alternative treatments. Few studies have examined treatments over an extended time span, and none are specific to mixed pine (*Pinus* spp. L.) and oak (*Quercus* spp. L.) stands typical of the Ouachita Mountains. Examination of esthetics before and after treatments are applied can address tradeoffs among alternative silvicultural practices.

Esthetics is defined as an emotional response to an object. This emotional response can be divided into three measurement categories: the attributes of the object, the viewer, and intervening conditions between the viewer and the object. Esthetics is commonly quantified by viewers as scenic beauty ratings and standardized with techniques developed by Daniel and Boster (1976).

The majority of this report focuses on within-stand visual attributes for shortleaf pine (*Pinus echinata* Mill.)-hardwood stands on the Ouachita and Ozark National Forests (NF) (Baker 1994). Other works in progress address a viewer's

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background, a viewer's perception of scenic beauty, and some of the intervening conditions. These are being investigated in studies by cooperators at Arkansas Tech University, Texas A&M University, and Mississippi State University.

Arkansas Tech's role, directed by Theresa Herrick, focuses on the viewer (Rudis and others 1991). Herrick reports on a recreation user survey of scenic preferences in the Ouachita NF (Herrick and Rudis 1994). Work has also begun on stand-level (Phase II), within-stand scenic beauty estimation of pretreatment conditions prior to even-aged treatment. A postharvest assessment of seasonal differences in scenic beauty is planned.

Texas A&M University's role, directed by Jim Gramann, focuses on the object as perceived by viewers and some of the varying conditions (Rudis and Gramann 1990). Jim Gramann reports on progress in characterizing within-stand scenic beauty by season, landform, and treatment (Gramann and Rudis 1994). Uneven-aged timber management is examined for OS-acre plots in the Winona Ranger District near Lake Sylvia (Winona plots). Although not reported in this proceedings, Gramann and colleagues at Texas A&M have digitized photographs to examine color differences by season (Rudis and others 1991). Color, texture, and shadow effects are likely important in determining scenic beauty from distant views or vistas, an important component of landscape-scale (Phase III) ecosystem management research.

Mississippi State's role, directed by Dennis Cengel and Rebecca Ray, has just begun (Rudis and others 1993). Ray has taken posttreatment "intermediate" views of all 39 north, east, and south Phase II stands. Intermediate views are those typically seen from a roadside or from stand boundaries. The views encompass 3 control stands and 36 treated stands. Because views have just been photographed (October 1993), no results are reported in this proceedings. Specific objectives of this study include determining what constitutes the most visually acceptable harvests. Different groups of viewers will make assessments of scenic beauty and willingness-to-pay for altered treatments. A subset of views will be prepared as photographs and shown to loggers to estimate perceived costs. These estimates will be compared with actual cost information gathered by Kluender and others (1994).

Evaluating Within-Stand Visual Attributes

The proportion of each view within stands was sampled along a 30 degree arc outward to 50 feet (ft). Visual attributes were divided into visual penetration, foliage and twig screening, tree-bole screening, and nonvegetative screening. **Tree-bole screening** is defined as the occupancy of tree trunks at least 5 inches in diameter at breast height (d.b.h.); i.e., at 4.5 ft. **Foliage and twig screening** is vegetative screening by tree trunks less than 5 inches d.b.h. and all foliage and twigs. **Nonvegetative screening** includes rocks, bare soil, and litter. **Visual penetration** is the absence of the other three components, i.e., the "unscreened" portion of the view. Limited screening by foliage and twigs, abundant visual penetration, and a high density of tree-bole screening is correlated with high scenic beauty ratings in loblolly-shortleaf pine stands (Rudis and others 1988). The relationship of visual attributes to scenic beauty ratings is also interpretable in psychological terms (Ruddell and others 1989).

A scaling device called a screenometer was used to estimate the proportion of visual attributes. The screenometer was modified from that described in Rudis (1985) to include 9 instead of 10 horizontal segments, and two height zones instead of one. Nine horizontal segments per zone view were used to ease record keeping. Two zone views, a lower zone approximating 0 .O to 2.8 ft, and an upper zone approximating 2.9 to 5.5 ft above the ground, were etched onto the viewpiece to increase its resolution for detecting small-scale changes and compare its utility for foliage height-dependent wildlife habitat assessments.

Analysis of variance, means, and standard errors were calculated from arcsine square root transformation of proportions. Calculations, analysis of variance, F-tests, and standard errors used the general linear model (GLM) procedure (SAS Institute Inc. 1990). Means and standard errors were transformed back into proportions for display purposes. For Winona plots, planned comparisons between means associated with significant sources of variation ($P[F] < 0.05$) were conducted using t-tests and the least-squares means option (SAS Institute Inc. 1990).

Phase II Stands

Methods.--Pretreatment conditions for stands to be treated were examined in June 1992. Planned treatments included clearcut, shelterwood, group selection, and control in north, east, and south regions for a total of 16 stands (table 1). Screening estimates for each stand were based on 30 observations taken in June 1992. Observations comprised 15 sectors and 2 zone views per sector. Screening sectors were centered at 30 degree intervals beginning with azimuth 30 degrees. Sectors were viewed from the center of points coincident with the center of bird census plots (Petit and others 1994). One screenometer sector was assigned at random to each point; the second sector was 180 degrees in the opposite direction. In four stands with five points, a third sector was assigned at random. In eight stands with six points, the third sector was assigned to points 2, 4, and 6.

Table 1.-- *Region, planned treatment, and national forest compartment and stand number examined for within-stand visual attributes, Ouachita and Ozark National Forests of Arkansas*

Region*	Planned treatment	Compartment	Stand
North (Arkansas River Valley ecoregion)	Clearcut	458	16
	Shelterwood	457	12
	Group selection	46	18
	Control, no treatment	284	11
East (upper Ouachita Mountain ecoregion)	Clearcut	1067	15
	Shelterwood	1119	21
	Group selection	1124	11
	Control, no treatment	605	5
South (lower Ouachita Mountain ecoregion)	Clearcut	1658	5
	Shelterwood	27	1
	Group selection	35	42
	Control, no treatment	23	10

* See Baker (1994)

Points were systematically located across the portion of stands to be treated. Because of bird census requirements, points had to be at least 426 ft (130 m) apart and at least 295 ft (90 m) from stand boundaries. Potential stream management zones (SMZ's) were retained untreated within several stand boundaries. Points were moved away from potential SMZ's when obvious from field observations and topographic maps. Due to these restrictions and the variable shape of stands, there were five points in four stands and six points in eight stands. Photographs were taken along the same azimuths and points used to estimate screening. Scenic beauty beauty ratings, at present incomplete, will follow procedures noted elsewhere (Gramann and Rudis 1994).

Results.--Components of the analysis of variance are contained in tables 2 and 3. Table 3 lists the analysis of variance for nonvegetative screening by lower zone views, as there was no nonvegetative screening in the upper zone. An F-test failed to reject the null hypothesis that regional differences existed (P[F] = 0.08) (table 2). Analysis of variance tests revealed no significant differences by zone (P[F] ≥ 0.22). Differences by point were significant. Tests revealed significant differences among points within stands for all screening categories (P[F] < 0.01). Differences in variance among stands were not significant (P[F] ≥ 0.19) for tree-bole screening but were significant (P[F] < 0.05) for foliage and twig screening and visual penetration. Variance attributed to the two distance zones was not significant.

Table 2.--*Analysis of variance for summer 1992 visual attributes by screenometer category, Phase II stands*

Source	Degrees of freedom	Mean square variance by category		
		Tree boles	Foliage and twigs	Visual penetration
Region	2	2,057.2	2,551.4	676.8
Stand*region	9	728.5	2,713.6†	1,487.1†
Point*stand*region	56	485.3’	1,074.7‡	606.7‡
Pooled mean square combined from below: (P[F] ≥ 0.22. Denominator is residual mean square)	292	149.2	219.7	182.7
Zone	1	28.8	0.3	5.1
Zone by region	2	75.7	283.9	318.8
Zone by stand*region	9	51.8	116.1	92.6
Zone by point*stand*region	56	33.3	85.0	85.7
Residual	224	183.3	229.5	210.1
Total	359			

* within each. F-test significantly different: † P < 0.05, ‡ P < 0.01. Denominator is next lower mean square variance.

Screenometer estimates for Phase II stands are illustrated in figures 1, 2, 3 and 4. Differences among several stands were apparent. Stands to the right have higher foliage and twig screening than those to the left (fig. 2). Among stands, comparison of confidence intervals for the means among screenometer estimates suggests that there were significant differences. Actual tests of differences between stands would have to be conducted to assure statistical reliability of apparent differences.

Table 3.-- *Analysis of variance for summer 1992 nonvegetative screening 0.0 to 2.8 ft aboveground, Phase II stands*

Source	Degrees of freedom	Mean square
Region	2	225.8
Stand*region	9	124.6
Point*stand*region	56	103.5'
Residual	112	58.0
Total	179	

* = within each. F-test significantly different: † $P<0.05$.
Denominator is next lower mean square variance.

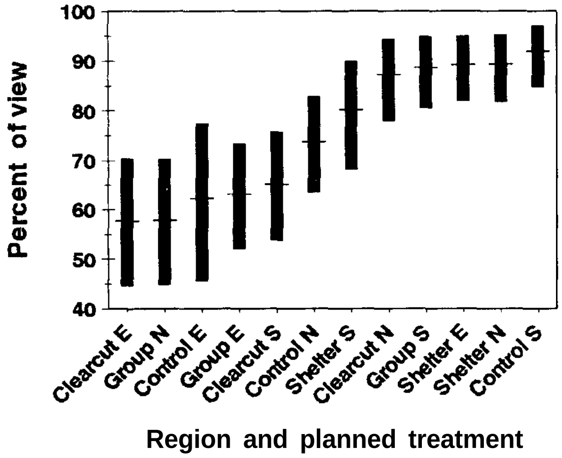

Figure 2.-- *Foliage and twig screening 0.0 to 5.5 ft aboveground, mean ±2 standard errors, by region and planned treatment, summer 1992 pretreatment conditions, Phase II stands. Region: N= north, E= east, S= south*

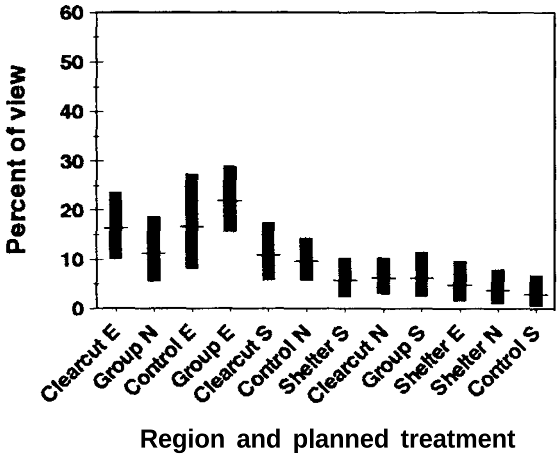

Figure 1.-- *Tree-bole screening 0.0 to 5.5 ft aboveground, mean ±2 standard errors by region and planned treatment, summer 1992 pretreatment conditions, Phase II stands. Region: N= north, E= east, S= south*

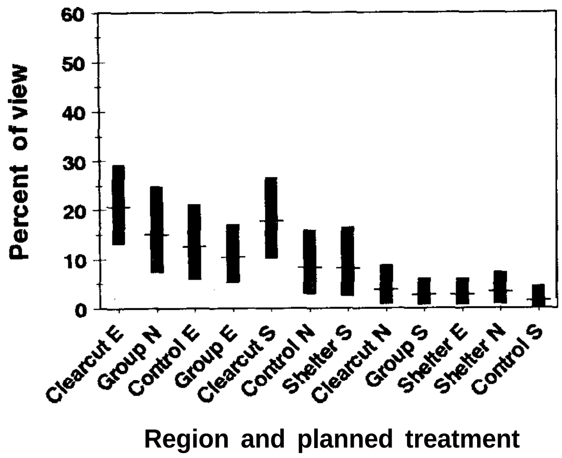

Figure 3.-- *Visual penetration 0.0 to 5.5 ji aboveground, mean ±2 standard errors, by region and planned treatment, summer 1992 pretreatment conditions, Phase II stands. Region: N= north, E= east, S= south*

From previous scenic beauty research (Ribe 1989) and studies of screening in east Texas pine stands (Ruddell and others 1989, Rudis and others 1988), we anticipate that scenes with a lower proportion of foliage and twig screening and high proportion of tree-bole screening and visual penetration will receive the highest scenic beauty ratings. Outcome of scenic beauty ratings is uncertain for stands and scenes where nonvegetative screening is present.

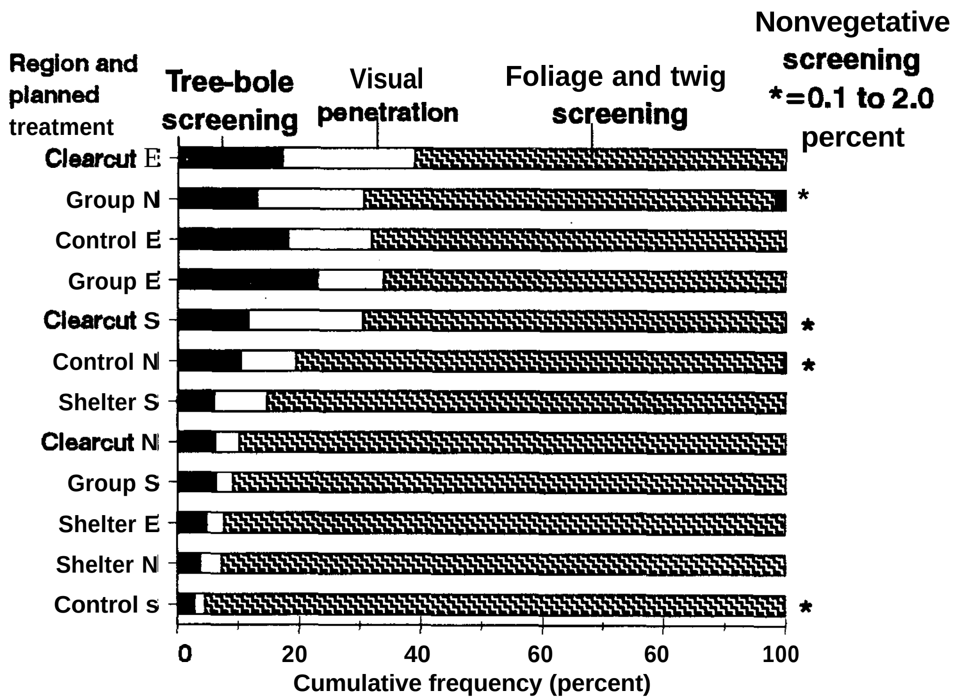

Figure 4.-- *Cumulative mean value of summer* 1992 *pretreatment visual attributes 0.0 to 5.5 ft aboveground by screenometer category, region and planned treatment, Phase II stands. Region: N= north, E= east, S= south*

Winona Plots

Methods. --Visual attribute conditions were examined from an ongoing plot-level study of silvicultural treatments made in January, 1989. Each plot was a OS-acre square area centered within a 1. l-acre treated area. Visual attribute estimates were made in 12 directions for each of 20 plots in summer and winter, beginning in summer (September 1990). For comparison with Phase II estimates, only summer data are discussed and reported here.

Screening estimates were based on 24 summer observations, comprising 12 sectors and 2 zone views. Sectors were located systematically and centered at intervals beginning with azimuths at 45 degrees from the azimuth of plot comers toward plot centers. Sectors were viewed from eight points inward toward the plot center: one at each of 4 comers of the plot and one half-way between each comer. Four sectors were also measured from the center of each plot with azimuths directed toward plot edges. Eight photographs were taken along the same azimuths as inward views used in scenic beauty assessments (Gramann and Rudis 1994).

Four blocks or landform positions with slopes ranging from 10 to 20 percent referred to elevation and slope aspect (lower north, middle north, upper north, and upper south) and corresponded to a moisture and potential microclimate or site-productivity gradient. Plots were assigned to treatments following procedures for a randomized complete block design. There were four plots harvested using uneven-aged guidelines and one unharvested plot (Control) for each landform. Treatments included alteration of existing stands to 60 square feet (ft^2) of pine basal area (BA) per acre and one of the following: 30 ft^2 BA hardwoods (Scatter 30, S30), 15 ft^2 BA hardwoods in a grouped condition (Group 15, G15), 15 ft^2 BA hardwoods in scattered condition (Scatter 15, S15), and 0 ft^2 BA hardwoods (No hwds). Initial BA ranged from 100 to 130 ft^2 BA, with the majority of BA in shortleaf pine trees approximately 70 years old. Hardwood BA consisted chiefly of oak species approximately 50 years old (Shelton and Murphy 1991). Shelton and Murphy (1990, 1991) provide other details on pretreatment stand conditions.

Results. --F-tests for analysis of variance among screenometer estimates revealed significant differences (table 4). Tree-bole screening was not significantly different by view zone (P[F] 20.4).

Table 4.--*Analysis of variance for summer 1990 visual attributes by screenometer category, Winona plots*

		Mean square variance by category		
Source	Degrees of freedom	Tree boles	Foliage and twigs	Visual penetration
Landform	3	42.4	4,200.0‡	2,902.0‡
Treatment	4	1,782.6‡	3,736.8‡	1,997.0†
Zone	1	77.3	85,218.6‡	68,782.3‡
Zone by treatment	4	19.8	5,850.4‡	6,297.3‡
Experimental design	27	137.4	793.8'	553.1'
Residual	440	161.3	381.0	356.8
Total	479			

F-test significantly different: † $P < 0.05$, ‡ $P < 0.01$. Denominator is residual sampling variance for the experimental design and experimental design for other variances.

Tree-bole screening means were significantly different ($P|t| < 0.05$) between substantially undisturbed (Control and S30) and more disturbed (G15, S 15, and No hwds) plots (fig. 5). Zone differences were significant for foliage and twig screening (fig. 6) and visual penetration (fig. 7). Differences were largest for foliage and twig screening between untreated (Control) and disturbed plots in the upper zone, and among substantially undisturbed (Control and S30), somewhat disturbed (G15 and S 15), and more disturbed (No hwds) plots in the lower zone (fig. 6). The three visual attributes are summarized in figure 8.

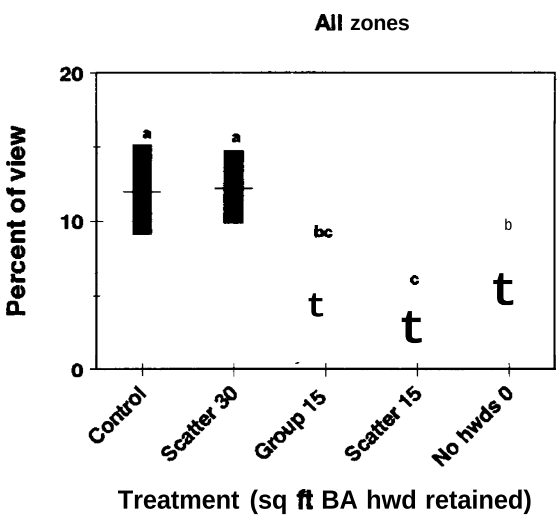

Figure 5. -- *Tree-bole screening 0.0 to 5.5 ft aboveground, mean ±2 standard errors by treatment, summer 1990, Winona plots. Means with the same letter are not significantly different ($P|t| > 0.05$)*

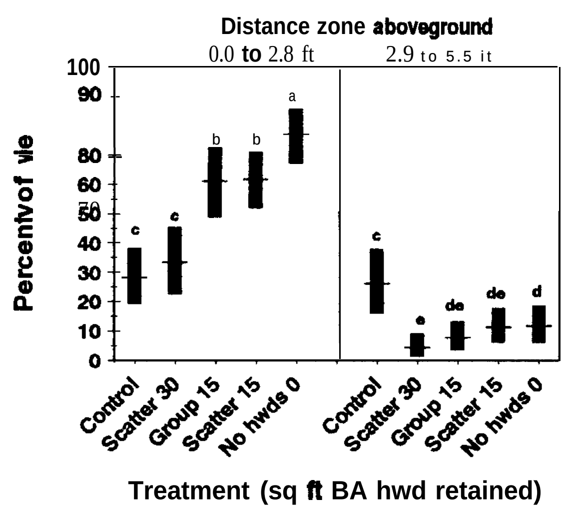

Figure 6. -- *Foliage and twig screening, mean ±2 standard errors, by treatment and zone (distance aboveground), summer 1990, Winona plots. Means with the same letter are not significantly different ($P|t| > 0.05$)*

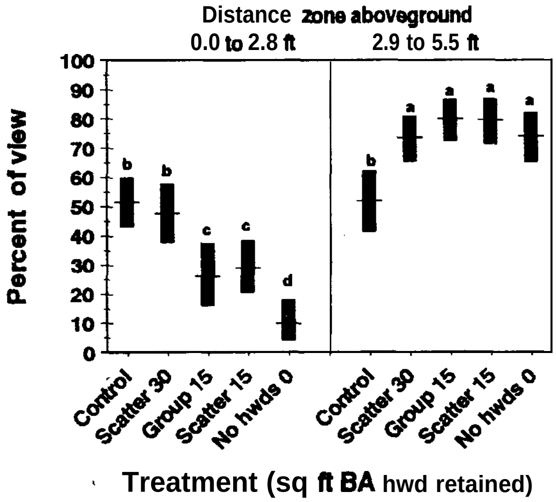

Figure 7.-- *Visual penetration, mean ±2 standard errors, by treatment and zone (distance aboveground), summer 1990, Winona plots. Means with the same letter are not significantly different (P|t| >0.05)*

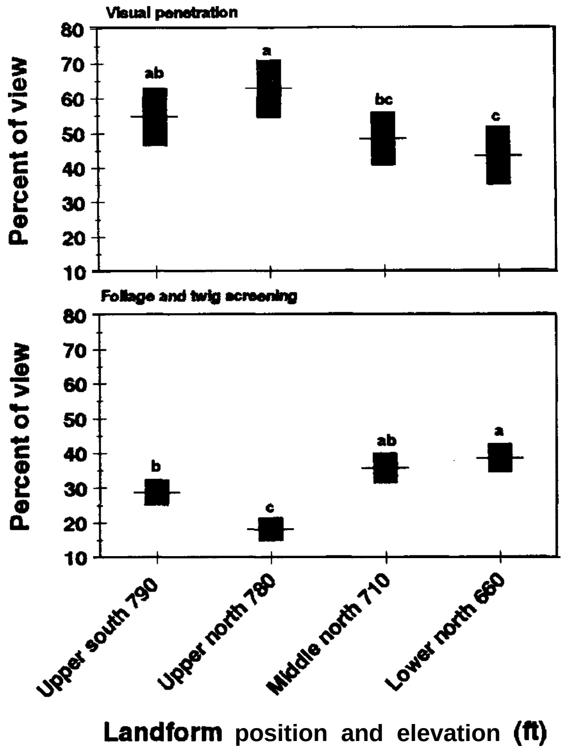

Figure 9.-- *Visual penetration and foliage and twig screening, mean ±2 standard errors, by landform position and elevation, summer 1990, Winona plots. Within each visual attribute, means with the same letter are not significantly different (P |t| > 0.05)*

Landform variance was significant for foliage and twig screening and visual penetration. Differences were largest between lower and upper Iandform positions (fig. 9). The experimental design variance was significant. Because landform interaction was not replicated, statistical examination of interaction with other sources of variation was not possible. Mean values among the three visual attributes varied widely by treatment and landform (fig. 10).

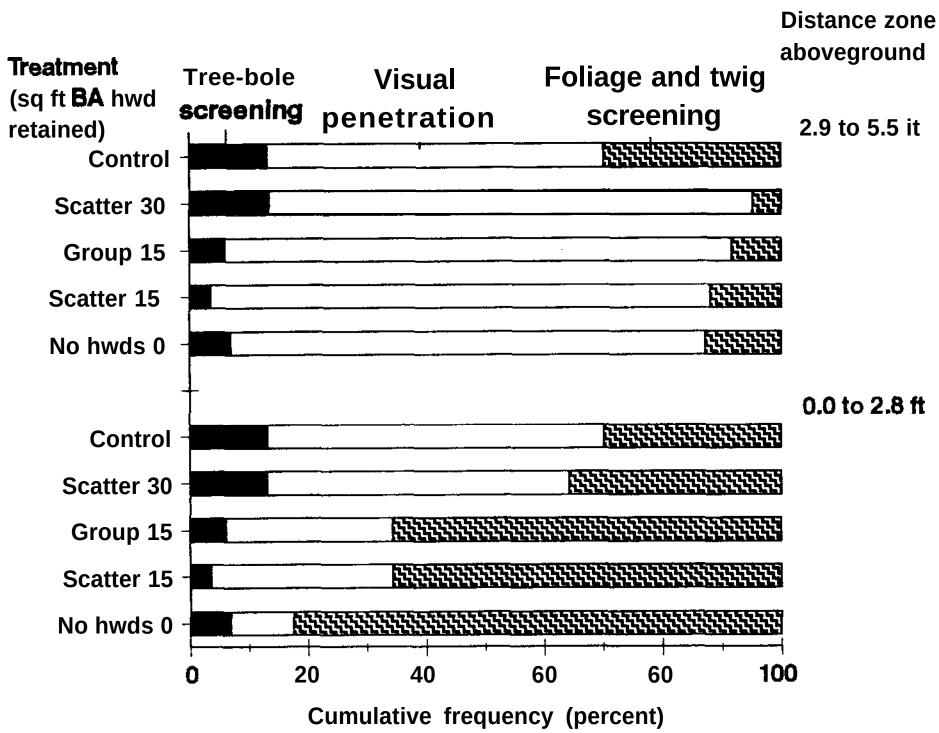

Figure 8.-- *Cumulative mean value of summer 1990 visual attributes by screenometer and zone (distance aboveground) category, Winona plots*

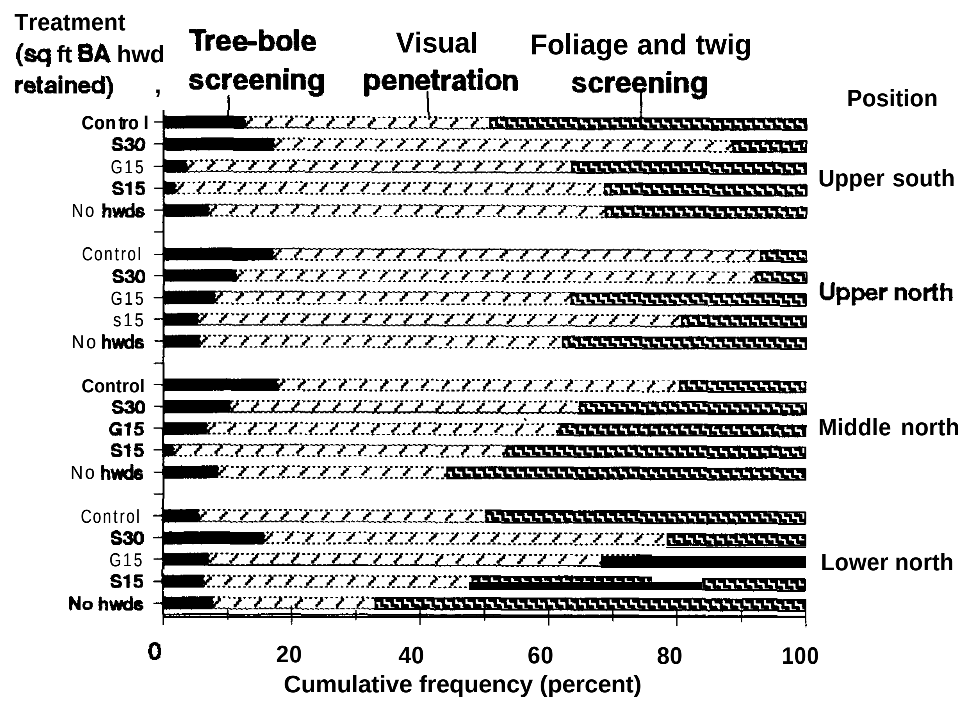

Figure 10.-- *Cumulative mean value of summer 1990 visual attributes by screenometer category, treatment, and landform position, Winona plots*

DISCUSSION AND CONCLUSIONS

No significant vegetative screening and visual penetration differences between upper and lower zones in pretreatment Phase II stands or Winona control plots were found. Only disturbed plots had significant zonal differences. We hypothesize that Phase II stand-level treatments will create zonal differences in summer visual attributes. The lack of differences among zones may be a useful gauge of a stand's recovery from treatments for comparable pine-hardwood stands in the Ouachita Mountains. Significant summer visual attribute differences between zones may be indicative of recent disturbance. With additional study elsewhere, visual attribute zone differences could serve as disturbance detection indices for stands with no known historical records.

Phase II Stands

Although the pretreatment sample design for Phase II stands considered point location as a random effect, significant differences in visual attributes were noted among sample points within stands. This finding suggests the need to further characterize point-location attributes and to consider points as fixed effects after treatments have been applied. Additional examination of visual attributes and scenic beauty measures by point before and after treatment may reveal significant differences in the diversity of scenic beauty values within stands.

Nonvegetative screening as a visual attribute may be important in estimating scenic beauty ratings and treatments in stands with steep terrain. However, previous visual attribute studies either occurred on gentle slopes, flat topography, or did not separate view zones. Group north, located on one of Arkansas' highest elevations (Mount Magazine), was one of the few stands with nonvegetative screening and the only stand examined with > 1 -percent nonvegetative screening. Group north's location, steep slopes, limited occurrence of understory foliage and twigs, and lack of obvious evidence of prior cutting activity (Rudis, personal observation) may make it unique in comparison to other stands in this study.

Winona Plots

Winona plot analysis indicated that foliage and twig screening in the lower zone view increases and visual penetration decreases with stand disturbance. Two-year old disturbances continued to maintain greater visual penetration above 2.8 ft.

The increase in sunlight and subsequent vegetative growth could account for most of the decline in visual penetration in the lower zone. The potentially drier and less fertile microclimate on higher landform positions may account for reduced foliage and twig screening and increased visual penetration when compared with lower landform positions.

Having no estimates of visual attributes before disturbance and no replication of landform interaction, we can only speculate on the landform relationship with treatment. We hypothesize that the favorable microclimate in the middle north and lower north landform positions enhances the vegetative recovery of recently disturbed forests, resulting in greater foliage and twig screening than in upper north and upper south positions. In future studies, sampling designs that permit statistical tests of the relationship among landform, treatment, and zones would be desirable.

From personal observation, some debris and forest floor disturbance from treatment activities were present. Debris included dead twigs, branches, and tree tops--all of which was included in foliage and twig screening. Scenic beauty ratings for Winona plots decline with increasing intensity of disturbance (Gramann and Rudis 1994). We conclude that, two growing seasons after disturbance, mitigating disturbance impacts on esthetics include removal of debris associated with lower zone foliage and twig screening.

The choice between retaining 15 ft^2 of hardwoods scattered (S15) or grouped (G15) is important from a silvicultural perspective and may be important from an esthetics perspective. From scenic beauty evaluation, G15 yields higher scenic beauty ratings (Gramann and Rudis 1994). Statistical tests for each of the three visual attributes failed to distinguish significant differences for foliage and twig screening ($P|t| = 0.38$) and visual penetration ($P|t| = 0.63$). However, there was a marginally significant ($P|t| = 0.07$) and higher proportion of tree boles visible in the grouped than in the scattered treatment. We know that tree-bole screening contributes positively to scenic beauty ratings (Rudis and others 1988), and conclude that grouping hardwoods has a marginal esthetic advantage. The mechanism remains unclear, however. We suggest group retention of hardwoods increases the number of views dominated by tree boles, on average, when compared with views from areas where retention of hardwoods is scattered.

Mitigating silvicultural alternatives might include retaining shade-producing overstory trees to suppress summer growth of understory foliage, periodic removal of unwanted foliage that screens the view, and removal of downed woody material from the forest floor. However, downed woody material assessment, examination of visual attributes in other seasons after plots have recovered from disturbance, and more detailed investigation of landform position are warranted. Such studies are needed before recommendations can be generalized beyond this initial examination.

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REFERENCES CITED

Baker, James B. 1994. An overview of stand-level ecosystem management research in the Ouachita/Ozark National Forests. In: Baker, James B., ed. Ecosystem management research in the Ouachita mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Daniel, T.C.; Boster, R.C. 1976. Measuring landscape aesthetics: the scenic beauty estimation method. Res. Pap. RM-167. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 66 p.

Gramann, James H. ; Rudis, Victor A. 1994. Effect of hardwood retention, season, and landform on perceived scenic beauty. In: Baker, James B., ed. Ecosystem management research in the Ouachita mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Herrick, Theresa A.; Rudis, Victor A. 1994. Visitor preference for forest scenery in the Ouachita National Forest. In: Baker, James B., ed. Ecosystem management research in the Ouachita mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Kluender, Richard A.; Lortz, David A.; Stokes, Bryce J. 1994. Production time, total costs and residual damage at varying harvest intensities. In: Baker, James B., ed. Ecosystem management research in the Ouachita mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Petit, Daniel R.; Petit, Lisa J.; Martin, Thomas E.; Thill, Ronald E.; Taulman, James F. 1994. Breeding birds of late-rotation pine-hardwood stands in Arkansas and Oklahoma: community characteristics and similarity to other regional pine forests. In: Baker, James B., ed. Ecosystem management research in the Ouachita mountains: pretreatment conditions and preliminary findings; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Ribe, R.G. 1989. The aesthetics of forestry: what has empirical preference research taught us? Enviromnental Management. 13(1): 55-74.

Ruddell, Edward J.; Gramann, James H.; Rudis, Victor A.; Westphal, Joanne M. 1989. The psychological utility of visual penetration in forest scenic beauty models. Environment and Behavior. 21(4):393-412.

Rudis, Victor A. 1985. Screenometer: a device for sampling vegetative screening in forested areas. Canadian Journal of Forest Research. 15: 996-999.

Rudis, Victor A.; Gramann, James H. 1990. Amenity impacts and seasonal dynamics of mixed pine-hardwood stand management. Study 4810 FS-SO-4801-1-90-31. On file with: Southern Forest Experiment Station, 701 Loyola Avenue, New Orleans. LA 70113.

Rudis, Victor A.; Gramann, James H.; Ruddell, Edward J.; Westphal, Joanne M. 1988. Forest inventory and management-based visual preference models of southern pine stands. Forest Science. 34(4): 846-863.

Rudis, Victor A.; Gramann, James H.; Whisenant, Steven G; Loh, Douglas K. 1991. Amenity impacts and seasonal dynamics mixed pine-hardwood stand management: visual quality evaluation and modeling of reproduction cutting methods. Study 4810 FS-SO-4801-1-90-31. Problem 1, addendum B. On file with: Southern Forest Experiment Station, 701 Loyola Avenue, New Orleans, LA 70113.

Rudis, Victor A.; Herrick, Theresa; Freed, Michael. 1991. Amenity impacts and seasonal dynamics of mixed pine-hardwood stand management: even-aged stands. Study 4810 FS-SO-4801-90-31. Problem 1, addendum C. On file with: Southern Forest Experiment Station, 701 Loyola Avenue, New Orleans, LA 70113.

Rudis, Victor A.; Ray, Rebecca J.; Cengel, Dermis J.; Clark, James D.; Watson, William F.; Stokes, Bryce J. 1993. Visual impact of recently cut stands on intermediate-view forest scenes: a benefit-cost comparison of alternative harvest regimes. Study 4810 FS-4801-1-93-I. On tile with: Southern Forest Experiment Station, 701 Loyola Avenue, New Orleans, LA 70113.

SAS Institute Inc. 1990. SAS/STAT user's guide. Version 6, 4th ed. Chapter 24: the GLM procedure. Cary, NC: SAS Institute, Inc.: 892-996. Vol. 2.

Shelton, Michael G.; Murphy, Paul A. 1990. Uneven-aged management of shortleaf pine in the Ouachita National Forest: effects of maintaining a hardwood component during conversion from even-aged management. Progress report 4110 FS-SO-4106-63. On file with: Southern Forest Experiment Station, 701 Loyola Avenue, New Orleans, LA 70113.

Shelton, Michael G.; Murphy, Paul A. 1991. Age and size structure of a shortleaf pine-oak stand in the Ouachita Mountains--implications for uneven-aged management. In: Coleman, Sandra S.; Neary, Daniel G., comps. Proceedings of the 6th biennial southern silvicultural research conference; 1990 October 30-November 1; Memphis, TN. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 616-629. Vol. 2.

Visitor Preference for Forest Scenery in the Ouachita National Forest[1]

Theresa A. Herrick and Victor A. Rudis[2]

ABSTRACT

The majority of forest visitors interviewed between June through October 1991 and April through October 1992 preferred forest scenery that was "undisturbed," contained a "variety of natural features," or was associated with "natural" or "beauty" descriptions. Few respondents preferred "younger tree species with open areas." Results suggest that undisturbed conditions are important along with vegetation management to support a variety of natural features. Slight differences are noted when examining preferences by respondents' sex, age class, education level, principal recreation activity, month visited, and sites where interviewed. The order of questions appeared to affect the respondents' forest scenery descriptions. Interviews were conducted as part of an onsite survey involving a larger recreation-user study (CUSTOMER survey) for sites among four USDA Forest Service Ouachita National Forest ranger districts. Recommendations are made for using CUSTOMER survey data in future forest scenery preference research.

INTRODUCTION

The U.S. Department of Agriculture, Forest Service (USDA-FS), National Forest System, is charged with managing it's nearly 200 million acres of public land under a multiple-use philosophy. Recreation is one of the identified multiple uses. To adequately plan for recreation, public land managers need data describing the characteristics and preferences of recreating visitors.

To provide information about recreational use and users of public land, an interagency, multidisciplinary group of scientists, planners, and policy analysts developed tools and procedures necessary for the task. The result of this effort was the Public Area Recreation Visitor Survey (PARVS) developed and tested in 1985 by the Outdoor Recreation and Wilderness Assessment Group (ORWAG) of the USDA-FS Southeastern Forest Experiment Station (Reed and others 1992). Data were collected on recreation activities, recreation trips, expenditures, demographics, and satisfaction with services and facilities. PARVS was later modified to obtain information about special issues identified by forest managers and believed to be important for particular sites. The revised PARV surveys became known as CUSTOMER surveys. CUSTOMER surveys were conducted for selected Ouachita National Forest sites in 1991 and 1992.

Parallel to CUSTOMER surveys, scientists from the visual quality research group associated with the New Perspectives (now Ecosystem Management) research team (Rudis and others 1994) began a study of various silvicultural treatments and their visual impacts. The ORWAG team and the visual quality research group made an effort to coordinate research activities for CUSTOMER survey sites on the Ouachita National Forest. However, due to budget and interview-time restrictions, flexibility in the use of additional questions and alternative sampling procedures was limited. As a compromise, two short questions were added to the special issues section: one ranking preferences for forest descriptions and another describing preferred forest scenery.

Presented in this report are initial findings of these two questions added to the special issues section. The primary goal is to describe the scenery preferences of CUSTOMER survey respondents by site and the utility of simplified survey questions to respondents' scenic preferences. A secondary goal is to develop likely hypotheses regarding differences in scenic preferences that vary with forest visitor demographics, principal recreation activity, month of visit, and survey site location.

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SURVEY SITES AND SAMPLING DESIGN

Survey sites were located in four ranger districts in the Ouachita National Forest. During the summer and fall of 1991, forest visitors were surveyed at 12 locations in or near the Winding Stair National Recreation Area (NRA) within Kiamichi ranger district in Oklahoma. In 1992, visitors were surveyed in Arkansas at 10 locations: 2 in the Caddo ranger district at Little Missouri Falls and Albert Pike Recreation Area; 1 in the Mena ranger district at Shady Lake; and 7 in or near Lake Sylvia on the Winona ranger district. A complete list of locations for both years appears in table 1.

Table 1.--*Ouachita National Forest sites and locations where CUSTOMER survey interviews were conducted in 1991 and 1992*

Site, ranger district (RD), time period, and **survey locations**
Winding Stair National Recreation Area, Kiamichi RD
June through October 1991
- Equestrian Campground
- Billy Creek
- Winding Stair
- Cedar Lake South
- Cedar Lake North
- Ctdar Lake Shady
- West End Vista
- Emerald Vista
- Kerr
- Horsethief and Ouachita Junction
- Cedar Lake Dam
- Cedar Lake Southshore
Lake Sylvia, Winona RD
April through October 1992
- Lake Sylvia campground
- Lake Sylvia beach and picnic area
- Ouachita National Recreation Trail, trailhead
- Trees of Forest Trail parking lot
- Flatside/Pinnacle Vista parking lot
- Winona Scenic Drive, FS #132
- Lake Winona Road FS #778
Caddo, Caddo RD
June through August 1992
- Little Missouri Falls
- Albert Pike Recreation Area
Mena, Mena RD
June through August 1992
- Shady Lake

Visitors responded to a 20-minute onsite interview that included a special issues section. Nearly all visitors encountered participated in the survey[3]. These onsite surveys served as an exit interview of visitors who had completed or nearly completed their visits. Details on nonscenery questions and other responses from both onsite interviews and a related followup mail questionnaire are reported elsewhere (Coker and others 1993a, 1993b; Reed and others 1992).

In 1991, the survey instrument was split into two versions. Both versions contained identical demographic and trip profile sections. One version also contained questions about other onsite activities, contingent valuation, and the National Satisfaction Index. Another version contained an annual activity profile and the special issues section. An example of the special issues section for the Winding Stair NRA is found in the Appendix. In 1992, all the survey instruments were the same, and all onsite surveys contained a special issues section.

Examined in this report are two questions about forest scenery in the special issues section: (1) What type of scenery do you prefer in a forest environment? and (2) What words would you use to describe your preference in forest scenery? The two questions were asked in their present order for Winding Stair NRA and Lake Sylvia sites; reverse order was used for the Caddo and Mena sites.

For the first question, respondents were asked to rank forest descriptions in order of preference from "1" (most preferred) to "5" (least preferred). Results are reported for the one description comprising the majority of responses that were most preferred; i.e., ranked “1” or “2” out of 5, for each of the sites surveyed. A second description is listed if one description did not comprise the majority of responses. Forest descriptions provided were:

_ Undisturbed.
__ Large mature trees.
__ Trees of mixed sizes and species.
__ Younger tree species with open areas.
__ Variety of natural features (cliffs, rocks, water, etc.).

[3] CUSTOMER survey staff, 1993 pers. comm. to senior author by phone, Athens. GA: USDA-FS, Outdoor Recreation and Wilderness Assessment Research Unit.

For the second question, a content analysis of responses was performed using PROC CONTENT (SAS Institute, Inc. 1989). Results are reported by survey site for the most frequently used word and word combinations.

RESULTS

Ranked Forest Descriptions and Demographics

Table 2 presents the distribution of forest descriptions by rank for Winding Stair NRA. Most (71 percent) respondents indicated "variety of natural features" as the preferred forest scenery. The majority of respondents were males (63 percent), between the ages of 31 and 50 years old (65 percent), and who had completed high school or some college courses **(64** percent). The majority were interviewed in July (53 percent) (table 3). Median preferences among demographic classes were for "variety of natural features" (table 3). Principal recreation activities of respondents were sightseeing (41 percent), followed by developed camping (25 percent), and other activities (33 percent) (table 4). Differences in preferred scenery were suggested, with sightseeing respondents preferring "variety of natural features" (77 percent) and developed campers preferring "undisturbed" scenery (63 percent) (table 4).

Respondent preferences at the Lake Sylvia site differed from those at Winding Stair NRA. The majority preferred "undisturbed" scenery; "large mature trees" and "trees of mixed sizes and species" were also important (table 5). Respondents were predominantly males (60 percent), between the ages of 21 to 50 years old (77 percent), and who had completed high school or some college courses (68 percent). The majority were interviewed in June and July (69 percent) (table 6). Median preferences among demographic classes were for "undisturbed" scenery and "large mature trees" (table 6). Principal recreation activities among respondents were camping (33 percent) and swimming (24 percent), followed by 18 other activities (43 percent) (table 7). Some variation in preferences existed among recreational activities.

Table 8 presents the distribution of forest descriptions by rank for the Caddo site. The majority (66 percent) of respondents indicated "undisturbed" as the most preferred forest scenery. The majority of respondents were males (65 percent), between the ages of 3 1 and 50 years old (57 percent), and who had completed high school or some college courses (65 percent). The majority were interviewed in August (52 percent) (table 9). Median preferences among demographic classes were for "undisturbed' scenery. Principal recreation activities among respondents were camping (49 percent) and sightseeing (22 percent), followed by eight other activities (28 percent) (table 10). Differences in scenery preferences between "variety of natural features" and "undisturbed" were slight, as both were closely ranked.

Respondent preferences at the Mena site were similar to those for Winding Stair NRA and the Caddo site. The majority indicated preference for "undisturbed" *scenery*, with "variety of natural features" competing for second place (table 11). Respondents were predominantly males (73 percent), between the ages of 31 and 50 years old (65 percent), and who had completed high school or some college courses (60 percent) (table 12). The majority were interviewed in July (85 percent) (table 12). Median preferences among age classes and education completed were for "undisturbed," "variety of natural features," and "trees of mixed sizes and species" (table 12). Principal recreation activities among respondents were camping (89 percent) and sightseeing (4 percent), followed by five other activities (7 percent) (table 13). The majority of campers preferred "undisturbed" scenery.

Comparisons of forest scenery preferences among the four sites were made by comparing modal rank; i.e., the rank associated with the maximum number of respondents. Modal rank for the "undisturbed" forest description is I (most preferred) for all sites (tables 2, 5, 8, and 11). Comparisons suggest that there are important differences in other preferences between Lake Sylvia and other sites. "Large mature trees" has a modal rank of 2 for Lake Sylvia and 3 for the other sites. "Trees of mixed sizes and species" has a modal rank of 2 for Lake Sylvia and 4 for other sites. "Younger tree species with open areas" has a modal rank of 3 at Lake Sylvia and 5 at other sites. "Variety of natural features" has a modal rank of 4 at Lake Sylvia and 1 at other sites.

Other modal rank comparisons suggest little difference in demographics (tables 3, 6, 9, and 12). A notable difference exists in principal activities between the variety of activities at Lake Sylvia and the prominence of sightseeing at Winding Stair NRA when compared with other sites (tables 4, 7, 10, and 13). Data in tables 2, 5, 8, and 11 illustrate a lack of response for forest descriptions from some forest visitors.

Table 2.-- *Forest scenery preferences by forest description and rank (1 = most preferred) in Winding Stair NRA, 1991. sample size = 78*

Forest description	Rank 1	2	3	4	5	Not ranked
	- - - frequency of responses - - -					
Undisturbed	24	18	11	13	9	3
Large mature trees	14	20	26	12	3	3
Trees of mixed sixes and species	10	14	18	29	4	3
Younger tree species with openareas	1	1	9	7	57	3
Variety of natural features (cliffs, rocks, water, etc.)	29	24	9	12	1	3

Table 3.-- *Preferred (ranked first or second out of five) forest descriptions for a majority of respondents by sex, age, education, and month of interview, Winding Stair NRA, 1991*

Demographic category	Sample size	Majority preferred Description	Frequency
All respondents	75	Variety of natural features	53
Sex			
Male	47	Variety of natural features	32
Female	28	Variety of natural features	21
Age class			
11-20	3	Undisturbed	3
21-30	11	Undisturbed	9
31-40	15	Variety of natural features	10
41-50	23	Variety of natural features	14
51-60	11	Variety of natural features	8
61-70	8	Undisturbed	6
71-80	4	Undisturbed	4
Education completed			
≤ 8th grade	1	Undisturbed	1
Some high school	3	Large mature trees	3
High school	22	Variety of natural features	16
Some college	26	Variety of natural features	18
Associate degree	13	Variety of natural features	12
Bachelor degree	10	Undisturbed, variety of natural features	6
Month of interview			
June	22	Variety of natural features	16
July	40	Variety of natural features	27
August	5	Undisturbed, variety of natural features	4
October	8	Variety of natural features	6

Table 4.-- *Preferred (ranked first or second out of five) forest descriptions for a majority of respondents by principal activity, Winding Stair NRA, 1991*

Principal activity	Sample size	Majority preferred Description	Frequency
All respondents	75	Variety of natural features	53
Sightseeing	31	Variety of natural features	24
Developed camping	19	Undisturbed	12
Horseback riding	11	Variety of natural features	8
Day hiking	3	Variety of natural features	3
Fishing	3	Large mature trees	3
Backpacking	2	Undisturbed	2
Primitive camping	2	Trees of mixed sixes and species, variety of natural features	2
Bicycling	1	Trees of mixed sixes and species	1
Hunting	1	Large mature trees	1
Swimming	1	Trees of mixed sizes and species	1
Wildlife observation	1	Undisturbed	1

Table 5.-- ***Forest scenery preferences by forest description and rank (1 = most preferred), Lake Sylvia, 1992, sample size = 283***

Forest description	Rank 1	2	3	4	5	Not ranked
	- - - frequency of responses - - -					
Undisturbed	127	26	25	6	81	18
Large mature trees	58	78	42	17	70	18
Trees of mixed sixes and species	31	94	70	31	39	18
Younger tree species with open areas	16	43	102	44	60	18
Variety of natural features (cliffs, rocks, water, etc.)	33	24	26	167	15	18

Table 6.-- ***Preferred (ranked first or second out of five) forest descriptions for a majority of respondents by sex, age, education, and month of interview, Lake Sylvia, 1992***

Demographic category	Sample size	Majority preferred Description	Frequency
All respondents	265	Undisturbed	153
Sex			
Male	159	Undisturbed	93
Female	106	Undisturbed	60
Age class			
1 l-20	11	Undisturbed	7
21-30	49	Undisturbed, trees of mixed sixes and species	25
3140	97	Large mature trees	57
41-50	59	Large mature trees	34
51-60	32	Undisturbed	24
61-70	14	Undisturbed	9
71-80	3	Undisturbed	2
Education completed			
≤ 8th grade	4	Trees of mixed sixes and species	3
Some high school	18	Undisturbed	11
High school	89	Undisturbed	16
Some college	91	Undisturbed	18
Associate degree	38	Large mature trees	12
Bachelor degree	26	Undisturbed	16
Month of interview			
April	25	Undisturbed	14
May	32	Large mature trees	20
June	83	Large mature trees	46
July	101	Undisturbed	61
August	18	Undisturbed, large mature trees	10
September	6	Undisturbed	5

Table 7.-- ***Preferred (ranked first or second out of five) forest descriptions for a majority of respondents by principal activity, Lake Sylvia, 1992***

Principal activity	Sample size	Majority preferred Description	Frequency
All respondents	265	Undisturbed	153
Camping	87	Undisturbed, large mature trees	49
Swimming	64	Undisturbed	44
Running or jogging	25	Undisturbed, trees of mixed sixes and species	15
Relaxing	20	Undisturbed, trees of mixed sizes and species	11
Picnicking	17	Undisturbed, trees of mixed sixes and species	11
Family gathering	14	Trees of mixed sizes and species	9
Day hiking	7	Undisturbed	5
Fishing	5	Large mature trees	4
Backpacking	5	Undisturbed	3
Sightseeing	1	Undisturbed	2
Leading a group	4	Large mature trees	3
Sunbathing	3	Large mature trees	3
Nature study	2	Younger tree species with open areas, undisturbed areas	1
Walking	2	Large mature trees, younger tree species with open areas	1
Berry picking	1	Large mature trees	1
Getting wood	1	Undisturbed	1
Horseback riding	1	Trees of mixed sixes and species	1
Joy riding	1	Undisturbed	1
Small game hunting	1	Trees of mixed sixes and species, undisturbed	1
Volleyball	1	Large mature trees	1

Table 8.-- *Forest scenery preferences by forest description and rank (1 = most preferred), Caddo, 1992, sample size = 139*

Forest description	Rank					Not ranked
	1	2	3	4	5	
	- - - frequency of responses - - -					
Undisturbed	63	28	13	24	10	1
Large mature trees	14	44	49	25	5	2
Trees of mixed sizes and species	12	27	43	52	3	2
Younger tree species with open areas	0	7	3	16	109	4
Variety of natural features (cliffs, rocks, water, etc.)	50	33	30	18	8	0

Table 9.-- *Preferred (ranked first or second out of five) forest descriptions for a majority of respondents by sex. age, education, and month of interview, Caddo, 1992*

Demographic category	Sample size	Majority preferred	
		Description	Frequency
All respondents	139	Undisturbed	91
Sex			
Male	90	Undisturbed	63
Female	48	Variety of natural features	33
Age class			
11-20	6	Variety of natural features	4
21-30	21	Undisturbed	15
31-40	47	Undisturbed	31
41-50	32	Undisturbed	22
51-60	13	Undisturbed	11
61-70	15	Undisturbed	9
71-80	2	Variety of natural features	1
81-90	1	Younger tree species with open areas	1
Education completed			
≤ 8th grade	3	Large mature trees, variety of natural features	2
Some high school	11	Undisturbed	7
High school	48	Undisturbed	32
Some college	42	Undisturbed	33
Associate degree	19	Variety of natural features	11
Bachelor degree	15	Variety of natural features	12
Month of interview			
June	6	Undisturbed	5
July	60	Undisturbed	45
August	72	Variety of natural features	47

Table 10.-- *Preferred (ranked first or second out of five) forest descriptions for a majority of respondents by principal activity Caddo, 1992*

Principal activity	Sample size	Majority preferred	
		Description	Frequency
All respondents	139	Undisturbed	91
Camping	68	Variety of natural features	45
Sightseeing	31	Undisturbed, variety of natural features	22
Swimming	21	Undisturbed	15
Picnicking	9	Variety of natural features	6
Family gathering	3	Variety of natural features	2
Walking	2	Variety of natural features, large mature trees	1
Backpacking	1	Variety of natural features	1
Relaxing	1	Variety of natural features	1
Running or jogging	1	Variety of natural features	1
Fishing	1	Variety of natural features	1

Table 11.-- *Forest scenery preferences by forest description and rank (1 = most preferred), Mena, 1992, sample size=87*

Forest description	Rank 1	2	3	4	5	Not ranked
	- - - frequency of responses - - -					
Undisturbed	38	13	7	20	7	2
Large mature trees	9	26	33	10	2	7
Trees of mixed sixes and species	10	21	21	27	1	7
Younger tree species with open areas	2	1	3	8	65	8
Variety of natural features (cliffs, rocks, water, etc.)	28	21	16	13	3	6

Table 12.-- *Preferred (ranked first or second out of five) forest descriptions for a majority of respondents by sex, age, education, and month of interview, Mena, 1992*

Demographic category	Sample size	Majority preferred: Description	Frequency
All respondents	85	Undisturbed	51
Sex			
Male	62	Undisturbed	38
Female	23	Undisturbed	13
Age class			
11-20	2	Variety of natural features	2
21-30	8	Variety of natural features	6
31-40	33	Undisturbed, variety of natural features	18
41-50	23	Undisturbed, variety of natural features	22
51-60	9	Undisturbed	7
61-70	8	Undisturbed, variety of natural features	5
71-80	2	Undisturbed	2
Education completed			
≤ 8th grade	3	Undisturbed	3
Some high school	7	Undisturbed	5
High school	25	Trees of mixed sizes and species, variety of natural features	14
Some college	26	Undisturbed	17
Associate degree	18	Variety of natural features	12
Bachelor degree	6	Undisturbed	5
Month of interview			
June	7	Undisturbed	6
July	72	Variety of natural features	42
August	6	Undisturbed	6

Table 13.-- *Preferred (ranked first or second out of five) forest descriptions for a majority of respondents by principal activity, Mena, 1992*

Principal activity	Sample size	Majority preferred: Description	Frequency
All respondents	85	Undisturbed	51
Camping	76	Undisturbed	46
Sightseeing	3	Undisturbed, variety of natural features	2
Swimming	2	Undisturbed, variety of natural features	1
Backpacking	1	Variety of natural features	1
Family gathering	1	Undisturbed	1
Picnicking	1	Undisturbed	1
No purpose	1	Variety of natural features	1

Content Analysis of Forest Scenery Preferences

Contents of forest scenery preferences described by respondents are reported in table 14. All word and word combinations comprising 5 percent or more of the responses are listed. Differences by order of the question presented, i.e., after and before the question about ranking of supplied forest descriptions, are apparent.

After Ranking Forest Descriptions

(Winding Stair NRA and Lake Sylvia sites).--Words occurring 10 percent or more included "tree," "natural," "undisturbed," and "variety"--all of which were listed in the previous survey question. Word combinations included "mixed variety," "hills or mountains," and "large trees."

Before Ranking Forest Descriptions

(Caddo and Mena sites).--Words occurring 10 percent or more included "beauty," "natural," "as is," "quiet," and "trees." "Beauty" and "as is" are difficult to translate into management terms. No word combinations appeared that represented 10 percent or more of the responses.

Table 14.-- *Frequently-used word or word combinations given in answer to "What words would you use to describe your preference in forest scenery?" by order of question, site, and respondent frequency*

Order of question, site, and number of respondents	Word	Frequency (percent)	word combinations	Frequency (percent)
After ranking forest descriptions				
Winding Stair NRA, all respondents=78	Tree	33 (42)	Mixed variety	18 (23)
	Natural	32 (41)	Hills (and, or) mountains	12 (15)
	Undisturbed	21 (27)	Large trees	10 (13)
	Variety	14 (18)		
Lake Sylvia, all respondents = 283	Natural	76 (27)	All water	12 (9)
	Undisturbed	70 (25)	Hills (and, or) mountains	12 (9)
	Trees	51 (18)		
	Wild	22 (8)		
	Variety	22 (8)		
	Scenic	19 (7)		
	Mountains	16 (5)		
	Clean	13 (5)		
Before ranking forest descriptions				
Caddo, all respondents = 140	Beauty	82 (59)	All water	12 (9)
	Natural	71 (51)	Hills (and, or) mountains	12 (9)
	As is	20 (14)		
	Trees	12 (9)		
	Mountain	11 (8)		
	Clean	10 (7)		
	Quiet	9 (6)		
Mena, all respondents = 87	Beauty	41 (47)	All water	7 (8)
	Natural	40 (46)	Hills (and, or) mountains	4 (5)
	As is	11 (13)		
	Quiet	11 (13)		
	Trees	10 (11)		

DISCUSSION AND CONCLUSIONS

The questions added to the CUSTOMER survey provide insight into respondents' preferences for forest scenery and forest descriptions. The majority of respondents preferred "undisturbed," "variety of natural features," "natural," or "beauty" forest descriptions. Variation existed in preferences by principal activity, user characteristics, recreation activity, and sites surveyed. "Younger tree species with open areas" was associated with few activities and few respondent preferences.

Results are consistent with findings for other recreation area studies in which visitors preferred conditions that were natural, but parklike, with some vegetation management that limits understory vegetation density (Hammitt 1988, Ulrich 1977). Findings in our study indicate that natural, undisturbed scenes are preferred. Vegetation management also is important--primarily to maintain a variety of natural features.

It should be emphasized that forest descriptions are not mutually exclusive, as more than one description can be used for each site. However, the prevalence of high ranks for "undisturbed" and "variety of natural features" and low ranks for "younger tree species with open areas" suggests a consensus among respondents for the meaning of these phrases.

Notable are majority preferences for "large mature trees" and "trees of mixed sizes and species" for some principal activity categories at Lake Sylvia. Also, a large proportion of respondents at Lake Sylvia ranked secondary preferences at odds with the majority at other sites. Reasons for these differences are many, some of which were gleaned from CUSTOMER survey reports (Coker and others 1993a, 1993b; Reed and others 1992). Lake Sylvia sample locations were more numerous and diverse, associated with more diverse principal activities, tied to more developed areas, associated with more out-of-state visitors, and was, perhaps, better known than other sites in the CUSTOMER survey.

Preferred forest descriptions associated with particular recreation activities appear inconsistent among sites. Small sample size precluded detailed examination by site and activity. Sampling was not designed to compare differences among sites, as surveys were conducted at different times of the year. Because the primary goal was to describe results by site, it was decided not to combine the data or categories for this initial examination. For future analyses, combining data from all sites to provide a larger sample and to conduct additional analyses, such as discrimination and clustering of answers by respondents and by season, is recommended. Such a study could help researchers better understand differences between Lake Sylvia visitors and those from other sites and help managers gain insight into different customer market segments for forest-selected areas.

The data in these two questions supplement information about visitor preferences but have their limitations. Because respondents were interviewed at recreation areas, it is suspected that respondents may have been describing scenes in and around the interview site. The possibility exists that useful analysis of scenery preferences with other CUSTOMER survey data will provide insight into respondents' perceptions and related interests. It is recommended that future surveys incorporate photographs rather than descriptions, that direction regarding scenic-preference rankings depicting forest areas also include forest management areas outside the interview location, and that future surveys use ratings of scenic preference, rather than rankings, to improve opportunities for analysis.

Additional research on visitor preferences for forest scenes of pre- and postharvest stand-level (Phase II) treatments is planned (Baker 1994, Rudis and others 1994). Procedures will involve rating, rather than ranking, forest scenes as depicted in photographs--a procedure that permits increased statistical analysis and limits potential confounding of scenic preferences with views during onsite interviews. When combined with stand inventory information, photographs and forest scenery ratings should provide detailed information about vegetation conditions preferred by visitors.

ACKNOWLEDGMENTS

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LITERATURE CITED

Baker, James B. 1994. An overview of stand-level ecosystem management research in the Ouachita/Ozark National Forests. In: Baker, James B., ed. Ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings: Proceedings of a symposium; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Coker, Jerry; Crane, Laura; Johnson, Cassandra; Hirsch, Gwen N.; Stueck, Arm; Ryder, Sean; Roberts, Cindy. 1993a. CUSTOMER final report, Ouachita National Forest: Mena and Caddo Ranger Districts. Athens, GA: Outdoor Recreation and Wilderness Assessment Group, Southeastern Forest Experiment Station. 170 p.

Coker, Jerry; Crane, Laura; Johnson, Cassandra; Hirsch, Gwen N.; Stueck, Ann; Ryder, Sean; Roberts, Cindy. 1993b. CUSTOMER final report, Ouachita National Forest: Lake Sylvia recreation area. Athens, GA: Outdoor Recreation and Wilderness Assessment Group, Southeastern Forest Experiment Station. 189 p.

Hammitt, William E. 1988. Visual and management preference of sightseers. In: Noe, Francis P.; Hammitt, William E., eds. Visual preferences of travelers along the Blue Ridge Parkway. Scientific Monogr. Series No. 18. Washington, DC: U.S. Department of the Interior, National Park Service. 26 p.

Reed, Roger; Coker, Jerry; Hirsch, Gwen N.; Johnson, Cassandra; Ryder, Sean; Whitlock, Kristy. 1992. CUSTOMER final report: Winding Stair NRA, Ouachita National Forest. Athens, GA: Outdoor Recreation and Wilderness Assessment Group, Southeastern Forest Experiment Station. 146 p.

Rudis, Victor A.; Gramann, James H.; Herrick, Theresa A. 1994. Esthetics evaluation. In: Baker, James B., ed. Ecosystem management research in the Ouachita Mountains: pretreatment conditions and preliminary findings: Proceedings of a symposium; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

SAS Institute, Inc. 1989. SAS Version 6.07. Cary, NC: SAS Institute, Inc.

Ulrich, Roger S. 1977. Visual landscape preference: a model and application. Man-Environment Systems. 7: 279-293.

APPENDIX

Special Issues Section for Winding Stair National Recreation Area (NRA) CUSTOMER Study

Now, I have a few more questions about your use of this area

INTERVIEWER -- PLEASE TRY TO WRITE WORD FOR WORD THE ANSWERS YOU RECEIVE.

1. Are you aware that this area has been designated a National Recreation Area?
   YES (go to 2) NO (go to 3)

2. Does this designation have any effect on your decision to recreate here?
   YES NO

3. Are you aware that the road between Mena, AR and Talihena. OK (OK ROUTE 1 - AR ROUTE 88) is a National Scenic Byway?
   YES NO

4. Did you pay a user fee to recreate here?
   YES NO

5. Are you willing to pay higher fees to recreate at an NRA than at other areas on the National Forest?
   YES NO

6. Is there some particular feature of Winding Stair NRA that attracts you here for recreation?
   YES (please specify) NO

7. Are there any problems occurring now that may have caused you to have an experience that was not as good as you expected?
   YES (please specify) NO

8. What could the Forest Service do to make your recreation experience better?

9. How do you feel about the Forest Service allowing a private individual to operate a concession (such as a small store) inside the NRA?
   Good idea Bad idea Other comment

10. Would you use this type of service if it were available?

YES NO MAYBE Other comment

11. Would you like to see outfitter/guide services (such as horseback riding with rental horses) available in the NRA?

YES NO

12. What additional facilities would you like to see on or near the NRA?

More campgrounds	YES	NO		
Trails	YES	NO		
Picnic areas	YES	NO		
Visitor center	YES	NO		
Lodge	YES	NO	On NRA	Near NRA
Restaurant	YES	NO	On NRA	Near NRA

13. The Forest Service would like to improve some of the views and vistas along the Talihena Scenic Drive (Skyline Drive)How do you feel about the removal of a few trees in order to do this?

Check all that apply:

Think it's a good idea
Don't like the idea
Vistas ate fine the way they are
Would like to be able to see more as I'm driving
Other____

Question.14. FOR TRAIL USERS ONLY:

14. How do you feel about different types of trail users such as horses, hikers, mountain bikes, all terrain vehicles sharing the same trails?

14a. Do any particular uses interfere with your recreation satisfaction?

YES NO

If yes, which ones:
Horses
Hikers
Mountain bikes
All-terrain vehicles

14b. What type of trail user are you on this trip?

14c. Do you ever do more than 1 of the 4 activities mentioned above on these trails?

YES NO

If yes, which ones?

THESE LAST 2 QUESTIONS REFER TO YOUR PREFERENCES IN FOREST SCENERY.

15. What type of scenery do you prefer in a forest environment? Please rank order your preferences by marking "1" by the forest type most preferred, "2" next to the second preference, "3" next to the third preference,"4" next to the fourth preference, and "5" next to the least preferred.

Undisturbed
Large mature trees
Trees of mixed sizes and species
Younger tree species, with open areas
Variety of natural features (cliffs, rocks, water, etc.)

16. What words would you use to describe your preference in forest scenery?

Effects of Hardwood Retention, Season of Year, and Landform on the Perceived Scenic Beauty of Forest Plots in the Ouachita Mountains’

James H. Gramann and
Victor A. Rudis[2]

ABSTRACT

Results from a study of the within-stand visual effects of alternative reproduction cutting methods on 20 experimental plots in the Guachita National Forest are presented. Treatments varied in their level of hardwood retention from complete suppression of hardwoods to retention of 30 ft^2/acre of basal area. Using color transparency film, plots were photo-sampled two growing seasons after treatments were imposed. The color slides were rated for their scenic beauty by students at Texas A&M University. Results showed that perceived scenic beauty increased with the level of hardwood retention and that summer, fall, and spring views were preferred over those taken during the winter. Ridgetop plots on north-facing slopes were rated as significantly more scenic than plots on gentle-slope north-facing positions.

INTRODUCTION

The within-stand visual-quality impact of alternative reproduction cutting methods carried out on 20 experimental plots located in the Guachita National Forest, Arkansas is described in this paper. The plots are installed on the Winona Ranger District and consist primarily of second-growth shortleaf pine (***Pinus echinata*** Mill.) with a hardwood component dominated by white oak (***Quercus alba*** L.) and lesser amounts of post oak (Q. ***stellata*** Wangenh.), black oak (Q. ***velutina*** Lam.), blackjack oak (Q. ***marilandica*** Muenchh.), and southern red oak (Q. ***falcata*** Michx.) (Shelton and Murphy 1991). Each plot consists of a 0.2-ha division within a 0.65ha treated area (fig. 1).

The Winona study area was established during the 1988 to 89 dormant season as a “pre-Phase I” plot-ievel component of the Ouachita/Ozark-St. Francis ecosystem management research program. (Subsequent phases have focused on stand-level and ecosystem-level analyses.) The Winona plots are oriented along an east-west ridge with elevations ranging from 195 to 240 m above sea level. In aggregate, they represent four replications of four treatments, plus four control plots that were not treated (plots 17 to 20, fig. 1). In installing the plots, pine basal area was reduced to 60 ft^2/acre in all treated stands. The four experimental treatments included three levels of hardwood retention: a 30 ft^2/acre basal area, a 15 ft^2/acre basal area, and total hardwood suppression. The treatment with 15 ft^2/acre was implemented so that residual hardwoods were retained in either a scattered or grouped spatial arrangement (Shelton and Murphy 1991). Because landform position can affect moisture availability and forest regeneration, the plots were blocked so that each treatment and control is replicated on four landform positions: a gentle-slope north-facing position, a moderate-slope north-facing position, a ridgetop north-facing position, and a ridgetop south-facing position.

METHODS

All 20 Winona plots were photo-sampled two growing seasons (1.5 years) after treatments were imposed. Photo sampling took place during each season of the year, beginning in summer 1990 and ending in spring 1991. Views were photographed with an f-112.8 lens and taken from eight surveyed points on each plot’s perimeter. The direction of the eight perimeter shots was toward the center of the plot. Ektachrome 35mm color slide film, speed ISO 400, was push-processed to ISO 800 to compensate for the dimly lit conditions that often characterize within-stand views.

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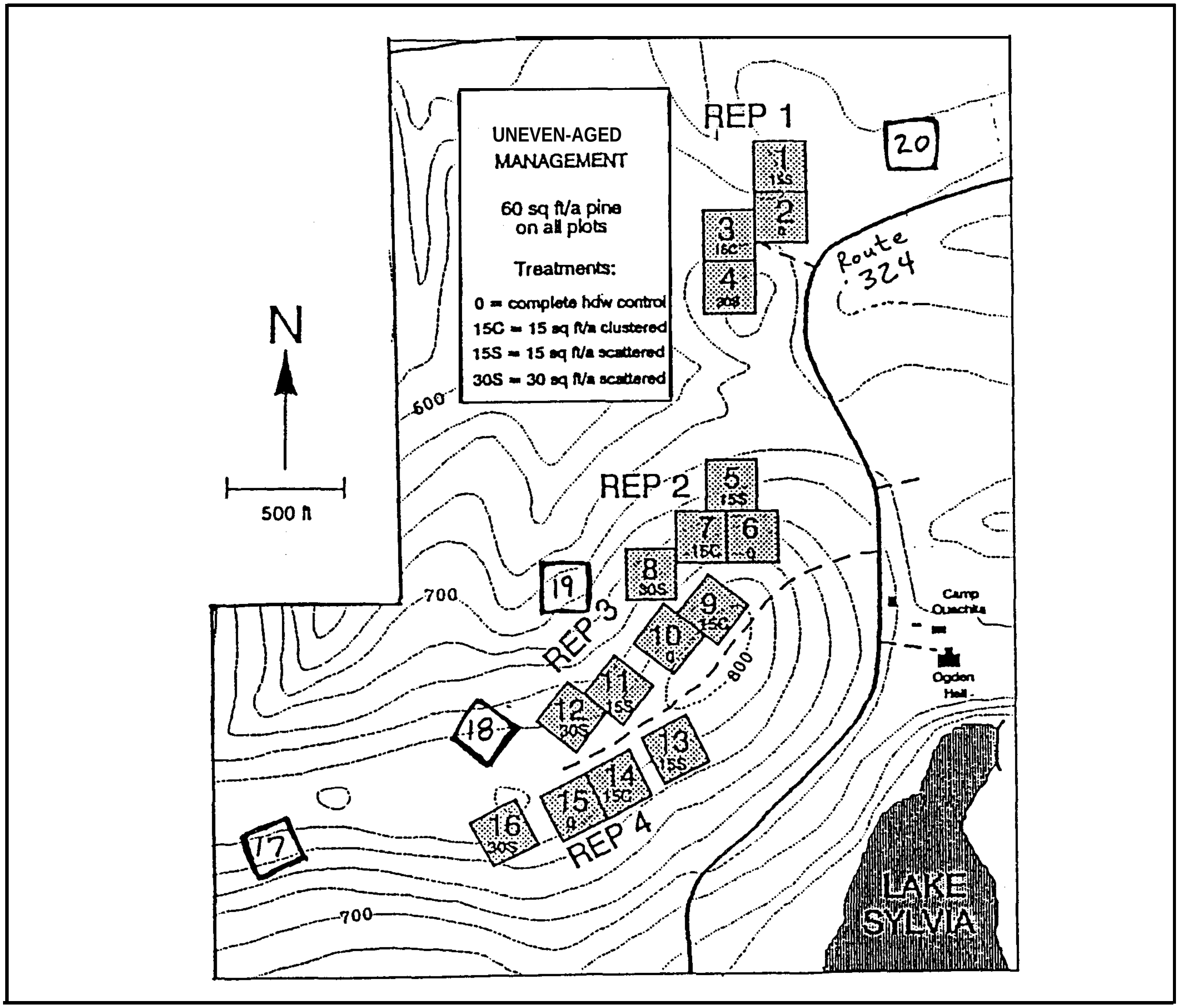


Figure 1.— ***Winona plot-level study area.***

During spring 1992, slides from the Winona plots were rated for their scenic beauty by classes at Texas A&M University. Rating sessions followed procedures developed by Daniel and Boster (1976). After viewing 10 "warm-up" slides, students evaluated scenes on a lo-point scale, ranging from " 1," which meant "very low in scenic beauty" to " 10," which meant "very high in scenic beauty. "

Slides used in the rating sessions were selected randomly from the inventory of photos with the constraint that they had to be of acceptable technical quality and not include obvious distractions that might bias judgments (e.g., spectacular lighting effects or the presence of human-made objects in the scene). Scenic-beauty judgments were obtained from three undergraduate and one graduate class. The undergraduate classes were in sociology, business administration, and civil engineering. The graduate class was in computer science. Ratings from students majoring in natural resource management fields were discarded.

Each class rated 100 slides that consisted of 80 unique slides shown only **in** one rating session and 20 common "baseline" slides, which were shown in each of the four sessions. Baseline slides were interspersed systematically with the remaining 80 slides so that they appeared as every fifth slide shown. Slides remained on the screen for five seconds. In total, 400 scenic-beauty ratings were obtained that covered 340 views. The 20 baseline slides were rated four times.

Each of the rating sessions replicated a four by five by four factorial design. The three factors were season of the year (four levels), treatment (i.e., reproduction cutting method-five levels), and **landform** position (four levels). Treatments were assigned at random within each landform. The dependent variable was the scenic beauty estimation (SBE) for each slide, which was calculated from the raw scenic-beauty ratings using the **RMRATE** software (Brown and Daniel 1990). Data were analyzed using three-way analysis of variance **(ANOVA).**

Prior to **ANOVA, the** correlations between the baseline **SBE's** from each of the rating sessions were examined to determine the agreement between rating groups on the scenic beauty of these 20 slides. The Pearson product-moment correlations ranged from 0.915 to 0.956, with an average correlation of 0.936 for the six **pairwise** comparisons. This high level of agreement between groups supports the application of **ANOVA** to the combined ratings of all four groups of judges.

RESULTS AND DISCUSSION

ANOVA results are shown in table 1. To maintain a balanced design, the 20 baseline slides were excluded from the analysis, leaving a total sample of 320 slides. In comparing levels within the three experimental factors, a priori contrasts were specified between complete hardwood suppression and each of the remaining silvicultural treatments and control condition, between winter and each of the remaining seasons, and between the gentle-slope north-facing **landform** and each of the remaining **landform** positions. It was hypothesized that plots with complete hardwood suppression would be rated as significantly less scenic than other plots and that summer, fall, and spring scenes would be judged as more scenic than winter views. It also was hypothesized that the lower-elevation **landform** position would be associated with lower scenic-beauty ratings because the moister conditions that presumably characterized it would produce lusher growth in the understory, which would create a less open and parklike appearance.

Main Effects

Table 1 shows that the simple main effects of treatment, season, and **landform** were statistically significant, whereas the interaction **between** treatment and season was insignificant. Because **landform** was not replicated in the study design, the interaction terms that included this variable were not evaluated. However, the significant effect of the experimental design suggests that **landform** may interact with other factors to influence scenic-beauty ratings.

Differences in SBE ratings within factors are graphed in figures 2 to 4. In general, a priori contrasts supported the hypotheses concerning the relationship between scenic beauty and silvicultural treatments, seasons of the year, and **landform** position.

Table 1.— *Analysis of variance of scenic beauty estimations (N = 320)*

Source of variation	*df*	*Mean square*	*F**
Landform	3	3884.0	3.1†
Treatment	4	17151.0	13.8‡
Season	3	122679.5	98.8‡
Treatment by season	12	1403.0	1.1
Experimental design	57	1242.0	1.4†
Residual	240	871.4	—
Total	319		

*The denominator for the F-test is the residual mean square for the experimental design (871.4) and the experimental-design mean square for the other effects (1242.0).
†$P < 0.05$.
‡$P < 0.01$.

Treatment

Figure 2 shows that the untreated control plots and those plots retaining 30 ft^2/acre of hardwoods in a scattered pattern were rated as significantly more scenic than plots with complete hardwood suppression. Leaving 15 ft^2/acre of hardwoods in a grouped pattern also resulted in significantly higher SBE ratings. However, there was no significant difference between the plots with complete hardwood control and the 15 ft^2/acre treatment in which hardwoods were left in a scattered configuration. This suggests that retaining residual hardwoods in a grouped pattern, as opposed to a scattered one, may partially mitigate the negative visual impacts of a reproduction cut that maintains only 15 ft^2/acre of hardwood basal area.

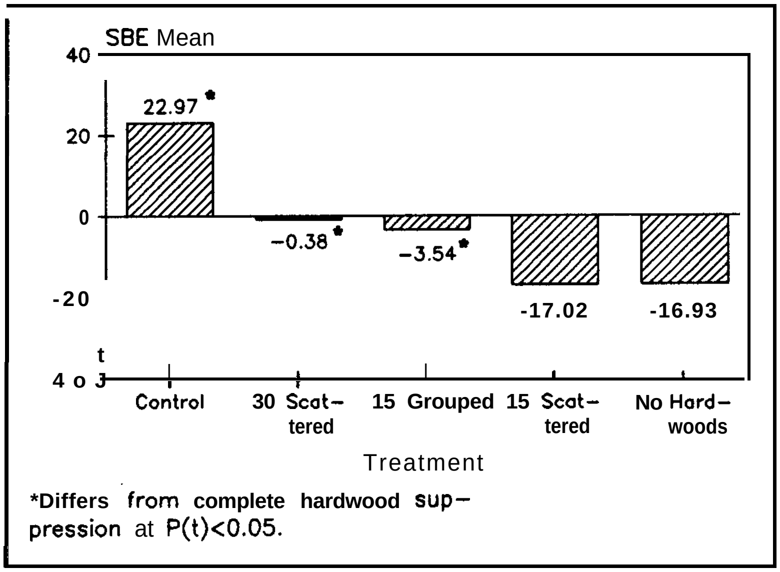


Figure 2.— ***Main effect of treatment on scenic beauty estimation.***

Season

Figure 3 shows that summer views were judged as significantly more scenic than winter views. A priori contrasts revealed that fall and spring scenes also received significantly higher ratings than winter views.

The preference for summer, fall, and spring scenes over winter views may be related to seasonal color patterns. Color variation by season is one of the most notable changes in forest vegetation. This variation could have important effects on human preference for forest scenes, even in landscapes dominated by pine. The exact nature of the relationship between silvicultural treatment, forest color, and scenic-beauty judgments is worthy of further investigation.

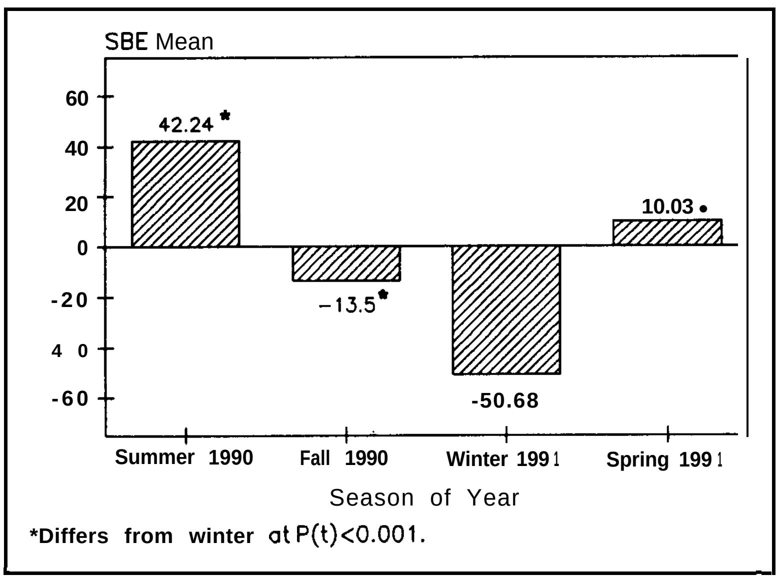
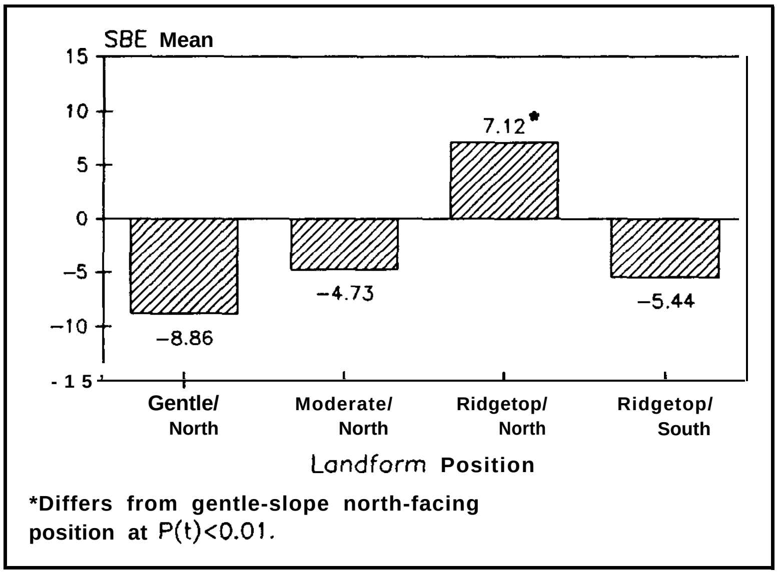


Figure 3.— ***Main effect of season of year on scenic beauty estimation.***

Landform Position

Figure 4 shows that **ridgetop** plots on north-facing slopes were rated as significantly more scenic than plots on **gentle**-slope north-facing positions. No other significant differences were found for any of the remaining comparisons with the gentle-slope north-facing plots.



'igure 4.— *Main effect of landform on scenic beauty estimation.*

The relatively low scenic-beauty rating for the lower elevation, north-facing position may be caused by variable response to disturbance. Lower elevation north-facing plots have the highest site index of all the Winona plots (Shelton and Murphy 1991). Thus, compared to other plots, they may have responded more rapidly to disturbance by increased growth of understory foliage and twigs. In summer, low-elevation positions had more foliage and twig screening (Rudis and others 1994). Previous research in southern pine forests showed that vegetative screening in the understory was negatively related to perceived scenic beauty (Ruddell and others 1989).

The landform effect on scenic beauty in the Winona plots also may be an artifact of the preparation work done to achieve hardwood stocking levels appropriate to a treatment. More disturbance may have occurred in the gentle-slope plots than in the higher-elevation positions. The passage of two growing seasons since treatment may not have been long enough for the slash left by these disturbances to become visually unobtrusive. While the effect of slash on visual preference in southern pine forests has not been clearly established (Rudis and others 1988), in other forest types it has been shown to detract from perceived scenic beauty (Brown and Daniel 1984).

CONCLUSIONS

Of the three factors examined, season of the year exhibited the most significant effect on SBE. This finding is important in that most forest scenic-beauty models are based on summer data. As demonstrated by this study, such models should not be generalized uncritically to other seasons of the year.

It seems likely that one source of seasonal differences in scenic-beauty ratings is color variation in forest vegetation. Visual inspection of the Winona slides indicated that summer views, which were the most preferred, were also characterized by higher amounts of green than were winter scenes, which were the least preferred. Future research should investigate more thoroughly the effect of seasonal color change on scenic-beauty ratings as well as the effect of forest management practices on seasonal color patterns.

Two years after treatment, the level of hardwood retention affected scenic-beauty perceptions in the Winona study area. Specifically, untreated plots and plots characterized by 30 ft^2/acre basal area in hardwoods were rated as significantly more scenic than plots with complete hardwood suppression. When remaining hardwoods were left in a grouped pattern rather than a scattered pattern, the negative visual impact of retaining only 15 ft^2/acre basal area in hardwoods was somewhat mitigated. Perhaps, this is because hardwoods growing in clusters present a more parklike appearance to observers than do single trees standing in isolation.

The impact of silvicultural treatment on perceived scenic beauty may change as the Winona plots regenerate. Analyses based on photo sampling taken only two growing seasons after treatment may not predict scenic-beauty effects five or 10 years after treatment. In particular, the impact of silvicultural treatment may become less noticeable in more mature plots as trees increase in size. Follow-up analyses of the Winona plots should be carried out to determine the long-term impact of hardwood management on scenic beauty in this forest type.

It was not possible to reach a firm conclusion regarding the impact of landform position on scenic quality. The landform effect uncovered in this experiment could be an artifact of differences in disturbance (e.g., downed woody material associated with establishing treatment basal area) and vegetation response to increased sunlight. The experimental design did not permit an evaluation of the interaction of landform position with either treatment or season. It is possible that the scenic-beauty effect of hardwood-retention level differs significantly between drier ridgetop plots and moister lower-elevation sites, especially during the early stages of forest regeneration. These interaction effects also need to be examined in future research.

LITERATURE CITATIONS

Brown, Thomas C.; Daniel, Terry C. 1984. Modeling forest scenic beauty: concepts and applications to ponderosa pine. Res. Pap. RM-256. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 35 p.

Brown, Thomas C.; Daniel, Terry C. 1990. Scaling of ratings: concepts and methods. Res. Pap. RM-293. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 24 p.

Daniel, Terry C.; Boster, R. 1976. Measuring landscape esthetics: the scenic beauty estimation method. Res. Pap. RM-167. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 66 p.

Ruddell, Edward J.; Gramann, James H.; Rudis, Victor A.; Westphal, Joanne M. 1989. The psychological utility of visual penetration in near-view forest scenic-beauty models. Environment and Behavior. 21: 393-412.

Rudis, Victor A.; Gramann, James H.; Ruddell, Edward J.; Westphal, Joanne M. 1988. Forest inventory and management-based visual preference models of southern pine stands. Forest Science. 34: 846-863.

Rudis, Victor A.; Gramann, James H.; Herrick, Theresa. 1994. Esthetic evaluation. In: Baker, James B., ed. Ecosystem management research in the Guachita Mountains: pretreatment conditions and preliminary findings: Proceedings of a symposium; 1993 October 26-27; Hot Springs, AR. Gen. Tech. Rep. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station.

Shelton, Michael G.; Murphy, Paul A. 1991. Age and sire structure of a shortleaf pine-oak stand in the Guachita Mountains-implications for uneven aged management. In: Coleman, S.; Neary, D., comps. eds. Proceedings of the 6th biennial southern silvicultural research conference; 1990 October 30-November 1; Memphis, TN. Gen. Tech. Rep. SE-70. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 616-629. Vol. 2.

Production Time, Total Costs and Residual Damage at Varying Harvest Intensities[1]

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ABSTRACT

Six stands were harvested by either clearcut, shelterwood, or single-tree selection methods. Harvest productivity was evaluated in 2 consecutive years (1991 and 1992) for each harvesting method. The single-tree selection harvests consisted of thinnings in even-aged stands as an initial basal area reduction cut required to convert the stand to uneven-aged structure. Harvest intensity (percentage of basal area removed) ranged from 3 1 to 100.

The same contractor used two skidders (one grapple, one choker) and production chain saws to harvest all six tracts. Harvested sites were similar in slope, average diameter at breast height (d.b.h.) and preharvest number of stems by d.b.h.

In 1991, total felling time (including walk, acquire, fell, and limb-top times) was inversely related to harvesting intensity. In 1992, total felling time averaged highest under the single-tree selection method and lowest under the shelterwood method. When these averages were adjusted for differences in stand characteristics, the inverse relationship between total time and percentage of basal area removed at harvest (harvesting intensity) was present for both years.

In both years, total cycle time (including travel-empty, bunch-building, travel-loaded, and deck times) was higher, and volume per cycle was lower for the cable skidder than for the grapple skidder. After adjusting for differences between stands, total cycle time was inversely related to harvest intensity.

Factors affecting total felling time (in decreasing order of importance) were d.b.h. of harvested stems, intertree distance, and harvest intensity. Factors affecting total cycle time for skidding (in decreasing order of importance) were travel distance, skidder type, number of stems per cycle, harvest intensity, and volume per cycle.

The total percentage of stand area trafficked was lowest for the single-tree stands. The single-tree selection method (in 1992) had the largest and only significant increase in bulk density in the skid trails. Residual tree damage (trees/acre) was greater for the single-tree selection method than the shelterwood method.

INTRODUCTION

Recently, comparisons of even-aged and uneven-aged management have attracted increased attention. One aspect of research includes comparisons of the time required to perform various harvesting operations and their cost. Previous studies often addressed only a single harvest method, (i.e., clear cutting or single-tree selection), (Kellog and others 1991, Miller and Sarles 1986) with differences among stands or harvesting crews and equipment confounded with treatment effects (Bell 1989, Hannah and others 1981, Miller and Smith 1991, Sloan 1991). Studies are needed using the same equipment and crew to harvest similar stands under prescribed conditions. The results of studies conducted over 2 years on harvesting time and estimated cost for clear cutting, shelterwood harvesting (two methods used in even-aged management), and single-tree selection harvest are presented here. Variation among stands, crews, and equipment was controlled by using the same crew and equipment on all stands and selecting similar stands.

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METHODS

Treatment of the Stands

Three harvesting methods were selected to represent a wide range of harvest intensities. Clearcutting and single-tree selection methods represented extremes in harvest intensity, and shelterwood harvests represented intermediate treatments. Three stands were harvested by each method in the summer of 1991 and then replicated in 1992. The stands were located on the Womble Ranger District, Ouachita National Forest west of Hot Springs, AR. Single-tree selection harvesting consisted of a light thinning of two even-aged stands. This was an initial basal area reduction cut required to convert the stands to uneven-aged structure.

There was a small hardwood component in all six stands. The hardwood stems were bypassed by the harvesting crew to be processed at a later time.

Diameter distribution and average height of the six stands were statistically similar. These stands were typical mature even-aged stands for the Ouachita National Forest. Table 1 shows the preharvest stand conditions for all six tracts. The percentage of basal area removed was used as an index of harvesting intensity for each stand.

Table 1. Preharvest stand condition summary for six stands.

	1991			1992		
	Single-tree selection	Shelterwood	Clearcut	Single-tree Selection	Shelterwood	Clearcut
Basal area (ft^2)	81	70	81	108	77	69
Harvest (% basal area)	31	57	100	43	71	100
dbh (inches)	10.0	11.4	10.5	10.6	10.5	10.0
Merchantable height (feet)	54	62	53	61	52	57
Size (acres)	52	11	40	40	40	40

Diameter distributions from preharvest cruises were compared using a Kolmogorov-Smimov distribution test to determine whether they were from the same parent distribution. This test showed all the stands were representative of the same parent population.

There were differences in the measured average values for each stand. These differences were adjusted for the final analysis by using global averages (average of all six stand values) into the regression equations. This adjustment accounted for variation between stands. The effect of harvest intensity was isolated.

Felling

The sawyer felled all marked trees within the stand boundaries according to felling ease and safety. Directional felling to optimize skidding was not a consideration, nor was it practiced. Hung trees occurred in all three stands. When trees were hung, the sawyer stopped work while a skidder was used to pull or push the tree to the ground or the sawyer moved to a new area until the hung tree was brought to the ground by the skidder operator. Trees were processed into tree-length stems by limbing and topping immediately after felling.

A felling observation was defined as the time required for the sawyer to walk to a tree (walk), clear the brush for a safe exit path and plumb the tree (acquire), fell the tree (fell), and limb and top the tree (limb and top). Not every felling cycle was observed. Observed felling cycles were randomly chosen as work progressed through the stand. Observed cycles did not necessarily mirror the stand's distribution. Field research team members timed and recorded each event in the cycle. Delay times (delay) and reasons were recorded. When a tree was limbed and topped so it was safe to approach, researchers measured the d.b.h. and merchantable length (5-inch top) of the felled tree. Individual tree volumes were calculated by a formula developed by Clark and Saucier (1990). Total time per tree (excluding delays) was calculated for each observation. Means for walk-time, acquire-time, cut, limb and top-time, and delay-time were computed by tract and the overall study. Differences in mean times were detected by Tukey's HSD pair-wise comparison test at the 0.05 level. Adjusted (for mean tree diameter and inter-tree distance) total-time-per-tree was calculated for the six harvested stands. Finally, a structural regression was estimated for total felling time with the percentage basal area harvested, d.b,h., and intertree distance as independent variables.

Skidding

Two 120 horsepower, turbo-charged Caterpillar@ 5 18 skidders[3] equipped with 34-inch tires hauled the tree-length stems on all tracts. One was equipped with a one-cord grapple, the other with a cable skidder with six chokers. The cable skidder operator hooked his own chokers. Both operators gathered approximately a full load before traveling to the landing. When skidders arrived at the landing, they dropped (grapple skidder) or unchoked (cable skidder) their load and pushed the stems into a pile for loading. Skidders incurred delays both at the deck and in the woods. Occasionally, the two skidders arrived at the deck simultaneously; when this occurred, one skidder waited on the other (productive delay) to finish dropping its load and piling stems. In-the-woods delays occurred when hung trees needed to be pulled or pushed down, or when sawyers had not completed their work resulting in no stems to haul. No mechanical delays were observed for the skidders during the study.

At the deck, hauled stems were measured to obtain d.b.h., top diameter, and length using tree calipers and a logger's tape. Applicable volume tables were used to determine individual stem volume (Clark and Saucier 1990). For each skidder cycle, travel-empty, travel-loaded, acquire (bunch-building), and dispose (deck time), times were recorded. Skidding distances along haul trails were measured; colored flagging was hung in nonharvested trees at measured distances from the deck to aid in measurement of exact haul distance.

Total time per haul was calculated for each skidder cycle. Averages for travel-empty, acquire, travel-loaded, and dispose were computed for each skidder by harvesting method and the overall study. A structural regression equation was estimated to determine the significance of each of the factors contributing to total time. Results were considered significant at the 0.05 level.

Postharvest Damage Assessment

A postharvesting site-damage assessment included area disturbed, residual tree damage, and soil bulk density. A 1-chain by l-chain grid was established on each of the tracts. At grid intersection points, site disturbance was identified and classified by disturbance class. Disturbance classes included: (1) undisturbed-untrafficked; (2) disturbed-trafficked, litter in place; (3) disturbed-trafficked, exposed soil; (4) disturbed-trafficked, exposed soil and or soil depression; (5) disturbed-slash; (6) disturbed-nonsoil (rock). At every fifth point along grid lines, a 1/10-acre circular plot was installed in the shelterwood stands and a 1/20-acre circular plot was installed in the single-tree stands to assess residual tree damage. Tree damage was classified as either bark damage, cambium exposed, or wood damage, and the area of damage was measured. Lengths of primary and secondary skid trails were measured in all six stands. Widths for each trail were measured at 100-ft intervals, and average widths were used to calculate the total area in skid trails.

Postharvest soil samples were collected on only the 1992 stands. Samples classified as disturbed were taken in three primary skid trail ruts in each stand at 100, 300, 500, and 700 ft from the deck. With each disturbed sample, a corresponding undisturbed sample was taken along a perpendicular line to the trail from the disturbed sample. The distance from the disturbed sample to the first undisturbed sample was measured. Disturbed and undisturbed samples were also taken along three secondary trails, 100 ft from their junction with the primary trail.

The samples were weighed wet, dried at 105 °C for 72 hours, and reweighed to obtain dry weight. Bulk density and percentage of moisture content were then determined for each sample. Bulk density was adjusted for rock content according to American Society for Testing and Materials Standards (ASTM 1992) for samples with 40 percent or more of total dry weight in rock.

RESULTS

Stands

The diameter distribution for the three stands harvested in 1992, while not statistically different from the parent population, averaged slightly higher than the 1991 stands. In the two stands harvested by single-tree selection, the distribution of removed stems was similar to a mixed thinning with cutting in the 6- to 10- inch classes (low thinning) and in the 14- to 18- inch classes (thinning from above).

Felling

The diameter distributions of harvested stems in the felling study were not statistically different from their parent stands. Intertree distance was inversely related to harvesting intensity. The sawyer had to walk further to find marked trees in the single-tree selection stands than in the clearcut stands; walk-time decreased as harvesting intensity increased. There was no identifiable trend in acquire-time. Felling time was dictated by the d.b.h. of the individual tree. Limb and top-time was influenced by merchantable height, d.b.h., and harvest intensity. This was attributed to the problem of

[3] Use of trade names is for the reader's information and does not constitute official endorsement by the University of Arkansas or the USDA Forest service to the exclusion of other suitable harvesting machinery.

working with longer, and wider stems, and working around unharvested trees. Figure 1 illustrates the average values for each component in the six stands.

The structural regression for the estimation of time to fell a tree had an R^2 = 0.585. All regression coefficients were significant at the .01 level. The structural equation was:

$$\text{Total Time} = -0.581 - 0.610\ HZ + 0.007\ Dist + 0.224\ d.b.h.$$

where:

Total Time = sum of time required to walk to, acquire, fell, and limb and top a tree in minutes

HI = Harvest intensity (Percentage of basal area harvested)

Dist = Intertree distance in feet

d.b.h. = Tree diameter at breast height in inches.

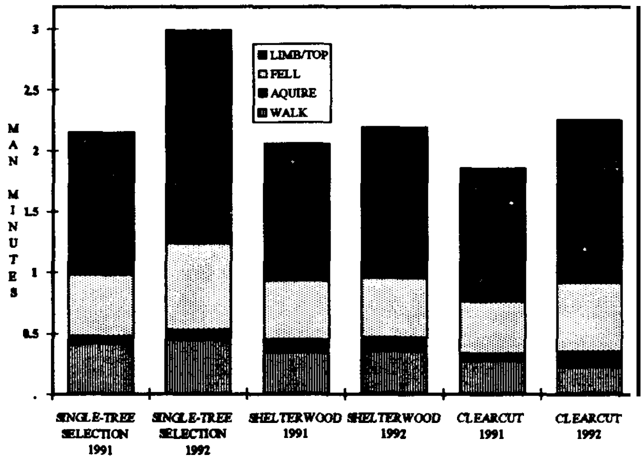

Figure 1. Average felling time for an individual tree broken down by operation components.

Table 2 gives the range of values for harvest intensity, intertree distance, and d.b.h., which were the significant independent variables. Harvest year was tested as a possible independent variable but was not significant.

Table 2. Summary of the felling data variables used in the felling regression equation.

			1991						
	Single-tree selection n= 51			Shelterwood n = 50			Clearcut n = 61		
	max.	min.	mean	max.	min.	mean	max.	min.	mean
Harvest (% basal area)			31			57			100
dbh (inches)	19.8	6.4	11.4	23.6	5.6	11.5	18.7	5.8	11.7
Intertree distance (feet)	408	8	75	3	122	46	93	7	49
			1992						
	Single-tree selection n= 107			Shelterwood n = 121			Clearcut n = 141		
Harvest (% basal area)			43			71			100
dbh (inches)	25.0	10.6	14.8	22.4	6.7	13.6	24.5	8.0	14.4
Intertree distance (feet)	408	8	75	3	122	46	93	7	49

Application of the regression equation is straightforward. For example, a 3-inch increase in average d.b.h. would increase total time to process a tree by 0.67 minutes (40 seconds). Examination of the standardized coefficients in the structural regression equation indicated the most important factors influencing total felling time (in decreasing order of importance) were d.b.h., intertree distance, and harvest intensity. Figure 2 demonstrates the expected total time per tree using individual stand averages for d.b.h. and intertree distance. Figure 3 shows the expected total time per tree when d.b.h. and intertree distance are adjusted to reflect global averages (averaged across all six stands) for d.b.h. and intertree distance.

Average productivity was calculated using expected time and average stem volume. Productivity was used in combination with estimated hourly operation costs to derived cost per unit of volume.

Felling cost per unit volume varies directly with productivity. An hourly fixed cost of $0.30, a variable cost of $1.63 per productive hour, and a labor cost of $7.98 per hour were used in calculations. The adjusted (50 percent availability)

(Miyata 1980) hourly operating cost under these assumptions would be $9.10 per hour. Hourly cost was combined with total time estimates (from the regression equation) and volume estimates to derive cost per hundred cubic feet (ccf)

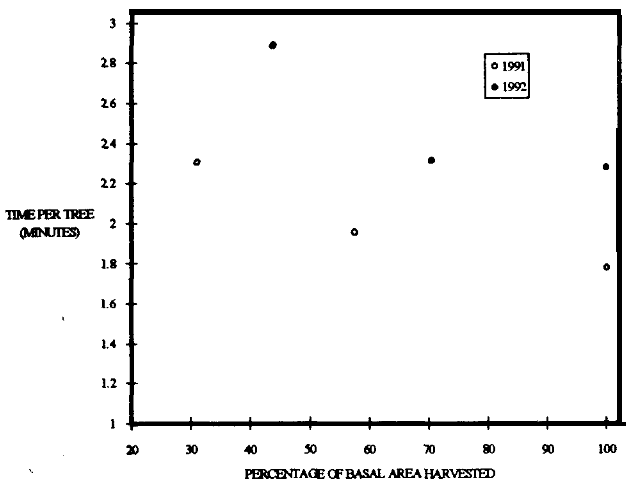

Figure 2. Estimated felling time based on indivicual stand averages.

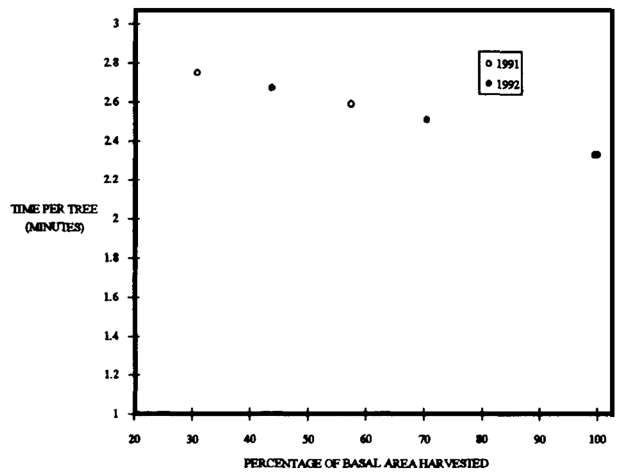

Figure 3. Estimated felling times based on global averages

produced. These were $3.40/ccf and $1.71/ccf for single-tree selection in 1991 and 1992, respectively. For the shelterwood, they were $2.81/ccf and $2.00/ccf in 1991 and 1992, respectively. Finally, the clearcut \costs were $2.89/ccf and $1.61/ccf in 1991 and 1992, respectively. Figure 4 shows the costs of production for each stand. These costs are not adjusted to remove differences in stand characteristics.

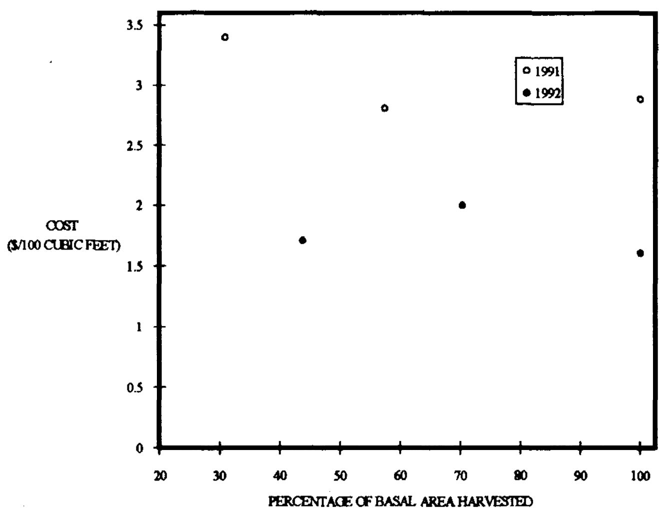

Figure 4. Estimated felling cost per 100 cubic feet

Skidding

In 1992, the measured stems were larger than in 199 1. Skid volumes tended to be higher and cycle times lower in 1992; thus, overall productivity (volume per unit time) was higher in 1992. This was particularly true for the stand harvested with the single-tree selection method in 1992. Skidding productivity was unexpectedly high in this stand because average stem d.b.h. was larger and merchantable length was longer than any other stand. However, when the variation attributable to differences in skidded volume was removed, the inverse relationship between cycle time and harvest intensity was again evident.

Figures 5 and 6 illustrate the average time components for a grapple skidder and a cable skidder cycle, respectively. There was no clear trend in the travel-empty and travel-loaded time variables. Acquire-time was related negatively to both average d.b.h. and percentage of basal area removed. It was related positively to, and was strongly influenced by, the average number of stems per turn. For the grapple skidder, there was no apparent trend in the dispose variable. The cable skidder did show a positive relationship between number of stems and disposal time.

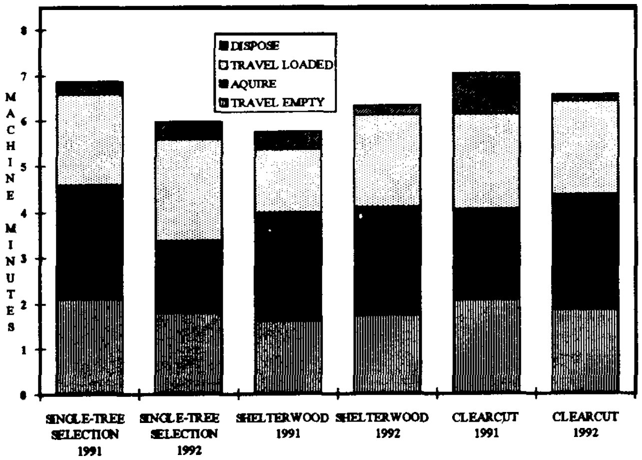

Figure 5. Average time of a grapple skidder cycle broken down into operation components

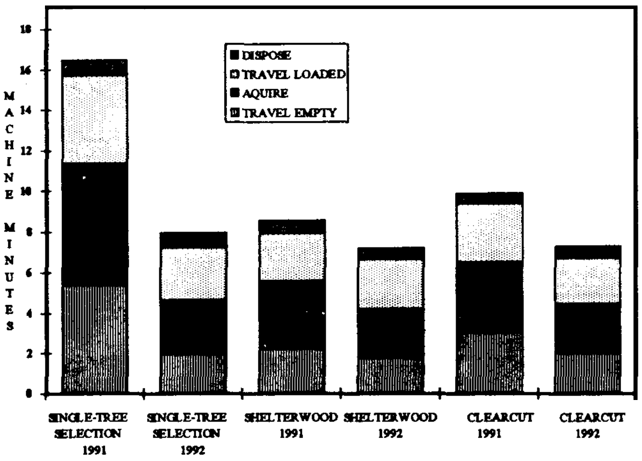

Figure 6. Average time of a cable skidder cycle broken down into operation components

The R^2 value for the structural regression estimating skidder-cycle time was 0.461. All coefficients were significant at the 0.01 level. The equation was:

Total Time = 4.154 - 2.297 HI - 2.087 Skid + 0.003 Distance + 0.497 Stems + 0.022 Volume

where:

Total Time = sum of travel-empty, acquire, travel-loaded and dispose time
HI = Harvest intensity (percentage of basal area harvested)
Skid = 1 if the skidder is *a* grapple skidder; 0 if the skidder is a cable skidder
Distance = Travel-empty distance (feet) + Travel-loaded distance (feet)
Stems = Average number of stems per turn
Volume = Average volume hauled per turn in cubic feet.

Tables 3 and 4 give the range of values for the independent variables (harvest intensity, skid distance, stems per turn, and volume per turn) on which this equation was based. The specific year of harvest was tested as a possible variable and was not significant when combined with the other variables.

Table 3. Summary of the cable skidding data used in the skidding regression equation.

	1991								
	Single-tree selection n = 8			Shelterwood n = 35			Clearcut n = 34		
	max.	min.	mean	max.	min.	mean	max.	min.	mean
Harvest (% basal area)			31			57			100
Stems per cycle	7	3	4.1	5	2	3.7	5	3	3.6
Volume (100 ft^3)	84.0	25.8	51.1	105.3	22.1	61.7	137.0	37.2	76.7
Total skid distance (feet)	2849	1300	2355	2436	609	1369	2472	1050	1864

Table 3 continued. Summary of the cable skidding data used in the skidding regression equation.

	1992								
	Single-tree selection n = 44			Shelterwood n = 67			Clearcut n = 85		
	max.	min.	mean	max.	min.	mean	max.	min.	mean
Harvest (% basal area)			43			71			100
Stems per cycle	5	1	3.0	5	2	3.9	5	2	3.9
Volume (100 ft^3)	180.6	21.5	104.2	122.9	18.7	58.3	140.1	13.6	73.1
Total skid distance (feet)	3170	237	1279	2738	292	1347	3245	446	1470

Table 4. Summary of the grapple skidding data used in the skidding regression equation

	1991								
	Single-tree selection n = 53			Shelterwood n = 50			Clearcut n = 65		
	max.	min.	mean	max.	min.	mean	max.	min.	mean
Harvest (% basal area)			34			57			100
Stems per cycle	7	1	4.1	8	2	4.2	7	2	4.0
Volume (100 ft^3)	161.2	19.1	81.8	153.9	32.2	82.9	180.0	30.1	98.7
Total skid distance (feet)	3315	390	1350	2266	394	1109	2772	524	1325
	1992								
	Single-tree selection n = 59			Shelterwood n = 71			Clearcut n = 70		
Harvest (% basal area)			43			71			100
Stems per cycle	6	2	3.3	14	2	5.6	9	3	5.3
Volume (100 ft^3)	189.0	58.3	112.4	176.2	19.5	93.1	157.7	29.9	97.7
Total skid distance (feet)	3444	316	1468	2563	493	1330	2918	361	1484

The equation demonstrates the sensitivity of total time required per cycle to changes in the independent variables. For example, under the conditions studied, a grapple skidder took approximately 2 minutes and 5 seconds less time per cycle than the cable skidder. Additionally, loading the skidder to only 60 ft^3, rather than fully loading to 100 ft^3, will reduce the total travel time by 0.88 minutes (53 seconds) per haul. The standardized coefficients of the structural regression analysis showed the most important factors influencing time per cycle (in decreasing order) were total turn distance, skidder type, stems per turn, percentage of basal area harvested, and average haul volume. Figure 7 shows the estimated total times using individual stand averages for skid distance, number of stems per turn, and volume for the grapple and cable skidders. Figure 8 shows the estimated total time per turn when distance, number of stems, and volume are adjusted to reflect global averages (averaged across all stands).

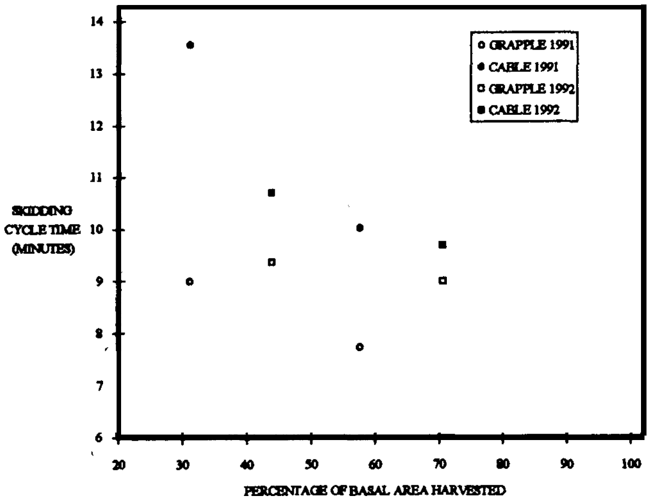

Figure 7. Estimated average skidding time for one cycle based on individual stand characteristics

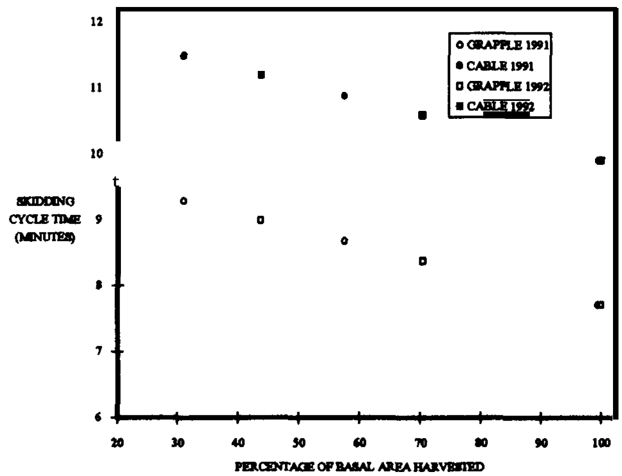

Figure 8. Estimated average skidding time for one cycle based on global characteristics.

Skidding cost per unit volume varies with fixed and variable operating cost and productivity. Assumed availability for the skidders was 67 percent (Miyata 1980). In 1991, total estimated costs ($/ccf) for the cable skidder were $21.77, $17.06, and $12.50 for the single-tree selection, shelterwood, and clearcut methods, respectively, versus $11.60, $10.70, and $7.97, respectively, for the grapple skidder. In 1992, total estimated costs ($/ccf) for the cable skidder were $10.40, $17.57, and $13.12 for the single-tree selection, shelterwood, and clearcut methods, respectively, versus $8.18, $9.20, and $8.06, respectively, for the grapple skidder. Cable skidder productivity was more sensitive to differences in stem size than the grapple skidder. Figures 9 and 10 illustrate the costs of production for the grapple and cable skidders, respectively. All the costs are based on unadjusted time estimates.

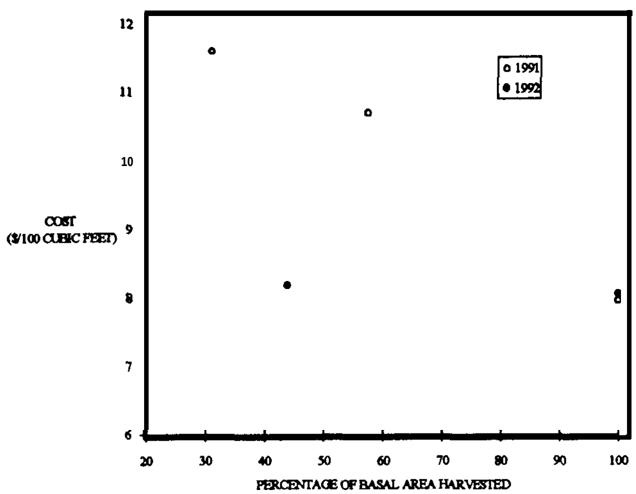

Figure 9. Estimated average grapple skidding costs per 100 cubic feet

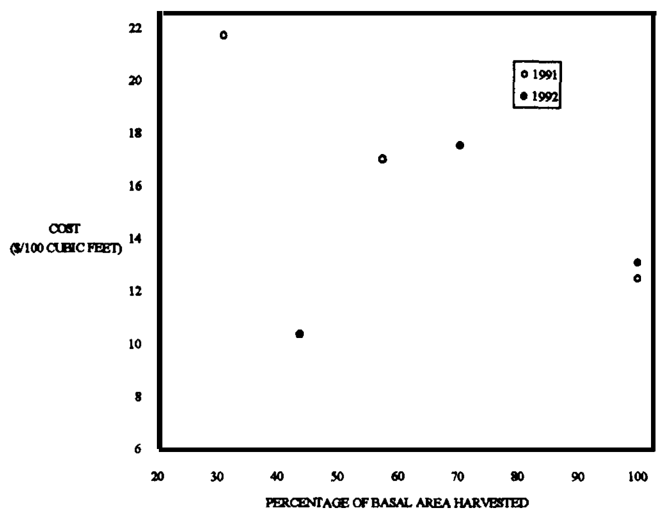

Figure 10. Estimated cable skidding costs per 100 cubic feet

Postharvest Damage Assessment

Trees with cambium exposed were considered damaged All cambium exposure was counted, regardless of area. In 1991, Average exposure area was as low as 0.1 ft’ per tree (3.79 inches by 3.79 inches). The 1991 postharvest damage assessment revealed 16 residual trees per acre damaged from the single-tree selection method (Table 5). There were only six damaged trees per acre from the shelterwood method. The 1992 postharvest damage assessment revealed that the single-tree selection method resulted in 10.2 damaged trees per acre. The shelterwood method resulted in 2.5 damaged trees per acre. There was a decrease in damage between the 2 years that may have resulted from gaining experience with the harvesting method. The average number of damaged trees per acre for the 2 years from the single-tree selection method was 13.1, whereas the shelterwood method averaged only 4.3 damaged trees per acre for the 2 years.

Table 5. Postharvest residual damage assessment for three harvesting methods for 1991 and 1992.

	Harvest method								
	Single-tree selection			Shelterwood			Clearcut		
	1991	1992	mean	1991	1992	mean	1991	1992	mean
Tree damage due to cambium exposure (trees/acre)	16.0	10.2	13.16	6.0	2.5	4.3	na	na	na
Area of cambium exposure (ft^2/tree)	0.4	0.4	0.4a	0.1	0.2	0.2a	na	na	na
Area in skid trails (percent)									
Primary	2.0	6.6	4.3a	7.0	19.1	13.0a	7.5	10.1	8.8a
Secondary	1.6	3.6	2.6	0.6	6.9	3.7a	4.8	7.6	6.2a
Total	3.6	10.2	6.9	7.6	26.0	16.7a	12.3	17.1	15.0a
Stand disturbance (percent)									
Undisturbed									
Untrafficked	48.3	36.6	42.4a	18.0	16.7	17.3b	9.6	11.5	10.5b
Disturbed									
Litter in place	22.3	29.2	25.7a	29.2	27.6	28.4a	25.6	23.7	24.6a
Soil exposed	5.6	15.1	10.3a	11.2	21.1	16.1a	8.0	16.5	12.2a
Soil exposed/ depression	9.9	9.2	9.5a	14.6	10.9	12.7a	15.2	14.3	14.7a
Slash	13.9	9.1	11.5b	27.0	21.8	24.4ab	40.8	30.2	35.5a
Non-soil	0.0	0.7	0.3a	0.0	1.9	0.9a	0.8	4.3	2.5a

letters indicate groups similar at the 0.05 level in a means separation test using Tukey's HSD multiple comparisons test.

Primary and secondary skid trails accounted for 3.6, 7.6, and 12.3 percent of the total area for the single-tree selection, shelterwood, and clearcut methods, respectively (Table 5). Primary trails were defined as those having branching trails, whereas secondary trails did not. The 1992 harvests had total skid-trail area of 10.2, 26.0, and 17.7 percent of the total area for the single-tree selection, shelterwood, and clearcut methods, respectively. The 2-year skid-trail area averages were 6.9, 16.8, and 15.0 percent of the total area in primary and secondary skid trails for the single-tree selection, shelterwood, and clearcut methods, respectively.

Table 5 also gives the percentage of each stand in each disturbance class. As harvesting levels increased, so did the proportion of the total tract trafficked. There was significantly more undisturbed area for the single-tree selection methods than the other two methods. Combining the area disturbance data for the 2 years shows that the single-tree selection method left an average of 42.4 percent of the stand undisturbed as compared to 17.3 percent for the shelterwood method and 10.5 percent for the clearcut method. This results in 144 percent more undisturbed area for the single-tree selection method compared to the shelterwood method and 300 percent more compared to the clearcut method. The clearcut method resulted in 163 percent more area with slash than the single-tree selection method and 24 percent more than the shelterwood method. Additionally, the percentage of total area covered by slash increased with increasing harvest intensity. There were no significant differences among treatments for the amount of area disturbed (this includes three classes).

The single-tree selection method had less area in skid trails and less disturbed area based on total area. This analysis, however, does not account for quantity of wood harvested. If disturbance is related to wood recovery, the treatment effects would be more balanced rather than skewed toward lower removal levels.

After testing for the effect of distance from the deck, the soil bulk densities were grouped by treatments. The average bulk density on primary skid trails was 1.49 g/cm^3 for the single-tree selection method, 1.30 g/cm^3 for the shelterwood method, and 1.26 g/cm^3 for the clearcut method (Table 6). There was an increase in bulk density for all harvesting treatment. A paired comparison test showed a significant difference for the single-tree selection method only. Due to fewer trees removed (high residual stand density) for the single-tree selection method, the skidders were more restricted in their travel, and, therefore, used the same primary trails more frequently than with the shelterwood and clearcut methods. This resulted in a higher bulk density for the single-tree selection method due to cumulative traffic impacts.

Table 6. Summary of soil analysis.

	Harvest method					
	Single-tree Selection		Sheltenwod		Clearcut	
	Mean	S.D.	Mean	S.D.	Mean	S.D.
Bulk Density (g/cm^3)						
Undisturbed	1.12	0.27	1.22	0.17	1.15	0.21
Trail	1.49	0.19	1.30	0.19	1.26	0.27
Difference	0.37	0.23	0.08	0.25	0.11	0.37
Prob > $\|t\|$	0.0003		0.2732		0.3017	

DISCUSSION

The most important factors in felling time per tree were the d.b.h., the intertree distance, and the harvesting method. In the analysis of co-variance and the structural regression analysis, harvest intensity acted as a surrogate variable to collect otherwise unexplained variation in felling time. For felling, the extra time spent finding marked trees, planning the cut, and working around residual stand components affected production for the single-tree and shelterwood methods.

Skidder productivity was significantly influenced by skidder type, total haul distance, volume per haul, and harvest method. The harvest intensity variable collected the additional time required to build bunches in a single-tree selection harvest, and the lower volume per cycle for both skidders.

Estimated skidding productivity increased with the percentage of the stand removed but was also influenced by differences in average stem size. Felling productivity was more closely related to the d.b.h. of the felled stems. For the grapple skidder in 1991, a IO-percent increase in harvest intensity resulted in a 30 cf/hr increase in productivity, and a $0.70 decrease in the cost per ccf produced. The dual benefits of increased productivity and decreasing per-unit cost associated with increasing harvest intensity substantiate conventional wisdom that clearcutting is a cheaper form of harvest, is more productive, and hence, more efficiently utilizes logging machinery capital investment. For example, in this study the average yearly investment (a measure of yearly capital cost) for the grapple skidder is $95,000. Estimated productivity of this skidder for the single-tree selection harvesting method was 3.21 ccfihr, for the shelterwood method, 4.47 ccf/hr, and for the clearcut method, 5.06 ccf/hr. Thus, productivity on the clearcut is 1.58 times that of the single-tree method, a 58-percent increase in capital-use efficiency.

The residueal impact analysis identified a significant increase in soil bulk density in the skid trails because of the concentrated traffic patterns. Residual tree damage was higher for the single-tree selection method than for the shelterwood method because of the high residual tree density.

Although the lower harvesting intensities had higher costs, higher residual tree damage, and a higher soil bulk density increase, it had the lowest percentage of total area in skid trails and disturbed area, thus providing a continuous ground cover. For some forest land managers, the higher cost of the single-tree selection method is compensated by its esthetic quality, continuous canopy, high percentage of site unaffected by harvest, and improved natural regeneration. The effect of multiple, closer spaced entries by harvesting equipment into forest stands on some of these qualities is still unknown. Additionally, the results of the postharvest survey confirm that total ecological disturbance, based on the percentage of the stand trafficked, is much lower with single-tree selection than with clearcutting.

The results of the harvesting study describe relative time and cost of operations for different harvest intensities given a single operator. The predictive ability of these equations for a broader spectrum of options is yet to be tested. In the summer of 1993, harvesting operations were observed, and postharvest assessments were performed on six new stands. The stands included group selection, single-tree selection pine, and single-tree selection pine/hardwood. The operator and equipment used in the 1991 and 1992 studies were not used in the 1993 study. The diameter distributions of these six new stands were statistically similar to the stands from the 1991 and 1992 studies.

The regression equations developed in 1991 and 1992 will be applied to this new data. Additional variables to account for differences in machinery will be added to the equations. This is the next step in developing reliable predictive equations.

The controversy between even-aged versus uneven-aged management and their associated silvicultural methods will continue, especially for public land management. For many proponents of uneven-aged management, harvesting cost and economic efficiency are a distant third consideration after maintaining stand visual quality and minimizing individual stand disturbance. Even-aged management advocates champion harvesting and capital efficiency as preeminent concerns. Two even-aged reproduction methods are compared in this study with a single-tree selection harvest in an initial basal area reduction cut intended to bring an even-aged stand to uneven-aged structure. Harvesting productivity and cost for these operations were determined by the pre-harvest stand conditions, average tree size removed and the spatial distribution of the trees on the site.

Literature Cited

American Society for Testing and Materials. 1992. Standard practices for correction of unit weight and water content for soils containing oversized particles. In: ASTM Standards on soil compaction. Standard D 47 18-87. Philadelphia: American Society for Testing and Materials: 123-124.

Bell, R. D. 1989. Influences of varying stand harvest methods on timber harvesting costs in southwestern Virginia hardwoods. Blacksburg, VA: Industrial Forestry Operations Program, College of Forestry, Virginia Polytechnic Institute and State University. 69 p. M.S. thesis.

Clark, A. C.; Saucier, J. R. 1990. Tables for estimating total-tree weights, stem weights and volumes of planted and natural southern pines in the southeast. Res. pap. 79. Macon, GA: Georgia Forestry Commission, Research Division. 23 p.

Hannah, P.; Kiln, M.; Kinnett, D. 198 1. Some impacts of whole-tree harvesting under some different silvicultural methods. Northern Logger and Timber Processing. 29(11):60-61,82,84.

Kellogg, L. D.; Pilkerton, S. J.; Edwards, R. M. 1991. Logging requirements to meet new forestry prescriptions. In: Proceedings: Council on Forest Engineering 1991 Annual Meeting; July 22-25, 1991; Nanaimo, British Columbia. Nanaimo, British Columbia: Faculty of Forestry, University of British Columbia with McMillan Bloedel Ltd.: 43-49.

Miller, Gary W.; Sarles, Raymond L. 1986. Costs, yields and revenues associated with thinning and clearcutting sixty year old cherry-maple stands. Res. pap. NE-582. Brosmall, PA: U. S. Department of Agriculture, Forest Service, Northeastern Forest Experiment Station. 16 p.

Miller, G. W.; Smith, H. C. 1991. Applying group selection in upland hardwoods. In: Proceedings: Uneven-aged silviculture of upland hardwood stands workshop. February 25-27, 1991; Blacksburg, VA. Blacksburg, VA: Industrial Forestry Operations Program, College of Forestry, Virginia Polytechnic Institute and State University, Cooperative Extension Service. 6 p.

Miyata, E. S. 1980. Determining fixed and operational costs of logging equipment. Gen. tech. rep. NC-55. St. Paul, MN: U. S. Department of Agriculture, Forest Service, Northcentral Forest Experiment Station. 16 p.

Sloan, H. 1991. Uneven-aged silviculture: impacts on loggers. In: Proceedings, Uneven-aged silviculture of upland hardwood stands workshop. February 25-27, 1991; Blacksburg, VA. Blacksburg, VA: Industrial Forestry Operations Program, College of Forestry, Virginia Polytechnic Institute and State University, Cooperative Extension Service. 4 p.

Understanding People and Natural Resource Relationships: Ouachita National Forest Timber Purchasers and Changing Timber Harvest Policy[1]

Christine Overdevest and Donald B.K. English[2]

ABSTRACT

Seventeen woods workers addressed the Ouachita National Forest's 1967 shift from uneven-aged management to even-aged management and the 1988-89 shift to uneven-aged management of the forest. Respondents' unique views, values, and stakes are heard, and emergent similarities and differences among them are analyzed in a qualitative study. While a majority of 17 participants criticized the Ouachita National Forest's recent transition to uneven-aged management, other study participants lauded the Ouachita National Forest's move to uneven-aged management. In the following pages, the variety of ways in which the woods workers perceived and valued the use and management of timber is reported. Studying perceptions and values regarding timber management aids us in generating a better understanding of people and natural resource relationships.

Keywords: Harvest method, even-aged management, uneven-aged management, ecosystem management, loggers.

INTRODUCTION

The Strategy for the 1990's for USDA Forest Service Research calls for increased understanding of people and natural resource relationships, increased understandii of how people perceive and value the protection, management, and use of natural resources (USDA **1990b),** and. studies of rural community residents' values and ways of life (USDA 1991). Harvest policy changes on the Ouachita National Forest in southwestern Arkansas and eastern Oklahoma have affected woods workers and their natural resource relationships. In this study, an attempt is made to reconstruct the perceived past effects of harvest policy change and to document the anticipated future impacts of recent policy change on Ouachita National Forest woods workers. The **first** section of this paper provides information on Ouachita National Forest harvest policy changes; reviews of previous studies are documented in the second section. Methods and sampling techniques are described in the third section. The major portion of the paper presents a summary of 17 in-depth interviews with Ouachita National Forest timber purchasers. The final section provides discussion and conclusions.

Harvest Policy Changes

Even-aged management is a system of managing timber so that all trees within a particular stand are the same age class (Horwitz 1974). Certain tree species regenerate better under even-aged conditions, particularly shade-intolerant species. These species include yellow poplar, black walnut, black cherry, and white birch as well as southern pine and Douglas fir (Horwitz 1974). Harvest methods used to establish and maintain even-aged management include clearcut, seedtree, and shelterwood.

Uneven-aged management is a system of cutting single trees, or small groups of trees, of varying ages, leaving others to grow and disperse seeds in the resulting openings (Smith 1986). Harvest methods used to establish and maintain uneven-aged stands include single tree and group selection.

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A thinning is a preharvest cut used in uneven-aged and even-aged management. Thinning is undertaken to remove undesirable species and trees in poor health from a growing stand to increase the total yield of high-quality trees at harvest time in either type of management (Holland and others 1990). The illustrations in figure 1 depict a harvested area after removal by even-aged and uneven-aged harvest methods.

Figure I.-Definition of harvest methods **Source:** U.S. Department of Agriculture. **1990a.**

Single Tree Selection --

Trees of various **sizes,** dispersed throughout the forest, are **individually** selected for cutting **Harvest** treatments enhance or maintain the uneven-aged character of the stand.

Group Selection --

Small groups of trees are cut in **1/4** to 2 acre sires.

Shelterwood Method --

Several cuts are made over a period of 10 years. The first cut is designed to remove over-mature trees. The second cut uniformly opens the canopy in **order** to afford **sufficient** light and warmth to stimulate germination, establishment and survival of the seedlings. Finally, comes one or more cuttings in which the remaining old **trees** are removed for the development of the new stand.

Seedtree --

Most trees ate removed in one cut, leaving 12 to 15 well-spaced, seed producing trees over each acre.

Clearcutting --

Trees larger than 1 to 2 inches in dieter are generally removed from a specific **area** at one time. Some trees **are** left within the area to address wildlife, soil, water and visual needs.

Harvest Policy Change 1: From Uneven-aged Management to Even-aged Management

The Ouachita National Forest practiced uneven-aged management on its 1.6 million acres of forest land until 1967. In 1967, it began replacing single-tree selection with clearcutting and seedtree removal. In 1969, the multinational Weyerhauser Corporation bought the firm, Dierks Forest Inc. Dierks owned 1.8 million acres of forest land adjacent to and intermingled with the Ouachita National Forest timberlands and had also practiced uneven-aged management by single tree selection. When Weyerhauser bought Dierks in 1970, Weyerhauser implemented an even-aged management strategy. Weyerhauser used clearcutting, slash removal, site preparation, and planting of genetically superior loblolly pine seedlings. Clearcuts were performed on 30-year intervals and the land was replanted (Smith 1986).

Thus, the two largest timberland holders in the Ouachita Mountains changed their harvest policy to even-aged management in the late 1960's. Through 1988, over 250,000 acres of the Ouachita National Forest were harvested by the even-aged method. According to forest records, no uneven-aged management was used in the intervening two decades, 1967 to 1988 (see table 1).

Table 1. – Acres Harvested by Harvest Method, ONF FY 1967 - 1992*

	Uneven-aged management	Even-aged management
1967-1988	0	268,762
1988-1992	14,378	24,045

SOURCE: Ouachita National Forest timber management staff, November 1992.
***Includes all sales valued greater than $2000 and all permit sales, excluding personal use firewood.**

Harvest Policy 2: The Return of Uneven-aged Management on the Ouachita National Forest

In fiscal year (FY) 1989, the Ouachita National Forest reintroduced uneven-aged management and significantly reduced clearcutting in the forest. Planned uneven-aged management sales increased from zero acres annually to 15,000, and planned annual clearcut sales decreased from 16,000 acres to 5,300 acres (a 67-percent reduction in clearcutting). A 9-percent reduction in total timber available for sale was planned as well (USDA 1990a). However, due to a variety of factors, including policy changes and appeals on timber sales since 1988, reduced amounts of timber have been sold. In FY 1991, zero acres timber by the clearcut method and 3,761 acres by uneven-aged management methods were sold on the Ouachita. In fiscal year 1992, harvesting by uneven-aged techniques increased to 11,349 acres while the number of clearcut acres remained at zero.

A typical pulpwood operation before 1976 involved no investment beyond a chainsaw and a single-axle truck (Watson and others 1977). By 1987 in Arkansas, one-quarter of all logging operations were high-production operations having eight or more employees (27.4 percent), and investments of more than $100,000 were not uncommon. For example, in 1992, a crew with a feller buncher, grapple skidder, knuckleboom loader, and truck driver would require a $380,000 to $450,000 equipment investment. In 1987, 63 percent of operations in Arkansas used knuckleboom loaders (at a cost of $90,000 to $110,000); the same percentage used diesel tractor trailers ($70,009 to $100,000); 57 percent used rubber-tired grapple skidders ($85,000 to $95,000) and 26.1 percent used rubber-tired feller bunchers ($135,000 to $145,000) (Watson and others 1989).

ISSUES RAISED IN OTHER STUDIES

In three recent studies, loggers and other timber industry members were interviewed concerning forestry activities in their communities. Kusel (1991) interviewed independent and gyppo[3] loggers who expressed concern that national forest policies favored the interests of large-scale forest industry over the interests of independent and gyppo loggers. More timber was harvested from the two studied national forests in the 1980's than *ever* before, but

[3] An independent operator who does not purchase timber directly, but generally operates timber purchased by others.

independent and gyppo loggers reported it more difficult to purchase timber because large companies dominated timber sale contracts (Kusel 1991). When large companies dominate local timber purchases, Kusel suggests such companies hold powerful influence over the well-being of independent and gyppo loggers by setting logging rates, and telling loggers when and how much timber to harvest. Once independent and gyppo loggers are constrained in how much work they can get and how much they will be paid for it, they perceive a loss of control over their lives, reducing their sense of social well-being (Kusel 1991, Fortmann 1991).

Bliss and Flick found that while most timber industry members valued the economic efficiency of businesslike high volume producers and high volume producers depended on high-volume per acre sales to pay off equipment debt, truck and chainsaw pulpwood producers highly valued maintenance of subsistence patterns associated with low volume logging. Access to wood was a main concern for these producers. In the focused interviews, truck and chainsaw loggers complained about how difficult it was to locate timber because of the competition from mechanized producers, 'timber brokers, and mills.

Bliss and Flick concluded that while traditional truck and chainsaw haulers are largely a thing of the past, low volume operators continue to find a niche in small tracts, salvaging damaged timber or in environmentally sensitive areas. One of Bliss and Flick's interviewees described the niche for low-volume producers:

> "It is still a need for little producers, because you got somebody who's got five acres, a little tract of timber here around their house, may not be but 50 cords of wood. Big producers, he can't move all his bii equipment in, his bull dozer up there to make a road, and his loader, and skidder and all that to cut one day, you see. So it's a demand for the little producer, and it always will be" (p. 17).

Fortmann and others (1990) in a study of participants at Redwood Summer[4] found that some local timber industry workers were concerned with potential adverse effects of harvest intensity on forest health. Some timber-sector employees concerned about forest health felt the Forest Service and forest industry used inappropriate practices. One logger complained about the extent of timber harvesting in the area: "If we didn't have a Sierra Club, we probably would have no trees up here. People are greedy. The companies would have cut all the trees up here." A number of timber industry workers interviewed claimed they hated clearcuts (Fortmann and others 1990).

Each of these qualitative studies suggests that some timber industry workers have concerns and interests different from large-scale forest industry. Bliss and Flick found truck and chainsaw loggers that were concerned about access to timber sales and competition from economically powerful actors. Kusel's independent and gyppo loggers feared the domination of timber purchases by forest industry, and Fortmann and others' "environmentalist loggers" were concerned about the amount of timber taken from local national forests. These studies suggest that some members of the timber industry, particularly truck and chainsaw and independent and gyppo loggers, have experienced the modernization and mechanization of the timber industry as a potential threat to their way of life or as a perceived threat to forest health.

METHODS

Samples for this study of attitudes toward changing harvest policy were taken from USDA Forest Service form 2400-17, timber sale proof listings, from the first quarter of FY 1985 through the fourth quarter of FY 1991. Such a form is completed for each timber sale valued at over $2,000. Information such as timber purchaser name, purchase date, size, and minimum bid from each sale were compiled. All purchasers who bought Ouachita National Forest timber sales contracts, both before and after the implementation of uneven-aged management in FY 1989 were the target sample. Twenty-seven timber purchasers met the target sample criteria; they included 15 product mills, 6 timber brokers, and 6 loggers in the target sample. Contacts were attempted with all of them. The final sample of 17 included 5 of the mills, all 6 of the timber brokers, and all 6 of the loggers. Years of experience in woods work in the Ouachita Mountains in this final sample ranged from 8 years to 42 years with a mean of 23 years.

[4] An environmentalist-sponsored event, protesting the cutting of northern California redwoods.

Interviews were conducted in person between December 30, 1991, and January 11, 1992, at respondents' homes or businesses. Interviews lasted from 1 to 2.5 hours and were tape-recorded. In the semi-structured interviews, an interview schedule was used to guide discussion, and interviewees were encouraged to discuss their views and perceived experiences related to Ouachita National Forest harvest policies. Semistructured interviews are approximations of a formal questionnaire and are usually chosen when the researcher wants to develop comparative data (Fetterman 1989). In this case, comparisons of respondents' perceptions of harvest policy were planned.

After wllecting life-history data regarding early experiences in the local timber industry, respondents were asked about the anticipated impacts and perceived past impacts of harvest policy change. Respondents were asked questions about what it was like when the Ouachita National Forest switched harvest policies (i.e., "Do you remember when the Ouachita National Forest started even-aged/uneven-aged management? Describe that time. How did the change affect you? Was the change for the better?"). While each respondent was asked to restrict their comments to perceptions of different harvest policies, respondents raised issues of timber availability as well.

Qualitative methods of research differ from quantitative in that quantitative methods are generally used for quantifying population parameters, generating statistically valid generalizations about population samples, and for estimating degrees of confidence associated with research hypotheses. Qualitative research results, on the other hand, are generally used for discovering unknown relationships between beliefs, attitudes, behavior, and contexts, thus generating important parameters and hypotheses rather than quantifying and testing them (Bliss and Martin 1989). Because people may perceive and experience circumstances differently, respondents' perceptions may not wnform to "objective" reality, nevertheless understanding them may help researchers, research audiences, and policymakers understand why members of a particular social group feel and act like they do (Fetterman 1989, Henderson 1991). For more information about qualitative research see Linwln and Guba (1985).

RESULTS

The Supporters of Even-aged Management

The majority of interviewees (n= 12) highly valued even-aged management for its production efficiency and its capability to produce high volumes of timber. They think that clearcutting is environmentally feasible and sustainable. Because of the percieved economic inefficiency of uneven-aged management, the supporters of even-aged management feel that the size and number of timber harvesting operations will decline, and they are wncemed with the impact of reduced-timber availability. The combination of reduced efficiencies and reduced stumpage has caused this group apprehension and fear about their current and future dependency on Ouachita National Forest timber and about the viability of the local economy. The supporters of even-aged management included all 5 mill buyers, 4 of the 6 timber brokers, and 3 of the 6 loggers.

The Supporters of Uneven-aged Management

The supporters of uneven-aged management (n=5) fondly remembered the forest management that Dierks and the Ouachita National Forest practiced before 1967. They recalled the high quality of timber and the small crews of harvesters that were supported by uneven-aged management in the 1960's. In the 1970's, when clearcutting became the dominant harvesting method and timber production increased, these interviewees remembered the demand for high-production logging. However, it appears that some logging operators resented the changes and felt that high-production operations were squeezing smaller operations out of their traditional ways of life. Much like the respondents to Bliss and Flick's study, these respondents report seeing large mills often outbid everyone else on desirable high-volume sales. The respondents began to associate clearcutting with both the demise of low-production logging and to the clearing of the forest. As evidenced in the interviews, they questioned whether even-aged management would lead to the whole forest being cut. Today, these interviewees praise the return to uneven-aged management, because they think uneven-aged management will lead to more low-production loggers and to better protection of the forest resource. However, they fear the effect of "preservationists" and "environmentalists" on timber availability because less timber has been available to harvest than planned.

Thus, the interview data suggest that not all members of the timber industry view changing harvest policy in the same way. In the eyes of uneven-aged management supporters, the intensive timber management of the Ouachita

National Forest and surrounding lands practiced in the 1970's and 1980's threatened demise of local forests and thus their livelihoods. The high volume harvesting is felt to be non-sustainable, and the high production crews are felt to be stealing jobs from low volume loggers. From the perspective of supporters of even-aged management, the intensive management of the 1970's and 1980's was acceptable, supported their livelihoods, and they fear that the return to uneven-aged management will negatively affect high volume operations. All interviewees agree that even-aged management favors high production logging, which is felt to be threatened by the return to uneven-aged management.

In the rest of the paper, the perspectives presented above will be documented through the actual words of the respondents? Fist the views of the supporters of even-aged management will be presented and the views of supporters of uneven-aged management follow. Tables 2 and 3 provide descriptive statistics of respondents.

Table 2 – Supporters of Uneven-aged management on the ONF

Respondent	Yrs in local timber industry
Logger 1	25
Logger 2	22
Logger 3	42
Timber broker 1	18
Timber broker 2	17

Table 3 – Supporters of Even-aged management on the ONF

Respondent	Yrs in local timber industry
Mill buyer 1	23
limber broker 3	35
Timber broker 4	26
Logger 4	13
Logger 5	31
Timber broker 5	12
Timber broker 6	34
Mill buyer 3	18
Mill buyer 4	15
Mill buyer 5	25
Mill buyer 6	26
Logger 6	8

[5] Written permission was obtained from respondents by researchers to include direct quotes in publication.

The **Interview** Data

The 12 supporters of even-aged management criticized the economic inefficiency of uneven-aged management, and praised the efficiency of even-aged management, particularly clearcutting. Many noted their logging and production costs will increase significantly under uneven-aged management.

> "On a thinning, just the average thinning sale, you're going to cut [a logger's] production down. You're going to take off at the least, at the very least 30 to 35 percent of their production (Timber broker **6).**"

> "It'll cost **20** to 25 percent more to harvest uneven-aged cuts than it does clean cuts, and that was the, that's one of the big things that's happened to us (Timber broker **4).**"

> "You still got the same amount of labor involved, at the end of the day, and you get half the production (Logger **6).**"

Because of the reduced **efficiencies** and profits, **timber** purchasers emphasii that uneven-aged management has resulted in higher costs to **mills,which** they believe will make their products less competitive with products from other areas and will result in lay-offs for both logging hands and mill workers.

> "When you take a local area and change from even-aged management to uneven-aged management, you increase the logging cost and that is reflected in the total cost of the finished product and then that product has to go out on the market place and compete with other products from other areas and it's not possible to do that; you can't compete with someone when your cost is more than theirs (Mii buyer **3).**"

> "You've got to have a certain volume per acre before it's profitable for that [logging] contractor to go out there.... If he can't get two loads a day, I end up paying him for that second load because it takes him two loads to make payments and everything and to show a profit.... It gets to the point where you add the **stumpage** and what I paid for the logging and manufacturing costs, I can't sell it for a profit... (Mill buyer 4)"

> "[Under uneven-aged management] all your men that's working for you that's paid by the ton **-** they can't make it.... You've got hands that you've got to lay off on single tree selection... Just strictly going to **uneven-**aged management is **-** we'd just have to fold up **-** there's just no way that we can do it up here (Logger **4).**"

Many supporters of even-aged management felt that the size of timber operations will decline, noting that larger logging operators will have to downsize. It will be **difficult** to support highly mechanized operations with uneven-aged management. The following comments were typical:

> "The size of them is definitely having to change... I'm not saying a larger contractor can't work a **thinning** or anything **-** but most of the larger contractors are just locked in with 'I have to have this amount of volume per acre before I can make any money... [One large contractor I know's] got three trucks, three skidders and a loader and he's got eight people **-** three truck drivers, three skidder drivers, and a couple of saw hands and himself. Well he has to move four loads a day just to pay these guys to be out there and then he has to move another load to pay the insurance and costs . . . it was narrowing down to where he was going to have to split his crew, buy another loader and promote him somebody to run one of the crews while he run the other one. Well he just wasn't going to do that so he sold out. He was a million dollar operator (Mill buyer **4).**"

> "In this area, basically all the loggers are equipped the same, some of them just have more, they have the same types of equipment, some of them just have more than the others. Four-wheel drive skidders and hydraulic loaders and tree-length operations, basically. We still have a few small shortwood guy who cut with a chainsaw and load them by hand and haul with small loading each day. There's very few of the small equipment operators still left here. I think that the changes that would affect the loggers, if you go down to uneven-aged management, where you've got a smaller clip per acre and smaller sales in an area, the loggers that have a lot of equipment will be forced to downsize because they can't move every other day (Mill buyer **3).**"

> "We have cut back to just two skidders and two trucks... (Logger 4)"

Supporters feared that environmental groups will be successful in stopping timber sales, reducing timber needed to supply mills and sustain logging operations. While respondents were asked to restrict comments to opinions on even-aged and uneven-aged management on the Ouachita National Forest, they often raised issues of reduced timber availability.

"Just by a stroke of the pen [a **preservationist]** can appeal every sale that comes out of the Ouachita National Forest. They can lock you out, and the Forest Service has its administrative appeals process which was created to allow the public to have an input in Forest Service decisions and to appeal any decisions they felt like were a problem. But these appeals are just automatic appeals. Anything that has to do with even-aged management, that is not selective cutting [a **preservationist** can] just automatically appeal. And you can stop an entire forest, and that has been clearly illustrated here on the Ouachita... Where they have a normal sale schedule of 175 million feet, they only sold something like 35 million feet (Mill buyer **1)."**

"Originally the preservationists, is a word I like to use rather than environmentalist, because I consider myself as much an environmentalist as anybody. The preservationists originally only appealed sales for clear cutting that were geared toward even-aged management. **Originally.** It seems to be now they appeal everything . . ..They have had a tremendous number of appeals on the Ouachita which its my understanding has slowed the process down, even kept a lot of timber off the market. Many **millions** of board feet that otherwise would have been sold have been delayed, a lot has been cancelled. The main problem everybody [in the timber industry] has is they're not selling anything (Mii buyer **5)."**

With the combination of uneven-aged management and reduced timber availability, timber purchasers expressed concerns about the total economic impact to the area.

There's three counties right here that really depend on timber and without it, they just don't know what to do. Our schools are going to suffer, county roads are going to **suffer...I** don't want to say anything bad about anybody because they have their points too. And we could all work right here if they'd set down at the table and be broad-minded about it. They could have what they wanted and we could have what we wanted. I think everyone involved in the timber should be at a table somewhere giving his point **(Timber** broker **3)."**

"From your loggers out in the woods all the way down to your grocery store in the community, your service stations, everybody suffers as a result of it. So you can't say its just the timber industry --that they're the only ones, just those old loggers and sawmill people. That's not all that's involved - your schools are involved in it. Your supermarket's **involved in it. Your bank's involved in it. Your parts store in that town-he's selling parts to those loggers - your tire dealership.** He's **not going to be able to sell any tires if those loggers aren't rolling those trucks and blowing out tires you know (Mill buyer 2)."**

"All **of** Arkansas really is heavily dependent on the forest industry, and a lot of people tend to forget **that...I** just want the people of Arkansas to realize how vital it is to the economic **well-being** of this state and to these areas throughout the Ouachita and Ozark Forests, and that they should do everything they can to keep the programs, support the programs, and support the Forest Service (Mill buyer **1)."**

To mitigate these negative consequences, even-aged management supporters suggested several courses including increased volume per acre on single tree selections, maintaining the total sales volume as in the USDA Forest Service, Ouachita National Forest Plan, and balancing more clearcuts with the uneven-aged management.

"It wouldn't be (bad) if they'd mark more volume per acre. They still could have uneven-aged management, still leave a good stand and they could go in there two or three times and thin it (Timber buyer 6).

"As long as they would just sell something close to their sales targets which are part of their forest plans that they spent many millions of dollars developing, if they'd get even close to those sales targets everybody would be okay.... (Mii buyer **5)"**

"Basically, what the Forest Service has done for the past ten years, from the late seventies to the middle eighties was a good plan. But as far as coming out with all this uneven-aged management... I just don't know... I'd like to see clearcutting put back in places, I believe it's got it's place. I just want to make sure that gets in there, the clearcutting (Logger **4)."**

On the other hand, a consistent theme in the interviews with supporters of uneven-aged management is that smaller operators will benefit from uneven-aged management and that uneven-aged management ensures the protection of the forest resource for future generations while clearcutting threatened demise of the forest. The 5 supporters of uneven-aged management expressed approval of the Ouachita National Forest management for de-emphasizing clearcut harvesting and reintroducing uneven-aged management since FY 1989. These respondents see uneven-aged management as capable of indefinitely sustaining high quality timber harvesting as a natural resource employment opportunity; while they see even-aged management, especially clearcutting, as exploiting timber and curtailing natural resource employment opportunities for themselves and their children.

> "I'm glad to see it [clearcutting] stop . . . but it's something that I thought that ought to be done 20 years ago. Because I've got a grandson and I hope that he never logs but, if he wants to log...in 20 years if we keep clearcutting what's he going to haul? (Logger 1)"

> "I could say yes I'm 100 percent in favor of the clearcutting . . . But I can say if we do there'll come a time when we won't have anything to do. If you clearcut everything, you know, you've got to wait for it to grow back and that just ain't going to work (Logger 2)."

Several believed that both Weyerhauser and the Forest Service would run out of timber if they continued clearcutting at the rate of harvest between 196%1988.

> I'd seen that they (Weyerhauser) were going to run out of timber. Anyone with common sense could tell it. I saw that it would grow, but it had to be thinned if they were going to grow more volume on those... I believe that they could have selectively managed it and continued on (Timber broker 2)."

> "They almost waited too long to stop clearcutting. That was the statement that I made. They've almost got everything clearcutted in this country...(How do you feel about clearcutting?)..Well I'm not for it. They're ruining the timber. Because they've got it cut out and it's not growing back. Of course, Weyerhauser wouldn't agree with this but that don't make any difference - I've lived here all my life and I can see. So long as Dierks lumber and coal company had the company here in Arkansas, they select cut. Well, they had timber to cut on all the time and when Weyerhauser bought them out they started clear cutting and they don't have it any more to cut. The Forest Service done like Weyerhauser - they clear cut a lot - and I wasn't for that - but that didn't make any difference; they did it anyhow. But the way they mark their trees in select cut why I think they do alright with that. Well of course naturally I think that's what they're suppose to do (Logger 3). "

Like Bliss and Flick and Kusel's respondents, several supporters of uneven-aged management felt that a clearcut policy favored forest industry and large-volume operations and marginalized smaller producers. The labor-saving technologies of the 1970's and 1980's increased the overall efficiency of the harvesting process but at the cost of some traditional rural subsistence occupations.

> When they went to clearcutting, the big operations bought all the clearcut timber because it was so much volume that the smaller loggers couldn't afford to buy it...I think that they went astray a little bit on their clearcutting; and one of the reasons that I think they did was they put too much volume into each sale, and that if they had kept the volume down for where the smaller, individual loggers could have handled it, it would have been better (Logger 2)."

> "If there's a million feet of timber, you can't go buy it. So it is, and I can understand their point about it, it's easier for the government to forget coming out here and painting a little old ranger sale. They'll just run out there and sell it all in a big sale. But what they was doing - they was starving the little man out. See, they forced that little man to go to work for the bii man and . ..then the only terms that we had was to get in, was to get the skidders and stuff and get in and go and play with the bii boys (Logger 1)."

> "They got these mills they just - the government just got to throwing everything out there for the bii man to buy so they just choked us out. Our only terms that we had left was to get in then and to get into bii logging and go a-logging for the bii outfit. Because they went to making these bii old clearcut units, and these sales was so big that a guy like me couldn't buy them (Logger 1)."

Finally, supporters of uneven-aged management sympathized with current high production, **mechanized** loggers. The supporters of uneven-aged management felt the high production loggers needed clearcuts in order to remain profitable and to pay their equipment capital costs. Without clearcuts they will have to downsize. As Bliss and Flick report, these respondents feel high production loggers need 'bii volume jobs' to remain viable.

> "True, I hate to see **clearcuts** stop **[because]** I got a lot of friends that are still in logging that needs the clearcuts. I know what it is to owe money. I know what it is to buy this equipment. I've been there.... They really need [clearcuts] to get by because it all comes down again to production. If you can't get production, you can't make it... But people get their operations too bii. With the loggers that's got the one truck, one skidder, one loader operation - they're going to survive (Logger **1).**"

> "Now I can see where some of the bii companies are coming from they got millions of **dollars** worth of machines that just **will** not work in a you know an [uneven-aged] management program. They just won't work in it. When you've got all kinds of expensive equipment and **stuff** like that it just won't- it's not feasible to use it. And that's the reason they're turning it back to a **smaller** logger again because he can deal with it and they can't. And I think that is the best place for it to be. When the companies - the bii companies get involved in it it takes a lot of logging really. It takes a lot away from the individuals and you know all of the loggers, in this area **especially,** are small operations run by families or one man and he is **responsible** for all of it and he can pretty well take care of it but when you get into a bii company and they contract it out nobody **hadn't** really got anybody to answer to.... And that I think is what **they're** running into a lot of times is damaging the forest to where it can't be repaired if you get people in there that don't care or you know just kind of make quick money in it and get out of there (Logger 2).

> "Course it's going to hurt these guys that are rigged up bii who have **$400-$500,000** invested. But there's just a few of those, there'll **be** a lot more employed. But see, a lot of bii ones aren't going to like that. It's going to hurt a few, but when they switched over back in the **70's,** when they switched it hurt a bunch of people **(Timber** broker 1).

The supporters of uneven-aged management also prefer uneven-aged management because they think it will ensure the protection of the forest from overcutting and provide high quality timber.

> "I think it was better when they was selective cutting than I do for clearcutting. Because you had a better grade of lumber, and you wouldn't run out of timber, and they worked so many more people (Timber broker **1).**"

> "I think that it's better for the environment, for the forest, and **everything,** to uneven-age manage the timber... [There] will always be timber there - there will always be a forest there (Logger **2).**"

DISCUSSION AND CONCLUSIONS

When the Ouachita National Forest and Weyerhauser switched to even-aged management, the production efficiency of high volume even-aged management provided the margins needed to support the rational ownership of expensive mechanized equipment. As mechanized equipment was adopted by several firms within the area, it altered the general demand for workers with particular skills. **Small** logging companies on the competitive margins were likely eliminated.

Some small operators survived by cutting **small** volume sales such as ranger sales or other sales in hard to get to areas because small operations are more efficient at low volume logging than large heavily-capitalized operations which need a certain production efficiency to cover the costs of the use of their equipment. As long as high volume per acre even-aged management dominated harvesting on the national forest, large operations were supported. Since the return to uneven-aged management, the rational size of operation likely will be smaller than that supported by an even-aged regime.

Several past studies have shown that some timber purchasers and timber industry members have experienced the economic rationalization of timber production and harvesting as a threat to their subsistence needs ***or*** a threat to the **sustainability** of the forest; while other industry members praised the economic efficiency and overall social benefit of high production silviculture and harvesting. The researchers point to the importance of understanding how historical aspects of harvest policy actively structure the rational **organization** of local timber industry.

Rational economic behavior among firms varies according to the profitability of various employment strategies under different market conditions (Marchak 1988). Behavior that is rational for a small company operating on a thin margin with a small capital investment may not be rational for a large company. Similarly, the amount of capital a large heavily-capitalized **firm** can invest in technological advancements may not be an option for a small company. In this study, the different levels of support for even-aged and uneven-aged management may vary with the rational economic interest at the firm level.

The interview participants suggested that even-aged management benefits high volume timber operations and **marginalizes** low volume operations. The even-aged management of the 1970's and 1980's was perceived by timber purchasers to favor the economic **well-being** of high production timber operations. Now uneven-aged management is expected by all to favor smaller operations. Thus, the viability of high and low volume timber operations seem to be directly related to harvest policy.

Forest managers plan for wildlife values, for recreation values, and for the effects of one resource use on a another. More should be done to assess the complex human dimensions traded off within resource decisions. In the case of Quachita National Forest, new management policies will not only affect the overall productivity of the forest and the overall economic impact on the area, but also the **well-being** and structure of people and natural resource relationships. An important consideration in implementing new policies is not only the interaction of ecological links among resource systems but also of ecological links with human systems, including the social structure and welfare of local timber industry members. In this paper, the researchers attempt to draw greater attention to the need to assess these human dimension affected by and traded off within resource decisions.

FUTURE DIRECTIONS

It is highly recommended that the Ouachita National Forest take on research that further develops information on the relationship between forest policy and the wellbeing of different operators. The number and kind of loggers in the Ouachita area, the number of mills, and their well-beii as defined by both their own values as well as traditional economic and ecological measures should be tracked through time while controlling for other variables. In order to develop a policy responsive to the needs of forest-dependent timber purchasers, the Oauchita National Forest must **recognize** the needs and values of different timber industry members. Once the nature of ecological, economic, and social benefits and tradeoffs of forest management are each better understood, a more rational accounting of forest management actions and polices may be possible (Brooks and Grant 1992).

LITERATURE CITATIONS

Bliss J.C.; Flick, WA. With a chainsaw and a truck: Lives of Alabama Pulpwood Producers. Unpublished 3-26 Manuscript. Auburn, SC: School of Forestry, Auburn University. **20** p.

Bliss J.C.; Martin, AJ. 1989. Identifying NIPF management motivations with qualitative methods. Forest Science. **35(2): 601-622.**

Brooks, D J.; Grant, G.E. 1992. New approaches to forest. management. Part 2: Background, science issues, and research agenda. Journal of Forestry. **90(2):** 21-24.

Fetterman, D.M. 1989. **Ethnography:** step by step. **Newbury** Park, **CA:** Sage Publications.

Fortmann, L., Kusel, J. [and others]. 1990. The human costs of the California Forestry Crisis. Unpublished Manuscript. Berkeley, CA: Department of Forestry and Natural Resources, University of California. 6 p.

Fortmann, L.; Kusel, J. [and others]. **1991. Well-being** in forest-dependent communities. Sacramento, **CA:** Forest Publishers, Inc. 245 p. Vol. 1.

Henderson, K. 1994. Considerations in using qualitative approaches in studying tourism and natural resources. Asheville, NC: USDA Forest Service, Southeastern Forest Experiment Station: 87-94.

Holland, 1.1.; Rolfe, G.L.; Anderson, DA. 1990. Forests and forestry. Danville, IL: Interstate Publishers, Inc. 476 p.

Horwitz, Eleanor CJ. 1974. Clearcutting: a view from the top. Washington, DC: Acropolis Books Ltd. 179 p.

Kusel, J. 1991. Well-being in forest-dependent communities. Sacramento, CA: Forest and Rangeland Resources Assessment Program. 130 p. Vol. 2.

Lincoln, Y.S.; Guba, E.G. 1985. Naturalistic inquiry. Beverly Hills, CA: Sage Publications. 416 p.

Marchak, P. 1983. Green Gold: Forest Industry in British Columbia. Vancouver: University of 'British Columbia Press. 454 p.

Smith, K.L. 1986. Sawmill: The story of cutting the last great virgin forest east of the Rockies. Fayetteville, AR: The University of Arkansas Press.

U.S. Department of Agriculture, Forest Service. 1990a. Amended Laud and Resource Management Plan Highlights: Ouachita National Forest. Hot Springs, AR. 8 p.

U.S. Department of Agriculture, Forest Service. 1990b. Strategy for the 90's for USDA Forest Service Research. Washington, DC. 9 p.

U.S. Department of Agriculture. 1991. Enhancing rural America: National research program. Washington, DC. 16 p.

Watson W.F.; Kucera, J.M.; Matthes, R.K. 1977. Pulpwood producer census southwest technical division of the American Pulpwood Association. Mississippi State, MS: U.S. Department of Agriculture, Forest Service, Mississippi Agricultural and Forestry Experiment Station. 20 p.

Watson, W.F.; Day, GA.; Altman, Jim [and others]. 1989. 1987 pulpwood logging contractor survey: Southwest aud southeast technical divisions of the American Pulpwood Association. Mississippi State, MS: U.S. Department of Agriculture, Forest Service, Mississippi Agricultural and Forestry Experiment Station. 16 p.

Management Costs Associated with Various Reproduction Cutting Methods[1]

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ABSTRACT

Management-cost data were gathered for various reproduction cutting methods as part of the ecosystem management research in the Ouachita Mountains. Costs were gathered on both traditional and nontraditional reproduction cutting strategies in an attempt to determine the cost-effectiveness of each management strategy and to estimate the resource requirements for wide-scale implementation of each method. Preliminary results indicate that sale preparation costs are higher for low volume-per-acre cutting methods.

INTRODUCTION

Little is known about the costs of implementing the management strategies being tested on the Ozark and Ouachita National Forests as a part of the ecosystem management research effort. The reproduction techniques are new to the area, and it is likely that silvicultural, management, and vegetation control costs will differ from current techniques. A study is currently underway to determine the management costs associated with the new reproduction methods. Data collection is not complete; however, an update on the methods of research and some preliminary results are provided here.

METHODS

Data were collected using USDA Forest Service operational crews from the Ouachita and Ozark National Forests. Cost-collection forms were filled out by crews after management tasks were performed, and the forms were returned to the Forest Supervisor's office for editing. Forms were then bundled and shipped to the researchers for data compilation and analysis.

Data recorded for each activity included location, management objective, area, distance from work center, and labor, equipment, and supplies used. Ouachita and Ozark National Forest personnel provided figures on the volume of pine and hardwood products harvested from each sale unit where cost data were collected. The location of each management activity was carefully noted with data collected on Phase II study sites separated from data collected for the same management activity on non-Phase II tracts. This was done to eliminate bias due to research activities. Some activities may cost more on tracts that are being actively monitored for several research studies than they would on operational sites, even though operational-sized (40 acres) units were used in the Phase II studies. Costs may also be higher on management activities that are new and different as each crew must learn the new requirements. Therefore, a large sample size collected over several years is proposed to deal with the inherent variability of the data collected and the problems associated with collecting data on new techniques, especially on actively monitored research sites.

Hours of on-site labor for each individual were assigned by pay grade and entered on the study forms. Labor cost was estimated by multiplying these labor hours by a standard cost, which included salary and benefits by grade. The assumption was made that the average employee had been on the job for about 4 years, making the employee a step 4 for pay purposes. The collection of hours of labor, not labor cost, will allow for easy updating of cost estimates and easy comparisons of data collected over several years.

Estimates of the supplies needed to accomplish each task, such as paint and ribbons for marking timber, were made on the cost-collection forms. Supply costs were obtained by multiplying the supplies used by the current unit cost of each item.

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Total transportation costs include the actual cost of operating a vehicle plus the lost labor hours spent commuting. These costs were estimated but were not used in the comparisons.

Timber harvest volume was calculated as the sum of sawlog volume in cubic feet equivalent and pulpwood volume in cubic foot volume. All costs were reported as cost per one hundred cubic feet (CCF).

Some difficulties were encountered using voluntarily supplied time and cost data. Records were sometimes obviously incomplete requiring the sample to be discarded, and, in other cases, time may have been incorrectly estimated. Nevertheless, there were advantages to using this method of data collection. Costs of this method of data collection, although significant, are far less than fielding a crew of researchers to gather the data. Obtaining precise estimates of new management activities is not cost-effective because the crews are likely to become more efficient as they practice the technique. It is better to have a larger sample size, spread out over several years, than to have more precise estimates of costs on a smaller sample size, given the variability in the data and the problems estimating the costs of new techniques. Finally, the key advantage is the use of operational Forest Service teams to perform the work. These teams would be responsible for undertaking the reproductive practices. Therefore, these crews' costs should be representative of the implementation cost for these practices.

RESULTS AND CONCLUSION

Preliminary results are presented to show initial trends in the data; more definitive results will be available as sample size is increased. Results of the comparisons of marking costs are shown in figure 1.

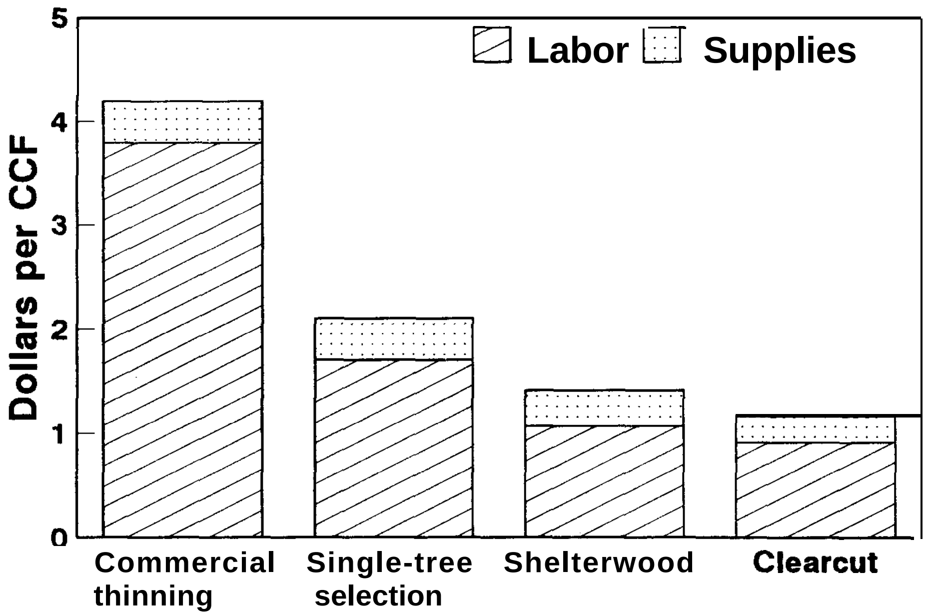

Figure 1.—Preliminary results of marking costs per CCF in the Ouachita Mountains.

Marking costs per CCF varied with the intensity of timber removals. On non-Phase II sites, on-site labor costs were $3.79/CCF to mark thinning tracts, $1.70/CCF to mark single-tree selection tracts, and $1.07/CCF to mark shelterwood tracts. The cost to mark clearcut tracts on the Phase II study site was $0.91/CCF. Thinning and single-tree selection call for more expertise and judgement than the clearcutting, and thus, more time is spent in marking. Removal volumes are concentrated for the intensive cutting practices and are dispersed for extensive cutting. Concentration or dispersal of marked timber is reflected in marking costs with higher concentration of removals yielding lower per-unit-volume marking costs.

Insufficient data points exist to differentiate between marking costs for all practices. For example, differences in marking cost between pine-single-tree selection and pine-hardwood-single-tree selection cutting strategies were undetectable at our sample size. Given the variability of the data, it is not certain that cost distinctions can be made from such similar activities even with larger sample sizes.

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Introductory and background material and pretreatment conditions and preliminary findings associated with ecosystem management research in the Ouachita Mountains is presented in 26 papers. Plant, wildlife, arthropod and microbial communities, soil, water, scenic, and cultural resources, and management economics are covered.

Keywords: Diversity, ecosystem components, forest plan, harvesting treatments, multiresource management, natural regeneration, partial cutting, shortleaf pine-hardwood ecosystems, stand-level study.

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