PROCEEDINGS OF THE FIRST ANNUAL SYMPOSIUM ON
THE NATURAL HISTORY OF
LOWER TENNESSEE AND CUMBERLAND RIVER VALLEYS

Held at Brandon Springs Group Camp
Land Between The Lakes
11-12 March 1988

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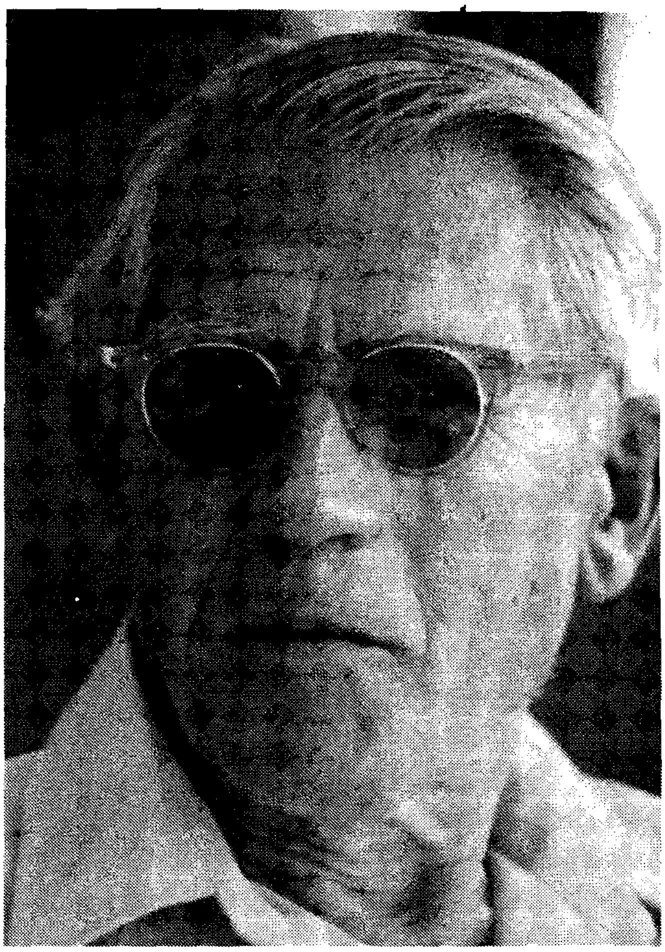

DEDICATION

To the Life and Legacy of Alfred Clebsch

Those privileged to have known him will understand why this dedication. His knowledge of and concern for the natural world around Clarksville, Tennessee, are local legends. As an extraordinary naturalist, he inspired many. But as a good and caring man, he inspired many more. His son Edward has kindly submitted the accompanying biographical sketch.

ALFRED CLEBSCH

1894-1980

Born in Düneheim, Germany, between Bremen and Bremerhaven, and educated through the gymnasium (requiring modern and classical languages), Alfred Clebsch's planned six-month visit to America lasted a lifetime. He got almost half way home aboard ship when the outbreak of World War I dictated that his ship proceed to the nearest neutral port--New York City. His return to Clarksville was because of his importer father's contacts in the tobacco business. Clebsch spent his professional life as secretary to the Clarksville Tobacco Warehouse Corporation. His avocation and second love (the first being Montgomery County native Julia Wilee Clebsch and their three sons) was nature and the out-of-doors. He was an early member and long-time secretary to the Tennessee Ornithological Society, and helped establish the Clarksville chapter. To fill those dull periods between groups of migrating birds in the field he, with the help and encouragement of Dr. Royal Shanks of the APSU Biology Department, began a study of bryophytes of the region. Interest in the broader flora followed naturally from his abundant curiosity, and resulted in the establishment of the herbarium at APSU. He never owned an automobile (though he was chauffer in one of the first in Clarksville!), preferring to walk or canoe or to ride with friends. His influences on younger people were many, good, and strong, whether they came from scouting (he established the first troop of Boy Scouts in Clarksville, and was still active in the movement fifty years later), from field companionship, or from tutoring friends in German. Election to membership in the Society of the Sigma Xi, now the Scientific Research Society, at about age 75 was based on his many publications in botany (including "Bryophytes of Land Between the Lakes") and ornithology. To him that was a real honor. He had no patience with false pride, and undoubtedly would respond to the honor of this dedication with, "By whose authority?". Perhaps the authority represented in the combined contributors, in the place that is Land Between The Lakes, and in the spirit embodied in the Center for Field Biology would be enough. Let us hope so.

Edward Clebsch
July 1988

PREFACE

In 1964 the Tennessee Valley Authority (TVA) was assigned stewardship responsibility for the area now known as Land Between The Lakes (LBL). The area was to be managed as a multiple-use facility, serving recreational, educational, conservation, and scientific research interests. Since then TVA has procured the land, and developed and implemented a management plan to that end.

Today the area, nearly 69,000 ha, has a different character than it did before TVA stewardship. No one lives there now. Wildness has crept back. Buffalo roam, eagles and Ospreys patrol the lakeshores and raise their young, and coyotes and bobcats stalk the night. River otters and Ruffed Grouse may soon join the ranks of the rescued, as the beaver, the white-tailed deer, and the Wild Turkey have done so successfully already.

But LBL is not a wilderness, and the human impress on the land is quite apparent. Hunting is allowed in much of LBL, and off-road-vehicle use and horseback riding in certain areas. Roads--most open to public use--provide convenient access to all but the remotest recesses of LBL, and campers may ensconse most anywhere. Most of the forest is professionally managed for timber production. Yet significant tracts--carefully selected and widely scattered throughout LBL--have been designated as natural areas of one sort or another, and are protected from most consumptive types of human use.

All in all, LBL provides to the region an unusual and useful resource. Of particular interest to readers of this volume is its value in studying the organisms and ecology of the region. Assuming continued enlightened management, the coming years can only see an appreciation in the value of that function of LBL.

In 1965, the Department of Biology of Austin Peay State University, under contract with TVA, began a series of investigations into various aspects of the biota of LBL. These investigations were largely inventories, and led to the publication of several scientific papers and a series of five non-technical booklets on the identification, distribution, and natural history of species in the following groups: lichens and ferns, spring wildflowers, summer and fall wildflowers, trees, and amphibians and reptiles.

In 1986, the Center for Field Biology of Land Between The Lakes was established at Austin Peay State University. The Tennessee State Legislature passed the enabling legislation, and the Tennessee Higher Education Commission approved the center. The purpose of the center represents a logical extension of the earlier groundwork laid by APSU faculty in LBL. The center's thrust is more ecological than the earlier work, though inventorying (an ongoing and necessary task) continues. "Listed" taxa (endangered, threatened, of special concern, etc.) are also receiving special attention (the Endangered Species Act of 1973 was passed after most of the earlier work by APSU faculty).

Recognizing the increasing value of LBL as a research site and ecological reference point for the entire region of the lower Tennessee and Cumberland river valleys, an annual symposium series was planned by the center. The intent was to allow a broad spectrum of researchers working on the natural history of the area to convene and discuss their findings. The first such symposium, sponsored jointly by the center and the Tennessee Valley Authority-Land Between The Lakes, was held at the Brandon Springs Group Camp facility in LBL on 11-12 March 1988. These proceedings are a result of that symposium.

Approximately 125 researchers, teachers, and students attended the symposium. Twenty-one papers were presented; 3 by the invited speakers on Friday, and 18 in the two contributed paper sessions on Saturday. In addition, there was an invited illustrated lecture on the birds of LBL, presented after dinner on Friday evening.

There is a lot of information about LBL and its neighborhood in this volume. Together with the information contained in the literature cited in the various papers it provides a good grounding in what is known about the natural history of the region, at least insofar as the subjects treated herein are concerned. But there is always more that needs to be learned. For one thing, the systems involved are not static. And in that fact lies one of the best reasons for our researches today; they will be useful, and in some cases essential, in understanding the systems of tomorrow.

For the reader wanting to know, we hope this volume will be helpful. And to the researcher who learns new things, we extend an invitation to join us as a participant in a future symposium.

David Snyder
July 1988

REVIEW AND EDITORIAL POLICIES

Speakers at the symposium were given the option of submitting for publication either a manuscript with an abstract, or an abstract only. Fourteen chose the former option, seven the latter. Every manuscript was refereed by at least one reviewer. The reviewers, several of whom are members of the editorial board, were selected because of their expertise in the appropriate area. A list of the reviewers is presented below (an asterisk indicates membership on the editorial board).

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Vanderbilt University
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The editing of such a volume as this, containing as it does papers in more than one discipline, presents some problems of editorial policy. The authors of the papers are of course most familiar with the editorial conventions prevailing in their respective disciplines. Generally I have tried to constrain such stylistic diversity within the limits of a single, consistent style (I use the word "style" here in its mechanical, not in its artistic or literary, sense). The major exception occurs in the case of the paper by Wallace on the history of the region, wherein the style of that discipline has been used. Harris' paper on the geology of the region also deviates, in some minor ways, from the style usually used in the biological sciences. I would like to herewith extend my thanks to the authors for their forbearance and cooperation in my efforts, sometimes floundering, to achieve a consistency of style throughout most of the papers.

ACKNOWLEDGEMENTS

Many people contributed to the success of the symposium. Special thanks are due those who presented papers. Without their willingness to not only collect the data, but to analyze, organize, and present it, there would be no such symposia as this. They provided the "meat" of the meal, and their efforts were considerable.

The logistical problems of conducting such a symposium must also be solved, and many persons helped in that regard. Dr. Thomas Forsythe of TVA-LBL was our principal liaison person, and handled most of the problems from that end. Several student research assistants performed a variety of essential tasks. They were: Patricia Alicea, Amy Bishop, Greg Clement, Crystal Elliott, Lisa Hight, Jennifer Jordan, Tom Kollars, Kathy Mount, Lance Richardson, Michael Stancil, Gwen Sunderland, and Laurie Williams. Margo Cole, secretary to the center, deserves double credit--for helping in the tasks involved in planning and conducting the symposium, and for typing the manuscripts.

Finally I want to thank Joanne Baria, Lisa Hight, and Cathy Petty, for their considerable help in proofing the manuscripts, and Wayne Chester for answering countless questions about botany and the botanical literature.

SYMPOSIUM REGISTRANTS

There follows a list of registrants at the symposium, in alphabetical order. Institutional affiliation (when available), city (may be of the person's institution, or of their home), and state are also given.

Ms. **Patricia Alicea**, Austin Peay State University, Clarksville, TN; Dr. **Fred Alsop**, East Tennessee State University, Johnson City, TN; Mr. **William H. Atkinson**, Austin Peay State University, Clarksville, TN; Dr. **Carol S. Baskin**, University of Kentucky, Lexington, KY; Dr. **Jerry M. Baskin**, University of Kentucky, Lexington, KY; Ms. **Amy Bishop**, Austin Peay State University, Clarksville, TN; Dr. **S. R. Bloemer**, Tennessee Valley Authority, Golden Pond, KY; Mr. **Floyd Brown**, Austin Peay State University, Clarksville, TN; Dr. **William S. Bryant**, Thomas More College, Crestview Hills, KY; Ms. **Elizabeth Bratton**, Belmont College, Nashville, TN; Dr. **Charles N. 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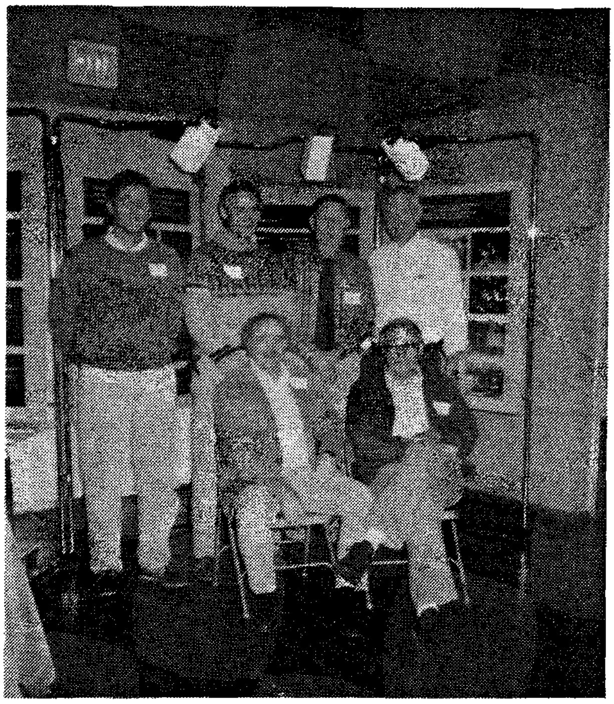
SYMPOSIUM PARTICIPANTS

SYMPOSIUM INVITED SPEAKERS

left to right: Fred Alsop, Michael Kosztarab, Elizabeth Thach, Director LBL, Betty Jo Wallace, Stanley Harris.

1986-87 PRINCIPAL INVESTIGATORS

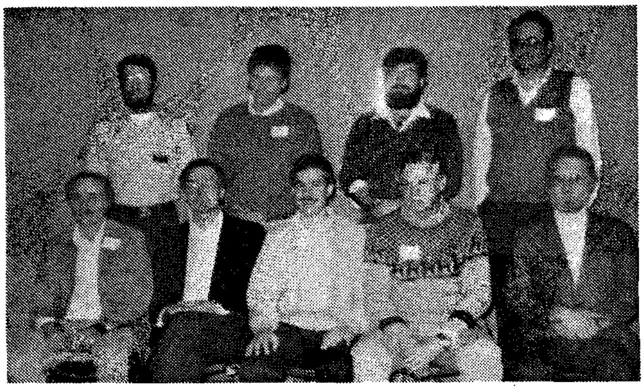


seated: Floyd Scott, Benjamin Stone, Director
standing: David Snyder, Charles Boehms, Wayne Chester, James Fralish

SESSION I CONTRIBUTORS

front row: Fred Crooks, Wayne Chester, Jackie Carpenter, David Webb.
back row: James Fralish, Bill Martin, William Bryant, James Vincent, Dick Jensen, Hal DeSelm

SESSION II CONTRIBUTORS



front row: Floyd Scott, P.B. Hamel, Steven Bloemer, Charles Boehms, R.D. Smith
back row: M.E. Cope, David Snyder, R.P. Ford, D.M. Johnson

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INVITED PAPERS

Friday 11 March 1988

Moderated by:

Benjamin P. Stone, Director,
Center for Field Biology of
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Biological Diversity: National Biological Survey

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KEY WORDS: biodiversity, biota, conservation, extinction, fauna, flora, National Biological Survey, NABIS, survey,

- - - - - - - - - - - - - - - ABSTRACT - - - - - - - - - - - - - - - -

The global biodiversity crisis is discussed, and benefits from maintaining biodiversity are enumerated. A proposal is made for managing and financing the protection and maintenance of global diversity. The frequent question--why is inventorying of biodiversity needed now--is answered both for the tropics and for North America. Detrimental changes in our biota, due to the human-generated pollutants and acid rain are given as one major justification for a National Biological Survey (NABIS) in the United States. Biological survey efforts of other countries are mentioned.

The history of U. S. efforts toward a biological survey is given, and a proposal is made for the initiation, maintenance, and organization of the National Biological Survey. Endorsements of such a NABIS have been received from 39 scientific organizations. Benefits anticipated from the survey are listed in 12 categories. The acute shortage of funds for systematic work and the shortage of systematists available to assist with studies on biodiversity and with preservation efforts are discussed.

INTRODUCTION

More than 1.5 million species of living organisms have already been named from the earth. We realize today that this sum is only a small fraction of the vast number of existing species. Recent studies on the diversity of the never-before-studied canopy of the tropical rainforest brought to light a very high number of new species, increasing the predicted total number of species on earth to as many as 30 million (Wilson 1985b). **As a result, only one in 20 species on earth is known to science today.** We can expect to discover millions of undescribed species among soil and leaf-litter-inhabiting fungi, insects, mites, nematodes and other animals, especially in the relatively untouched areas of the tropics and subtropics.

Public concern over biotic diversity usually relates to life forms with fur, feathers, or leaves (Knutson 1988). Only the vertebrates, especially birds and mammals, and the flowering plants have been intensively studied and described.

Although we have known for some time that our food plants depend heavily on the activities of soil microorganisms, we have not paid attention to studying the latter. About half of our staple food is derived from three plants--rice, corn, and wheat--but there are tens of thousands of plants with great potential to become part of our diet or serve us with their medicinal properties that we have never studied.

If current trends continue, a large fraction of the species now living will be lost in the near future. Even in North America, with its temperate climate, biologists are worried. We have never inventoried our living natural resources. We have not named or described more than half of the living organisms in the United States. We will need to name and describe, for the first time, approximately 180,000 new species. Often the sexes of many animal species are morphologically different, as are the developmental stages of many arthropods, fungi, and other organisms. When we include the required descriptions for both sexes and their developmental stages only for insects of North America, north of Mexico, we will need about 560,000 new descriptions and illustrations. This job will take at least 28 years for a cadre of 100 dedicated insect taxonomists, each turning out, daily, one description with illustrations. Because insect species make up only about half of all known organisms, the work will be doubled if all organisms are accounted for.

SHORTAGE OF SYSTEMATISTS TO ASSIST BIODIVERSITY EFFORTS

Conservation and environmental impact questions cannot be answered without systematics (Lovejoy 1977). But the lack of support for systematics is a problem. There are probably fewer than 1500 professional systematists in the world to deal with all tropical organisms. One shocking example involves the ants and termites that make up about one-third of the animal biomass in tropical forests. They cause billions of dollars damage yearly to agriculture, forestry, and to man-made structures. Still, there are only eight entomologists in the world able to identify tropical ants and termites! Only five of them are fully employed in their specialty (Wilson 1985b).

For the task of determining more than 90,000 already-described species of insects in North America, there are only about 250 persons in the United States who are competent specialists for some of the taxa. However, most of these systematists are earning their living as teachers at universities. Only 24 systematists are employed full-time by the Systematic Entomology Laboratory of the U. S. Department of Agriculture in 1988 to do the needed determinations and provide records for about 100,000 species of insects and mites in North America (Miller 1988, personal communication) not counting the samples from foreign shipments.

The acute shortage of replacements in systematics is well illustrated in a recent study by Lattin and Riley (1984, personal communication). Of a sample of 82 professors of systematics at U. S. universities, only 25 (30 percent) had graduate students in training during 1984, and about half of those had only one student working on problems in systematics. Seventeen of these 25 were full **professors within ten years of retirement.** While the need for identification of organisms has increased, the available individuals to do the work has decreased during the past two decades. **If adequate replacements in systematics are not trained, studies in biodiversity will soon face a grave setback.**

WHY DO WE NEED TO INVENTORY NOW?

Studies in biological diversity, as well as environmental protection efforts, need the data resulting from biological surveys. These include species inventories, species distribution maps, and identification manuals, in addition to information from survey databases on the components of the biota. At present in North America we do not have an organization that coordinates biological data assessments generated by state and federal agencies, or of individuals.

Increased urbanization, and construction of new highway systems, dams, and waterways, are all encroaching on and destroying many natural habitats. Efforts of The Nature Conservancy and other similar groups are at best a holding action for extremely limited areas and habitats, and are dealing with only a small fraction of the biota. Even worse, all these preserved areas as well as the rest of the country **are affected by increased air pollution--especially acid rain. We** have good reason to be worried. An increasing volume of fossil fuel is burned each year, as we use coal that is rich in sulphur to generate electricity, to heat homes, and to operate factories. Thus, more and more living organisms will be affected and even killed by the generated acid rain and accumulated air pollutants. The conifer forests in the Appalachians are already suffering and some have been destroyed (figure 1). We have only to visit Mt. Mitchell in North Carolina, Mt. Rogers in Virginia, or Camel's Hump in Vermont to be convinced. Our recent soil samples from Mt. Mitchell read 3.9 pH; those from Mt. Rogers, 3.4. There is very little life in those soil samples. The number of "dead" lakes has increased at an alarming rate both in North America and in northern Europe. We can't postpone the inventorying of our biota until a large portion of the living organisms are destroyed. We need to do the assessment now and **establish computerized baseline information before it is too late.**

I have observed that atmospheric pollutants, such as foliar nitrogen, increase the susceptibility of conifers to attack by sucking insects such as aphids and scale insects (Homoptera). For instance, balsam woolly adelgid (Adelges piceae), on fraser firs (Abies fraseri), built high populations at Mt. Mitchell (2037 m) in North Carolina, and also at Mt. Rogers (1747 m) in Virginia. There is similar evidence from beech trees, (Fagus spp.), in both Europe and North America. The beech bark scale (Cryptococcus fagisuga) population increased on pollution-affected trees, and the scale insect spread the Nectria fungus that gives the "mercy shot" to the trees.

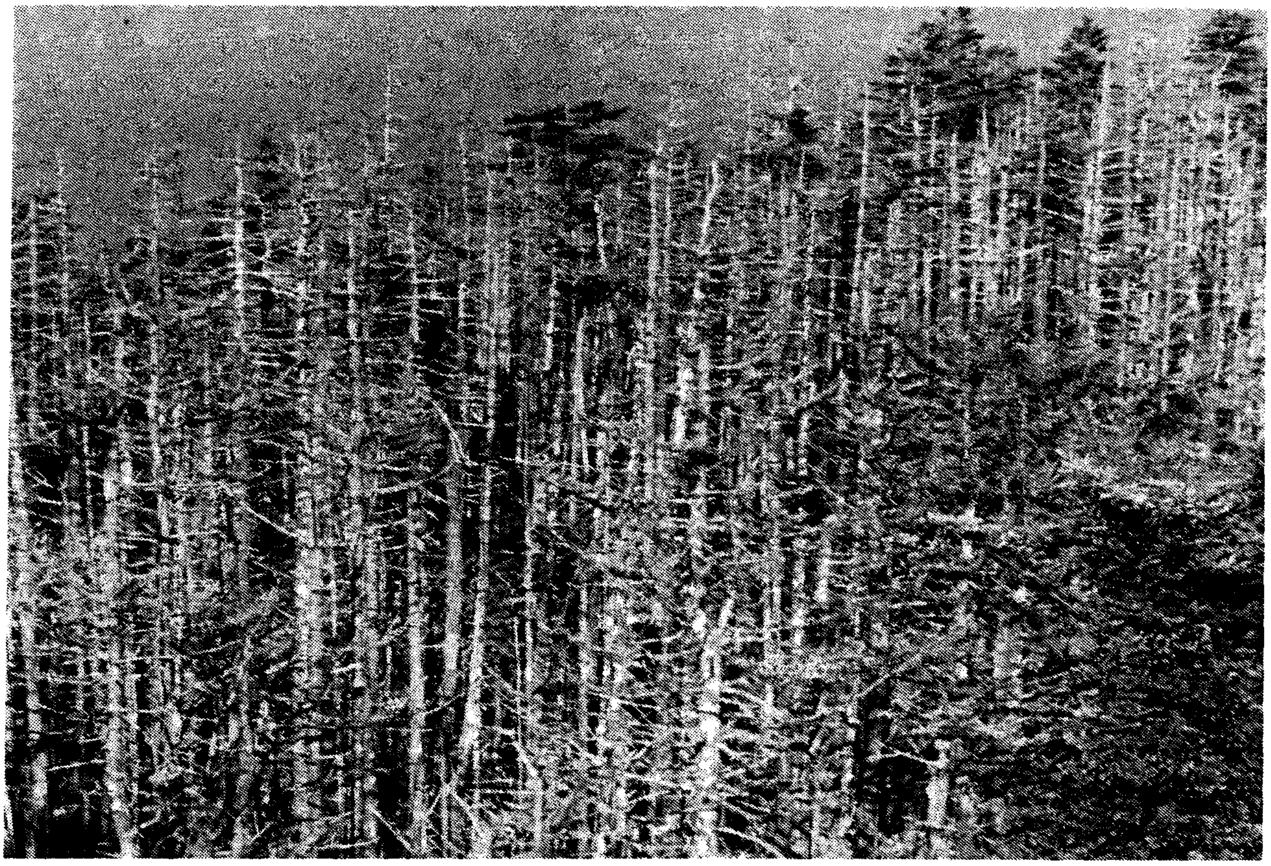

Figure 1. Fraser firs affected by acid rain on Mt. Mitchell, North Carolina (2037 m elevation), where soil pH is 3.9. Photo by David Neil Parks.

Acid rain dissolves aluminum that had been bound in the soil. The dissolved aluminum kills plant rootlets and it is the main cause of the uprooting of Norway spruce trees in Germany and Sweden. Unfortunately, the same trees often became top-heavy from assimilation of extra nitrogen received through the foliage from air pollution, and are even more prone to uprooting.

While visiting with colleagues at the Ecological Institute in Lund, Sweden, I was told that they regret not having inventoried their biota 30 or 40 years ago, because it is too late now. Too many detrimental changes have occurred because of the acid precipitation that reaches Sweden from western Europe. They recommended that we carry out a North American biota assessment now, before our environment is more seriously affected.

Researchers have known for some time that aluminum has a nerve-damaging effect, and Alzheimer's disease symptoms may be lessened through special dietary supplements. Preliminary research results suggest that Alzheimer's involves a hereditary alteration in the body's defense against aluminum (Alzheimer's Disease Research 1988).

One of the problems created with groundwater acidification is that **metals are dissolved out of the ground** and out of metal pipes. Metals used in water pipes include copper, lead, zinc, and cadmium. Each may be dissolved, causing corrosion and creating health hazards. High levels of cadmium concentrations were noted in kidneys and livers of elk and hares in southern Sweden, and in food grain for humans; both acid rain and agricultural fertilizers were responsible. The cadmium content of wheat has doubled in Sweden during the twentieth century (Committee 1982).

It is obvious that a hurried inventorying of the living organisms in North America will not solve the basic problem: **eliminating the source of acid rain and other air pollutants.** At present too many of our polluting industrial plants would rather pay monetary fines than install the scrubbers needed to drastically reduce air pollution. Tighter controls, new laws, and much higher fines are needed. Also, a new national awareness and policy are needed that condemns air pollution and provides a national plan to gradually reduce emission of air pollutants to a minimum level. Our government should also sign the 10-nation treaty, adopted by Canada and nine western European nations, with its long-range goals to reduce air pollution. Japan has made marked progress in reducing air pollution problems; we should be able to do so also.

WHAT ARE OTHER COUNTRIES DOING?

Canada started its biological survey in 1978 (Danks 1978) and is making excellent progress, at least with terrestrial arthropods. Two government agencies are already producing identification manuals and monographs on different segments of their insect fauna (Danks and Kosztarab 1988). It is my opinion that it would be advantageous to both the United States and Canada to make a joint effort for a biological survey of North America, thus avoiding duplication of effort and reducing expenses. Other countries with similar surveys include Hungary, India, Israel, Korea, New Zealand, the Soviet Union, and Australia.

The **Australian Biological Resources Study** (1987) provided funding for 43 survey-related taxonomic research projects in 1987. If we wanted to keep up with the Australians, then, in proportion to our U. S. population, our federal government should have at least tripled its efforts in 1987. We had only about 226 projects, including doctoral research fellowships, supported by the Systematic Biology Program of the National Science Foundation in 1987 (D. Schindel 1988, personal communication). An assessment of biological surveys of other countries is given by Danks and Kosztarab (1988).

BIODIVERSITY AND THE GLOBAL CRISIS

Biological diversity may be defined as the diversity of life or biota in natural ecosystems. That includes all the organisms present, from bacteria to mammals, and from fungi to flowering plants. We need a healthy biological diversity for improvement of livestock and food crops, for development of new pharmaceuticals, for scientific and aesthetic reasons, and for human survival in general. Biodiversity varies greatly with climate, habitat, and time. Biodiversity depends on a fragile ecosystem that is easily disturbed or destroyed.

There is an alarming rate of destruction in the diversity of our global living natural environment. The size and rate of the current destruction can be compared only with the great natural catastrophes of the Paleozoic and at the end of the Mesozoic Era, some 65 million years ago, when the dinosaurs, the archaic angiosperm forest, and many other organisms disappeared. Raup (1986) has discussed the causes and rates of biological extinctions through the earth's history. He concluded that the past five major extinctions may have been constructive in the Darwinian sense. We should not forget that the present mass extinction period is the only one of such magnitude. It is the **first created by man, and may be the last one involving human existence.**

The climate of a large part of the earth's surface depends on the existence of the tropical rain forests, where probably half or more of all living organisms live. These forests are being destroyed at an ever increasing rate. Each year about 0.7 percent of these irreplaceable forests are cut down for their lumber and for use as new agricultural lands. The area of the tropical forest lost each year equals that of West Virginia (Wilson 1985b). Along with the forest trees, the associated rich fauna and flora are also disappearing. With the environmental destruction, not only are many species wiped out, but the amount of genetic variation is also lessened with each disappearing species. **Many of the species becoming extinct have never been described or catalogued by science.** It has been estimated that with present trends more than 15 percent of the earth's present biodiversity will be destroyed by the year 2000 (Lovejoy 1980).

The problems precipitated by deforestation are multiplied when we realize that the now unprotected forest soils and accumulated organic material necessary for future agricultural and silvicultural use are quickly washed away by the torrential tropical rains. **It will take hundreds of years and enormous capital investment to reclaim soil fertility and reestablish new forests or agriculture there.**

MANAGEMENT AND COST OF GLOBAL BIODIVERSITY

Clear-cutting large areas of tropical rain forest, and slash and burn agricultural practices in tropical countries for short-term economic gains should be stopped and replaced with long-term, ecologically sound agricultural practices. We must realize that we need for this task the support of local governments and the now economically depressed inhabitants of many developing countries. Educational programs on the importance of maintaining biodiversity are essential for these people. In addition, new employment opportunities and/or alternative new food production sources need to be provided for the affected populations.

The obvious question is raised. Who is going to pay for the cost of needed educational programs, for policing and managing the natural preserves around the world, and for introducing new agricultural practices? Some advocates of the biodiversity effort have proposed that the **U. S. taxpayers should pick up the bill.** Is this a reasonable expectation? The advocates of this idea do not realize that many of the governments in those countries were not elected and consequently are based on shaky ground both politically and economically. Should we entrust our taxpayers' money to them? What assurance do we have that the money will be spent on what it was originally intended? Will these governments share the costs and provide effective protection for the preserved forests against forest fires, squatters, and "fuel" collectors? Since the price of kerosene went up in the mid-70s, more and more people in the developing countries rely on local wood for cooking fuel. I have observed this in Sri Lanka and Costa Rica. Although both countries have established and are maintaining natural preserves as National Parks, their democratic governments, due to population and economic pressures, are unable to keep squatters out of their parks and nature preserves. I understand that the situation is worse in Brazil and some African countries. What can we do in such quandaries?

Because preservation of biodiversity is a global imperative, **the United Nations through UNESCO needs to be involved** to prepare and set new policies--enforceable ones--and invest jointly with the World Bank and local governments in the protection of endangered natural habitats, and tropical rain and dry forests around the world.

If U. S. government agencies and/or the Congress are going to provide funding (e.g., through AID and/or other programs) for biodiversity efforts in foreign countries (U. S. Congress 1986b), **the sum should be matched to support simultaneous efforts** (e.g., a national biological survey) **in the United States.** As long as our own North American biota, with the many endangered habitats, has not been inventoried, nor baseline information has been prepared on its status, we should refrain from spending our taxpayers' money in foreign countries on similar efforts without investing at least the same amount of money and effort on our own living natural resources in this country.

BENEFITS FROM BIODIVERSITY

Maintaining ecosystem or biological diversity offers humankind a number of benefits. A major benefit is the **preservation of fertile soil for agricultural production.** For example, montane forest ecosystems not only preserve but create soil cover and prevent erosion, as do grasslands in prairies. Also, there are **tens of thousands of edible plant species** that have been or can be studied as possible future food resources. Previous genetic and breeding studies have produced high-yielding varieties of rice, corn, wheat, and many other staple foods (Wilson 1985b). Such varieties have enabled India, formerly an importer and recipient of food aid, to become not only self-sufficient, but a net exporter of food staples. Balandrin et al. (1985) estimate that only 5 to 15 percent of the higher plant species have been studied for active natural products. Another benefit of biodiversity is the **maintenance of the genetic pool**, allowing possible future discoveries of biological compounds **useful in medicine or industry.** About one-fourth of modern medicines, including digitalis and penicillin, are plant, fungi, or bacteria extracts, and millions of people in the third world traditionally depend on plants for medicinal purposes.

If we do not maintain and preserve our current world ecosystem diversity, none of the above benefits will accrue to future generations. Only if we maintain or even enhance the biological diversity of the planet will we have available the genetic material essential for animal and plant breeding programs, for developing new varieties, and for discovering new food sources.

Inventorying and describing our biological diversity must be done before we can effectively assist with preservation. Only a biological survey can document the extent of biological diversity and monitor the occurring changes. Research on biological diversity and environmental protection requires information on the taxonomy, biology, and ecology of the many species encountered in a given habitat.

HISTORY OF U. S. BIOLOGICAL SURVEY ATTEMPTS

In 1885 a survey limited to insect-feeding birds was initiated in the U. S. Department of Agriculture, Division of Entomology. The survey was expanded the next year to include work on mammals, and it was renamed the Division of Economic Ornithology and Mammalogy. The Division was reorganized in 1896 as the Division of Biological Survey and was given the additional responsibility for work on plants. Renamed the **Bureau of Biological Survey** in 1905, it conducted work principally on game animals, mammals, and birds. Although its work was considered useful and necessary (Cameron 1929), it was **dissolved in 1939**. Its duties were combined with those of the Bureau of Fisheries in the Commerce Department, and both bureaus were transferred in 1940 to the Department of the Interior to form the **U. S. Fish and Wildlife service** (F&WS).

Within the F&WS, the Section of Biological Survey, among other duties, has been conducting limited systematics research on vertebrates. Unfortunately, **the other 97 percent of organisms in the total biota have been excluded from their studies.** Its collections are housed in the National Museum of Natural History (Bean 1986).

The original Smithsonian Act of 1846 did not make a biological survey of the U. S. part of the responsibilities of the **Smithsonian Institution** (SI). But the SI was directed to work on a national inventory of the biota in the SI Authorization of 1877 (Public Law Chapter 69-20, USC 41). However, the SI **never initiated the survey.** Government-sponsored research on our native fauna and flora was left almost entirely to **U. S. Department of Agriculture** scientists. This small group of scientists, studying insects, mites, nematodes, animal parasites, plant pathogens, and other organisms, is overworked and underfunded at present. These few **alone cannot tend to the increased needs of this nation.**

Other attempts to initiate surveys on our biota included M. D. F. Udvardy's effort in 1966 for the initiation of a Faunal Survey of North America (1985, personal communication). Another notable effort in the late 1960s and early 1970s was the **Flora of North America (FNA) program** sponsored by the American Society of Plant Taxonomists, and funded jointly by the National Science Foundation and the Smithsonian Institution. It **lasted only three years** due to budgetary restrictions by both agencies. My proposal (Kosztarab 1975) for a survey of the **Insect Fauna of North America** (IFNA) did not receive quite enough support to get off the ground. This effort was resurrected in 1983, with the moral support of the Entomological Society of America, but it did not receive encouragement for financial support from federal agencies. It has become part of the **National Biological Survey (NABIS)** effort, possibly combined with the FNA project.

National attention has been drawn to the need for the NABIS project through articles in **Science** (Kosztarab 1984a,b; Gardner 1984); in the Association of Systematics Collections **(ASC) Newsletter** (Edwards 1984, Kosztarab 1984c); in **Bioscience** (Tangley 1985); **Science Digest** (Gilbert 1986); in a book resulting from a **national conference** on this subject (Kim and Knutson 1986); and through a summary of the NABIS effort (Kosztarab 1986).

The **Planning Committee** for the NABIS was formed on March 7, 1984, and, with the later addition of an **Advisory Board,** included in its final form 21 scientists and administrators that represented or served as resource persons for 15 organizations, 14 disciplines, and 11 government agencies. During 1985 members of the Planning Committee conferred with and obtained a positive response from 11 U. S. government agencies, and a direct endorsement from three of these. Supporting letters for a NABIS were also received from 14 leading life scientists and at least five U. S. legislators. I also held meetings with six government agencies and five scientific organizations. To further disseminate information on the proposed NABIS during 1984 and 1985, at least 20 news coverages were provided (Kosztarab 1986).

Our joint efforts bore fruit with the special interest demonstrated in a NABIS by a number of U. S. legislators and with the organization in May 1985 of a national meeting entitled **"Foundations for a NABIS"** that was sponsored by the Association of Systematics Collections (Kim and Knutson 1986).

Due to the Gramm-Rudman-Hollings Federal Deficit Reduction Bill, our progress has been temporarily halted. **It was recently resurrected** with the introduction of a Bill (H. R. No. 4335) for the **"National Biological Diversity Conservation and Environmental Research Act"**, in the Natural Resources Subcommittee of the House Science Committee. This bill includes the establishment of a **"National Center for Biological**

Diversity and Environmental Research" (Blockstein 1988, personal communication).

ENDORSEMENTS

The scientific community in North America has shown its conviction about the urgent need for a NABIS; **33 scientific organizations** (table 1), **representing about 200,000 scientists**, have passed resolutions or prepared endorsement letters in its favor. In addition, six international and/or foreign organizations also have endorsed the concept (table 1).

Table 1. Associations and other organizations endorsing a National Biological Survey.

A. United States or regional organizations

(Year of endorsement appears in parentheses)

1. American Arachnological Society (1986)
2. American Association for the Advancement of Science (1983)
3. American Bryological and Lichenological Society (1985)
4. American Institute of Biological Sciences (1984)
5. American Malacological Union (1987)
6. American Ornithologists' Union (1985)
7. American Phytopathological Society (1984)
8. American Society of Mammalogists (1984)
9. American Society of Parasitologists (1984)
10. American Society of Plant Taxonomists (1983)
11. Association of Southeastern Biologists (1984)
12. Association of Systematics Collections (1982)
13. The Crustacean Society (1986)
14. Ecological Society of America (1985)
15. Entomological Society of America (1982)
16. Entomological Society of Washington (1983)
17. The Lepidopterists' Society (1985)
18. Mycological Society of America (1984)
19. North American Benthological Society (1985)
20. North American Lake Management Society (1985)
21. Sierra Club - Gulf Coast Regional Conservation Committee (1985)
22. Society for the Study of Amphibians and Reptiles (1985)
23. The Society of Nematologists (1984)
24. Southern California Association of Marine Invertebrate Taxonomists (1985)
25. Virginia Academy of Sciences (1983)
26. Weed Science Society of America (1985)

Table 1. (Continued)

B. State biological surveys

1. Biological Survey, New York State Museum
2. The Florida State Collection of Arthropods
3. Illinois Natural History Survey
4. Kansas Biological Survey
5. North Carolina Biological Survey
6. Ohio Biological Survey
7. Oklahoma Biological Survey

C. International and/or foreign organizations

1. Australian Biological Resources Study - Bureau of Flora & Fauna - Canberra
2. Biological Survey of Canada (Terrestrial Arthropods) - Ottawa
3. Ecological Institute, Lund, Sweden
4. Israel National Collections of Natural History
5. Mexican Academy of Sciences (Mexico City).
6. 17th International Congress of Entomology, 1984 - Hamburg, West Germany

THE WASHINGTON SCENE

The present Administration for the past few years has been dragging its feet on legislation that will curb air pollution that causes acid rain. The excuse used is that there is a need for more scientific evidence to justify the cost. **The scientific data has already been gathered in western Europe.** The Administration is unwilling to recognize the long-range consequences of environmental damage to our economy, or the loss of scientific and cultural values of this nation, that will occur if no immediate and effective actions are taken. Apparently, the situation is no better today than it was during "Ding" Darling's time, who said in the 1930s: "As land goes, so goes man ... But just try to get politicians to do something about it" (Lendt 1979).

When members of the Planning Committee for the NABIS visited with U. S. government agency representatives in 1984 and 1985 (Kosztarab 1986), almost all of the visited officials expressed endorsement for the effort. Unfortunately, **none volunteered to provide leadership and/or funding (seed money)** for the initiation of the Survey when we requested it. Basically, the response from most was that while they agreed about the importance and urgency of the NABIS effort, they had no funds to spare, nor space nor personnel capability to start a new project, unless their agency received extra "earmarked" funding from Congress for this purpose. So, our Committee was encouraged to generate earmarked funds from possible congressional supporters. Extra funding was promised by my District Congressman in the spring of 1985, who asked us to name an appropriate agency or institution to receive the extra earmarked funding in their new budget allocation. We named the most logical choice and the one (name withheld for obvious reasons) which had expressed strong interest in the NABIS effort. Unfortunately for the cause, that agency declined to accept promised and earmarked new funding that was to be included in their budget allocation that year because their goal was to regain the 2 percent lost the previous year from their budget. Thus, they did not want to jeopardize their chances by accepting additional funds for a new (NABIS) project. They expressed regrets, and said that they would be pleased to accept this offer one year later. But in the meantime the Gramm-Rudman-Hollings Federal Deficit Reduction Bill was passed, which does not allow initiation of new projects by federal agencies for five years. This is one example of how institutions that had originally promised support let our common cause down and hindered the initiation of the NABIS project in 1985.

Dr. Richard Smith, Associate Director for Research and Development of the U. S. Fish and Wildlife Service, was quoted in the AIBS "Forum" (Nov./Dec. 1984) as saying: "Regarding the expansion of biological surveys, the Department of the Interior has a passive involvement. The Department of the Interior's position is that there are more important research issues to address than fauna and flora of North America". The message from this organization was clear: we can't count on the U. S. Department of the Interior for assistance with the NABIS effort.

There are some biologists in Washington today who are satisfied with gathering tens of thousands of specimens from tropical rainforest biodiversity studies and giving only a number for each new taxon discovered. They do not take the responsibility of describing and naming them. They stash away in museum basements hundreds of jars filled with unprocessed material, thus creating a headache for future generations of systematists.

No assessment of biodiversity in tropical rainforests can be completed without a thorough knowledge of local faunas and floras (Wilson 1985b). Thus we need to describe and name the newly-discovered species in order to be able to utilize the data for future work. Current financial support in the United States is inadequate for badly needed taxonomic work on new or poorly-known taxa, including family and generic revisions. The U. S. National Museum of Natural History and the National Science Foundation, along with the Department of the Interior,

provided only $38.6 million in 1985 for basic research in systematics, for museum services and other systematics-related research (Wilson 1985a).

There was another important federal granting agency (unnamed here, for obvious reasons) that also encouraged us to obtain earmarked extra federal funds for the NABIS project in 1984. But when U. S. legislators inquired about its interest in the NABIS project it declined, stating it could not take over a new responsibility without adequate staff and space to handle it. Agency officials were also afraid they would not receive extra funds but would be forced to use money from their present budget allocation for the new project. This was the second federal agency that declined to accept the responsibility to help with the initiation phase of the NABIS project. Both agencies were chosen by the majority of our peers as the best suited and best equipped agencies to handle this effort. Actually, **both should have initiated the NABIS project many years earlier**, as had similar foreign agencies with their biological surveys in a number of other countries.

PROPOSED SOLUTIONS

After the above-described events, can we trust any of the present federal agencies to do the work? If so, we want that agency to come forward and immediately request in its budget new earmarked line items for the NABIS project. Apparently, since none have come forward since 1982, the establishment of **a new independent federal agency remains the logical choice**, an agency with functions similar to those the U. S. Geological Survey used to have. This new agency, besides providing needed leadership and nationwide coordination to avoid duplication of effort, should depend on the U. S. Fish and Wildlife Service to continue its long-established responsibility for the **vertebrate fauna**, while the U. S. Department of Agriculture's Systematic Entomology Laboratory should be entrusted with overseeing research on the **insect fauna**. All efforts and work on other taxa should be shared with the entire systematics community in the United States, including the **state biological and/or natural history surveys**. A proposed organizational structure for NABIS is shown in figure 2.

The U. S. National Museum of Natural History may choose to take the responsibility for the **preservation of collections** associated with the NABIS effort. This contribution may be in line with what the current Smithsonian Secretary, Robert McC. Adams, referred to when he stated: "The Smithsonian... should be doing long-term things... one such project... is a biological survey of entire United States" (Holden 1985).

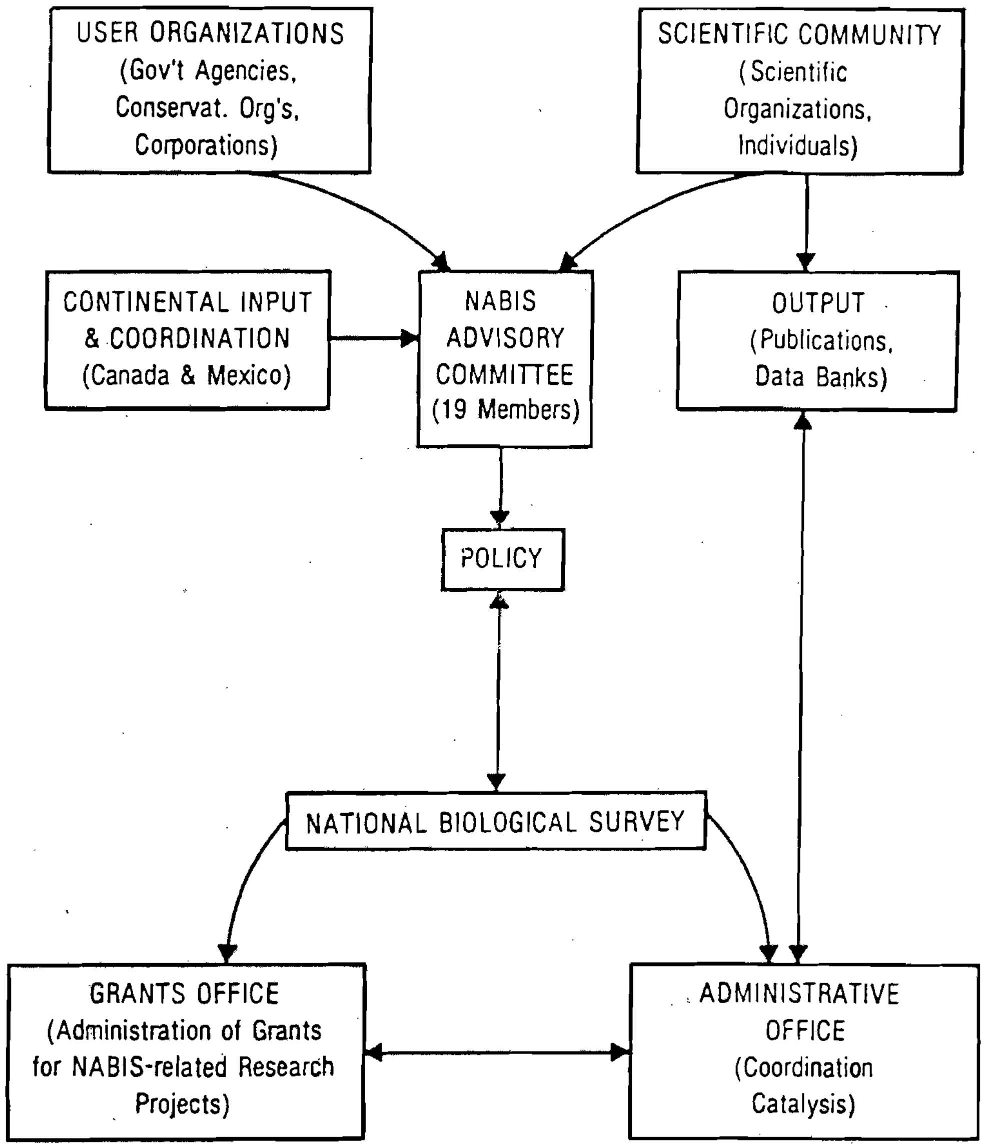

Figure 2. Organizational structure proposed for the National Biological Survey (NABIS)

A number of states (table 1) sponsor biological surveys. Their efforts are usually limited geographically because of their mandate and their low level of funding. Nevertheless, their precious biological material, gathered through many years of tedious work, should be fully utilized as part of the NABIS effort. The Illinois Natural History Survey stands out as the largest and most active of this group, with its 112-year-long record of continuous activities.

Each participating federal, state, or privately-supported agency should receive **proportional funding** for their NABIS-related activities, as individual researchers who are willing to contribute their talents. The proposed initial yearly budget of **12 million dollars** for the NABIS effort **is about one-third of the cost of one F-15 military fighter plane.**

It is unfortunate for the success of both the mainly-tropical biodiversity effort, represented at the Forum on BioDiversity during 1986 (Tangley 1986), and of the closer-to-home NABIS effort, represented through 33 scientific organizations in the United States, that they are running two different courses. There is going to be a credibility gap in Congress when the two separate efforts are recognized. It gives the impression that isolated special interest groups work against each other. Our NABIS effort was already well recognized in governmental and legislative circles and by the scientific community, when the biodiversity proponents arrived on the Washington scene.

Why not **join the two closely related efforts**, as was proposed by Miller (1986), so that such consolidation of efforts could benefit all, including our taxpayers? A window of opportunity is in sight for the joint cause at present if we work together and do not lose sight of the common goal.

The "National Biological Diversity Conservation and Environmental Research Act" (Bill H. R. #4335), under consideration in Congress, and other future bills on this subject, should include recognition of the needs of North America so that the allocated funds should be at least equally divided between our national needs and those of foreign countries.

BENEFITS FROM THE NATIONAL BIOLOGICAL SURVEY

A biological survey will identify and describe the components of our living natural environment. Without such knowledge it is impossible to understand the effects of human activities on natural habitats. The more important benefits for this nation from a nationwide comprehensive biological survey are listed below.

1. NABIS will provide for the first time for this nation a computerized **data bank** on the available **living natural resources.** It will be an **inventory** of the known animal and plant species in the United States, from bacteria to mammals,

with information on their distribution, habitats, ecology, and biology, and on their economic importance. A number of federal agencies currently maintain such data banks (Olson 1984), but their data is of limited scope and lacks central coordination (U. S. Congress 1986a). NABIS, by **interfacing with existing data banks** at state and federal agencies, will be able to provide the needed nationwide coordination of data on the living natural resources of the United States (Loucks 1986).

If a NABIS database had been available on distribution of our native animals and plants, we could have avoided the embarrassing situation with the snail darter, the small fish that caused the environmentalists to fight the Tennessee Valley Authority. The fight and the delays with the Tellico Dam construction caused a loss of millions of dollars. Subsequent surveys proved that the snail darter is present in at least seven habitats in the area, (R. J. Neves 1986, personal communication).

2. As soon as the NABIS data bank has been established, the **Congress of the United States, government agencies and U. S. corporations will be provided** for the first time **with a comprehensive report on the status of the biota.** The last such report was prepared in 1940 (Gabrielson 1940) and was limited to vertebrates only, which constitute less than four percent of our biota. Such updated status reports will be provided periodically to aid government agencies, corporations, and scientists.

3. NABIS will serve as a **catalyst** for needed work and will **focus** survey efforts first **on the endangered habitats** of our biota, and second on the entire biota. Some natural habitats are disappearing at an alarming rate at present while others may not be disappearing as fast as is presently thought.

4. A National Biological Survey could provide the needed information for **nature conservation and environmental protection** (Hirsch 1986) as well as for **land management** and future urban planning (U. S. Congress 1987).

5. NABIS will save money for the taxpayers by providing **nationwide coordination**, and by avoiding duplication of related efforts by federal, state, and private agencies.

6. The proposed NABIS inventory will serve as a basis for the **preparation of a series of species catalogs and identification manuals** for the components of our fauna and flora. The well-illustrated manuals will serve as teaching tools in our educational systems. Excellent examples of such manuals and field guides were provided by the six publications produced from 1971 to 1987 by scientists associated with the Center for Field Biology of Land Between The Lakes and sponsored by the Tennessee Valley Authority and Austin Peay

State University. The Soviet Union initiated such a series of publications 63 years ago.

State and federal agencies, especially those concerned with **human health, agriculture, forestry, and recreation, will benefit** from the NABIS effort. The identification manuals will allow workers to identify those species which are beneficial and those which cause harm to humans, domestic animals, agricultural crops, forest trees, and stored products. With few exceptions, we do not have the means of identifying a large portion of the species represented in our biota (Kosztarab 1975). For example, pest control experts are expected to find ways to **minimize the use of chemicals harmful to our environment**. A viable alternative is the use of biological control agents, e.g., **beneficial insects and fungi that attack pests**. Unfortunately, in the United States we do not have the descriptions and identification manuals needed for most of the beneficial insects that are or may be useful in biological control programs. The proposed NABIS would publish such manuals, and would thus **promote biological control of pests in the United States** by supplying adequate taxonomic, biological, and distributional information on the natural enemies of pest organisms.

The need for pest identification manuals in the United States is well documented from data provided by Thomas E. Wallenmaier (1984, personal communication) of the U. S. Department of Agriculture--Animal and Plant Health Inspection Service. He estimated that 77 percent of moths and butterflies, 81 percent of true bugs and 90 percent of the beetles are not identifiable by plant quarantine field workers in the United States because of lack of manuals. These are examples from three large insect orders with many pest species. It is recognized that our national plant protection and plant quarantine services are in need of the biological survey data (Johnson 1986).

The need for work on other animal groups and plants is illustrated in table 2, where column 3 expresses the estimated percentage of undescribed species, not including the high percent of undescribed developmental stages. The assessment is based on the data provided to me by colleagues, each considered expert for the taxa listed, and my own estimates on the undescribed developmental stages of arthropods, fungi, and other organisms. It is reasonable to conclude that despite many years of effort **we have described no more than one-third of the living organisms** and their developmental stages in North America (Kosztarab 1984a).

Table 2. List of major taxa with number of species described and percentage of undescribed--plants, protista, and animals

	North America		World	
Major Taxa	No. Spp. Described	Percent of Total Undesc., & Source	No. Spp. Described	Percent of Total Described
Plants				
Bacteria	3,800	(L. L. Holdeman)!	3,800	0.85
Algae	ca. 9,000	50(B. C. Parker)	21,675	4.85
Ferns & relat.			11,243	2.52
Mosses & relat.			23,600	5.29
Gymnosperms			665	0.15
Fungi* & molds	36,800	50(O. K. Miller)!	100,500	22.51
Angiosperms	20,000		285,000	63.83
Plants Total:			ca. 446,483	100.00
Protista				
Protozoa (Foraminifera)			28,350	2.60
Animals--Invertebrates				
Round worms	2,500	90(A. M. Golden)!	25,200	2.31
Mollusks	5,500	20(G. M. Davis)!	107,250	9.84
Annelid worms			8,500	0.78
Echinoderms			6,000	0.55
Chelicerates*			57,500	5.28
spiders	3,500	30(B. Opell)!		
mites	9,000	60(R. L. Smiley)!		
Crustacea*	2,000	50(J. R. Holsinger)!	35,000	3.21
Myriapoda	1,200	50(R. L. Hoffman)!	15,000	1.38
Insects*	90,000	50(R. H. Arnett)!	750,600	68.87
Other invertebrates			4,000	0.37
Animals-Vertebrates				
Vertebrates & allies			43,000	3.95
Birds	1,100	(R. C. Banks)+		
Fish	2,268	(C. R. Robins)!		
Mammals	467	(A. L. Gardner)+		
Reptiles/Amphib.	620	(R. W. McDiarmid)+		
Other small taxa			9,500	0.87
Animals Total:			ca. 1,089,900	100.00
Grand Total (Plants & Animals)			ca. 1,536,383	

Table 2. (continued)

Plants = 29.06% of all organisms described.
Animals = 70.94% of all organisms described.
Approx. 50% of species are undescribed.
*With several life forms.
+Banks, McDiarmid, & Gardner, 1987 (Includes U. S. Territories).
!Personal communication.

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7. NABIS will help elucidate the **effects of acid rain** and other environmental pollutants on the biota while at the same time supplying a base for monitoring changes in the composition of the biota as these effects continue or abate. We may already be losing natural resources necessary for survival. The identification and assessment of the impact of acidification on soil microorganisms that are essential for growing food crops is just one of many services that NABIS can provide to this nation. The present rate of damage by acid rain to our biota is showing only the tip of the iceberg. This could become a grave national calamity if no effective actions are taken. Why is it that in this country it takes a calamity before action is taken?

The NABIS database should be continuously updated with new records by **monitoring the quality of our biota**. A great deal of the life in the Chesapeake Bay died due to excessive agricultural and industrial pollution. The approaching environmental disaster could have been recognized in its early stages with the help of a NABIS, and possibly prevented before it was too late. Now it will cost billions of dollars, and many years of work, to reestablish life in the bay.

8. The NABIS effort will improve the **national security** of this country by providing new knowledge on certain natural resources essential for human survival in a national emergency. New data will be gathered through NABIS on poisonous and beneficial or pharmaceutical plants, on human external parasites (apparently more soldiers died during WWI on the eastern European fronts from insect-borne diseases than from enemy action), and on pests of stored food and fiber that are needed for **national defense**. Preparation of pictorial keys that enable non-specialists to identify pests could be incorporated into the NABIS program.

9. NABIS will **assist U. S. corporations** with needed data on the renewable natural resources of this country, as recommended by Train (1984) who noted that no such comprehensive database currently exists. His report on 'Corporate Use of Information Regarding Natural Resources and Environmental Quality', prepared in 1984, stresses the need for

improving the network of information sources on natural resources which are available to U. S. corporations. The NABIS Center will be able to fill such existing gaps.

10. The NABIS program can generate data needed to produce **climatic profiles for species**, by utilizing records available on the species and on temperature and precipitation of the area. Such a system enables **forecasting of the distribution of species** and is in use now in Australia (Bridgewater 1986).

11. The NABIS Center can **enhance international coordination and cooperation** on renewable natural resources in North America (Danks 1986) and elsewhere (Bridgewater 1986, Danks and Kosztarab 1988). Such coordination has been proposed by Dr. G. G. E. Scudder, Chairman, Scientific Committee, Biological Survey of Canada (Terrestrial Arthropods); by Dr. Hugh Danks, its Director; by the president of the Mexican Academy of Sciences, Jose Sarukhan (1984, personal communication); and by an International Conference (Cushwa and Tungstall 1983). Such coordination and cooperation on biological inventories already is in effect in western Europe. **Most developing nations are looking for the American example** in biological survey efforts, and the United States did lead until 1940 (Troughton 1940). But unfortunately the United States is not doing so now. Both Canada and Australia are providing good examples for our efforts. Other countries are making their biological survey a **national pride project**. For example, India, with its limited resources, employs over 1,000 persons in its zoological survey, and Hungary has already published 160 volumes of identification manuals for its fauna. Is the United States going to be the last "developed" country to initiate a nationwide biological survey?

12. Last, but not least, we should not overlook the **social value** of the NABIS program. Many former components of our environment became extinct before we learned enough about them to prevent their extinction. More species have become in danger of extinction during the past decade than ever before. Biodiversity is not only an important **aesthetic resource**, but--with the increasing reliance of agriculture, industry, and medicine on new species and varieties of organisms and new genetic combinations that are possible through genetic engineering--**it is imperative that we catalog and preserve our genetic natural resources now before it is too late.**

CONCLUSIONS

Every U. S. taxpayer is aware of our national monetary deficit and debt. But there is something that U. S. biologists have failed to emphasize strongly enough in the past--**a national deficit that grows by geometric progression.** It is **the neglect of our biota!** We have to start inventorying and monitoring our natural resources and ecosystems now before it is too late and before more habitats are irreversibly altered. There is an urgent need to establish baseline information now, that we can use for comparison later. The NABIS can serve as a catalyst and provide coordination for an important national effort in inventorying our neglected biota. Initiating the NABIS is **an issue in morality** because future generations will benefit or be harmed accordingly.

I would like to cite here in my closing remarks what Carl Sandburg states so eloquently:

> "All we need to begin with is a dream that we can do better than before . . . . All we need to have is faith and that dream will come through . . . . All we need to do is act, and the time for action is now . . . ."

ACKNOWLEDGEMENTS

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Summary Review of Geology of Land Between The Lakes, Kentucky and Tennessee

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KEY WORDS: Geologic review, geomorphic processes, Kentucky, Land Between The Lakes, physiography, Tennessee

ABSTRACT

Land Between The Lakes is at the northwestern corner of the Highland Rim Section of the Interior Low Plateaus physiographic division of the U. S. The Tennessee Valley is the boundary of the Mississippi Embayment of the Gulf Coastal Plain, though coastal plain deposits veneer much of the upland of LBL.

The physical nature of LBL is determined by the proximity of the parallel valleys of the Tennessee and Cumberland rivers. Closely-spaced tributaries form a dissected topography. These valleys are short with steep gradients in the headwaters, but broad down-stream bottomlands. The valleys are now occupied to an elevation of about 109 m by Kentucky and Barkley lakes.

Bedrock consists mainly of cherty limestones of the Mississippian System divided into Ft. Payne, Warsaw, Salem, and St. Louis formations. They are difficult to distinguish. Natural exposures occur mainly where stream channels impinge against the valley sides; the best are along the lake shores. Residuum of cherts and clays from weathering of the bedrock is distinctive enough to allow identification of the underlying bedrock.

Tuscaloosa white, well-rounded, chert gravels of Cretaceous age occur over much of the upland. Siliceous granules and sand fill their interstices. White and pink clay is abundant. Patches of Cretaceous McNairy sand overlie the gravel.

Brown, sub-angular chert gravels of Tertiary-Quaternary age overlie the Cretaceous. They have a more restricted distribution. Pleistocene silty loess, less than two meters thick, veneers the upland. It is mixed with soils on the slopes. LBL lies along the regional strike, on the flanks of the Cincinnati Arch-Nashville Dome. Structurally, central U. S. is a part of the relatively stable North American Continental Plate. During most of the Paleozoic Era broad, shallow, clear seas occupied the region. Vast quantities of carbonate, mostly siliceous, accumulated. Later, clastic erosion products,

sandstone and shale, were carried into the area from the Appalachian Mountains to the east and south, and the Canadian Shield to the north. Central U. S. emerged from the seas, regionally uplifted without mountain building. Then over 1500 m of sediments were eroded, ultimately uncovering the Mississippian rocks now exposed in LBL.

A structural depression permitted advance of the Cretaceous seas beneath the Mississippi Embayment of the Gulf Coastal Plain. Tuscaloosa gravels and McNairy sands were deposited near the margins of these seas. The embayment appears to be a downwarp along a late Precambrian failed rift zone within the North American Plate. The New Madrid earthquake zone is probably a manifestation of activity at a depth of several kilometers along this ancient rift.

The land is not favorable to cultivation nor intense cultural activity because of rough topography. Soils derived from parent materials are low in nutrients. On the ridge tops loess generally overlies gravels. On narrow ridges and slopes parent materials are gravel or residuum from weathering of the siliceous bedrock mixed with loessal silt. The bottomland soils are composed of fluvial sediment derived from erosion of the upland. Surface soils are generally silty over a stony subsoil. They tend to be chemically neutral and relatively favorable for cultivation and pasture; they are subject to flooding.

The dissected topography reflects a dominance of erosion by surface water over a long period of time. Mass wasting seems to have played only a minor role, manifested today mainly in slumps adjacent to stream banks and cultural over-steepening of slopes.

Surface run-off in the form of sheet wash dominates on the slopes. Upland slopes are steep and drainage lines are closely spaced. At the headwaters discontinuous gullies characterize the floor of open swales and many steep ravines. Bedrock is rarely exposed. Bottomlands have sediment fill incised by an active rocky channel with secondary channels. Alluvial fans at the mouths of tributaries appear to be favorable to plant growth.

Stream channels are characterized by the presence of chert gravels. These are derived from 1) the Tuscaloosa and Tertiary-Quaternary rounded gravels which mantle the upland, and 2) the more angular, and commonly tripolitic residual chert derived from the weathering of bedrock. Considerable sand is also present, both of quartz and chert composition. Silt and clay is transported in suspension during high waters, and accumulates in slack-water areas as flow decreases. Flow of surface water is limited to the cooler months of low transpiration and evaporation.

Considerable ground water moves through the unconsolidated materials and through solution openings in the limestones. Sink holes are rare. Springs from orifices in the limestone are present in every drainage basin, yet the collecting areas are so small that most springs cease to flow during the summer. Most drilled wells will yield 20 l/min, and a few 200 l/min.

Shorelines of the lakes show the most active geomorphic changes. Waves against steep slopes of the headlands are rapidly eroding the cherty residual surface material and exposing bedrock in many places. Wave action and shoreline currents have formed shingle beaches with large boulders, spits, and bay-mouth bars, and an under-water shelf. The drowned valleys receive much sediment from the streams. Annual fluctuations of lake level of two meters or more have an effect much like tides.

The Tennessee and Cumberland rivers are master rivers of the Interior Low Plateaus. Their origins are very ancient. The course of the Cumberland River and the north-trending segment of the Tennessee Valley probably predate the Mississippi Embayment. Both reach the head of the Mississippi Embayment at the structural junction of the Reelfoot Rift and its arms which split toward St. Louis and southwestern Indiana. The locations of the two valleys in the vicinity of LBL were influenced by the deposition of the Tuscaloosa gravels and later by the extensive sheet of Tertiary-Quaternary (Lafayette) gravels. Windblown loessal silts of Pleistocene age veneer the uplands. Much of the fine materials of the valley slopes and the bottomlands were derived from the eroding loess throughout the Holocene; human activities may have speeded up erosion.

INTRODUCTION

This report is a summary of the geology and geomorphology for "The study of flora and non-game fauna of Land Between The Lakes." It is not a review of the geologic literature. Rather, it is a description of the geology and geomorphology of the region and an interpretation of the geologic history based on the literature and the writer's knowledge of the area. The writer spent several days in the field to make some first hand observations, and to take photographs to illustrate an oral presentation. Emphasis is given to the elements which are likely to be of the most interest to biological research. Land Between The Lakes (LBL) is an area of deeply weathered Paleozoic limestone bedrock at the margin of the Highland Rim section of the Interior Low Plateaus. It also contains discontinuous unconsolidated sediments of the Coastal Plain to the west.

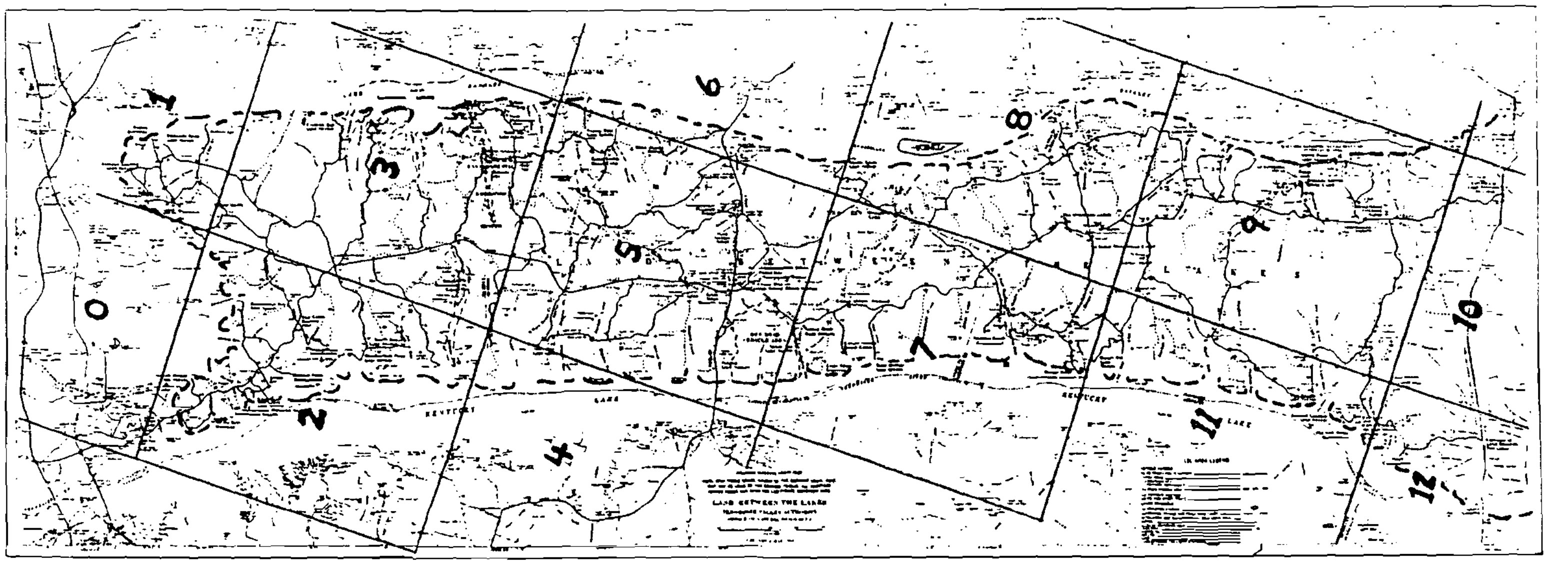
Geologic maps on a scale of 1/24,000 are available for the entire area of LBL (figure 1). These were made in the 1960s as part of the cooperative mapping projects between the U. S. Geological Survey and the state geological surveys of Kentucky and Tennessee. Text is minimal on these maps, but Marcher (1962) gives more detail about the geologic formations. The section on geomorphology is based on observation and the writer's experience. Excellent topographic maps of the same scale and a 20-foot contour interval form the base maps.

Very little geologic literature refers specifically to this area. It received little attention because it is small, much dissected, and was formerly quite isolated between the Tennessee and Cumberland rivers. It contains few economic mineral deposits. Small low-grade iron deposits were worked from time to time during the 19th century. Ground water is the most important product that has received attention of geologists. The cooperative ground water investigations between the State of Kentucky and the U. S. Geological Survey provide a useful hydrologic atlas map (HA-34). The U. S. Army Corps of Engineers made extensive subsurface studies during construction of the dams. Numerous reports of the Kentucky and Tennessee geological surveys include useful references to the area, or give information applicable to the area.

GEOLOGIC SETTING OF LAND BETWEEN THE LAKES

Bedrock of LBL is dominantly cherty limestone of the Mississippian System. Only five formations are represented because of the parallel relationship to regional structure. Figure 2 represents the geologic column above the Precambrian crystalline "basement" rocks; the chart is included for orientation. The short section at LBL is highlighted. Central U. S. is part of the stable North American continental plate or craton. Throughout the early Paleozoic Era from Cambrian until late Mississippian, shallow, relatively-clear-water marine conditions persisted in the LBL region. Sediments were largely carbonates formed by the accumulation of shell fragments or direct precipitation from sea water. Beginning with the Chesterian Epoch influxes of clastic sediments reached the area. These sandstones and shales, including beds of coal, remain in the structural basins but have been eroded from the domes. During the late Paleozoic the Appalachian Mountains to the east and south were undergoing dynamic growth, providing the source of the terrigenous sediments. The elevation of the craton persisted so near sea level that alternations of marine and terrestrial conditions were the rule.

The combination of broad basins and domes (or arches) of the craton and persistence of erosion has caused a beveling of the rock formations. The resulting pattern shown in figure 3 has exposed the oldest rocks at the center of a dome with younger formation bands around them. The youngest preserved formations are at the center of the structural basins.



TOPOGRAPHIC AND GEOLOGIC QUADRANGLE MAPS

0. Grand Rivers
1. Eddyville
2. Birmington
3. Mont
4. Fair Dealing
5. Fenton
6. Canton
7. Rushing Creek
8. Model
9. Tharpe
10. Standing Rock
11. Hamlin
12. Paris Landing

TVA Land Between the Lakes Kentucky-Tennessee

Figure 1. Outline map of Land Between The Lakes showing geologic maps on a scale of 1/24,000 from U.S. Geological Survey Atlas series GQ

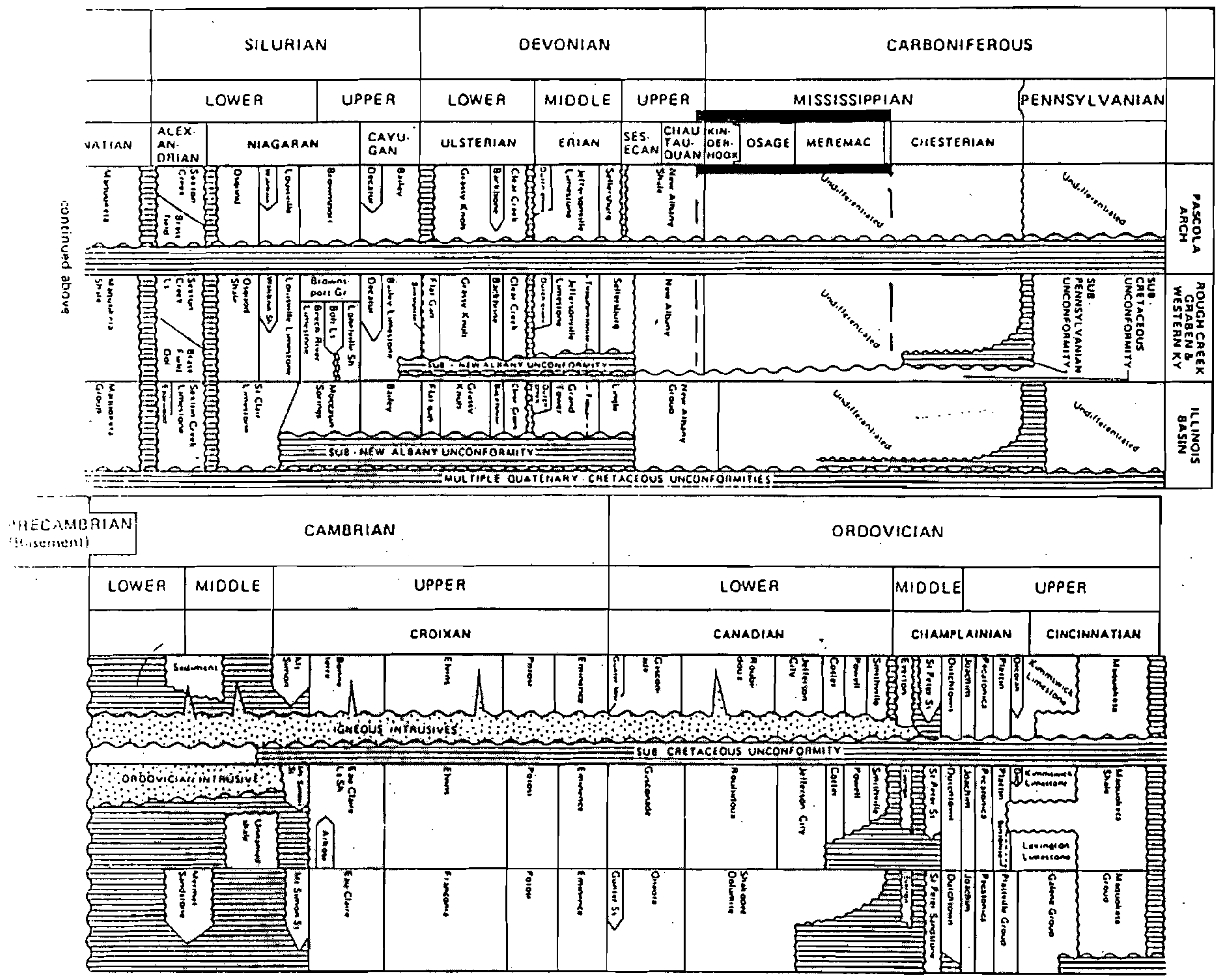


Figure 2. Stratigraphic column of eastern mid-continent U.S.A. (from IBUD 1987)

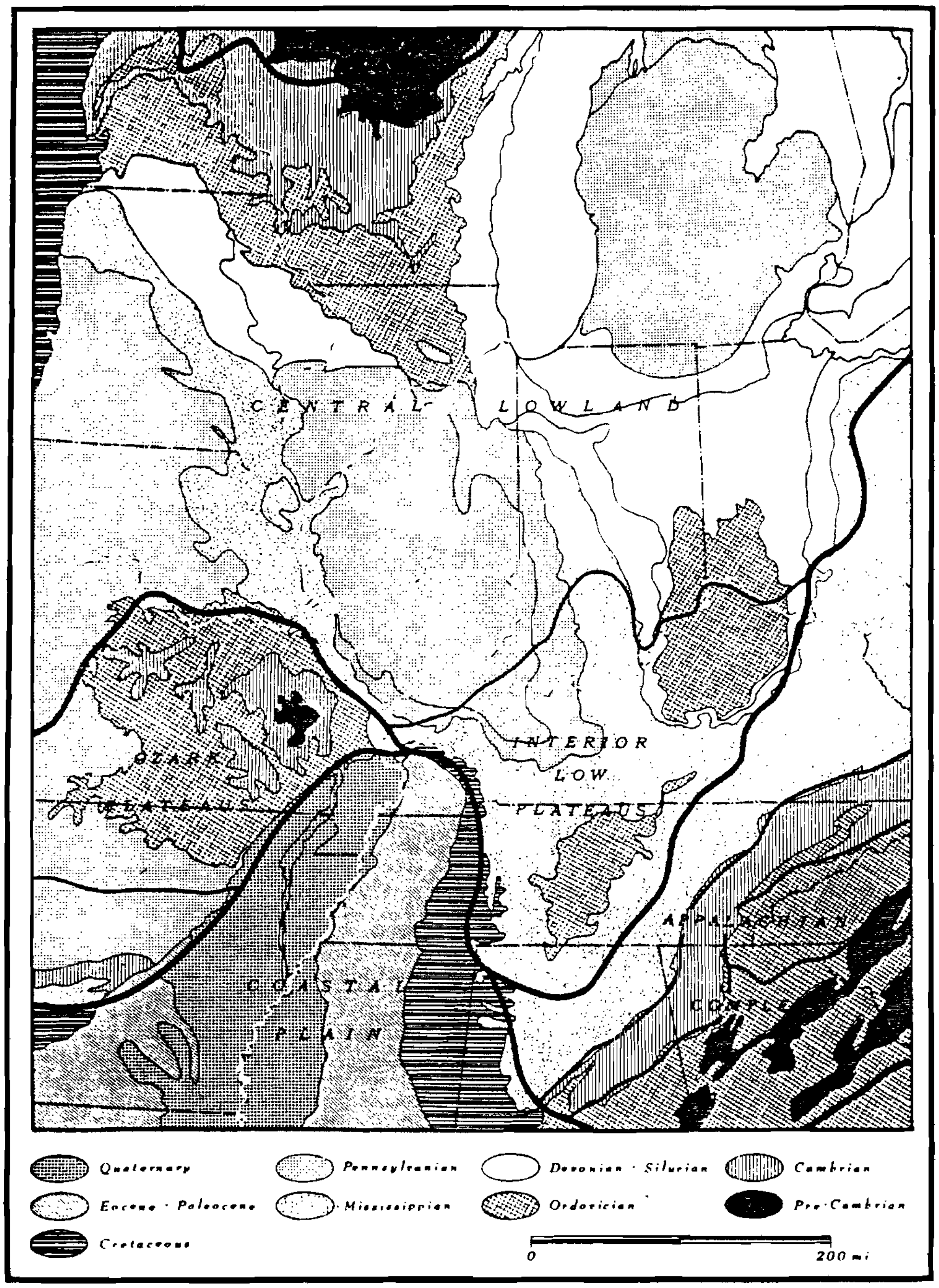


Figure 3. Geologic map of midwestern U.S.A. showing physiographic divisions and bedrock outcrop area by system (from Harris 1979)

The location of LBL is shown to be at the southern end of the Illinois Basin and on the west flank of the Cincinnati Arch-Nashville Dome (figure 4). It is also at the margin of the late Mesozoic-Cenozoic downfold of the Mississippi Embayment.

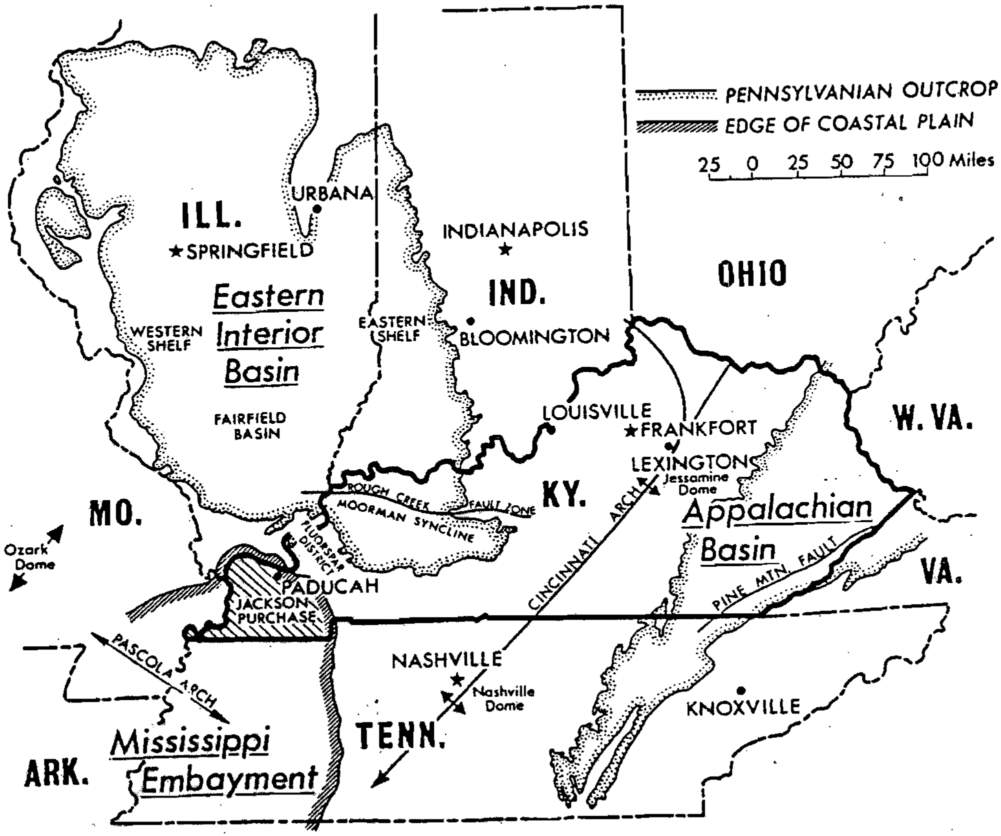


Figure 4. Regional geographic setting of Land Between The Lakes (from Schwalb 1969)

PHYSIOGRAPHIC SETTING

Land Between The Lakes is the northern segment of the western subsection of the Highland Rim section of the Interior Low Plateaus physiographic province (figures 5 and 6). The Tennessee River Valley marks the boundary with the embayment section of the Gulf Coastal Plain. The sandstone-dominated ridges of the Shawnee Hills lie not far to the north and northeast.

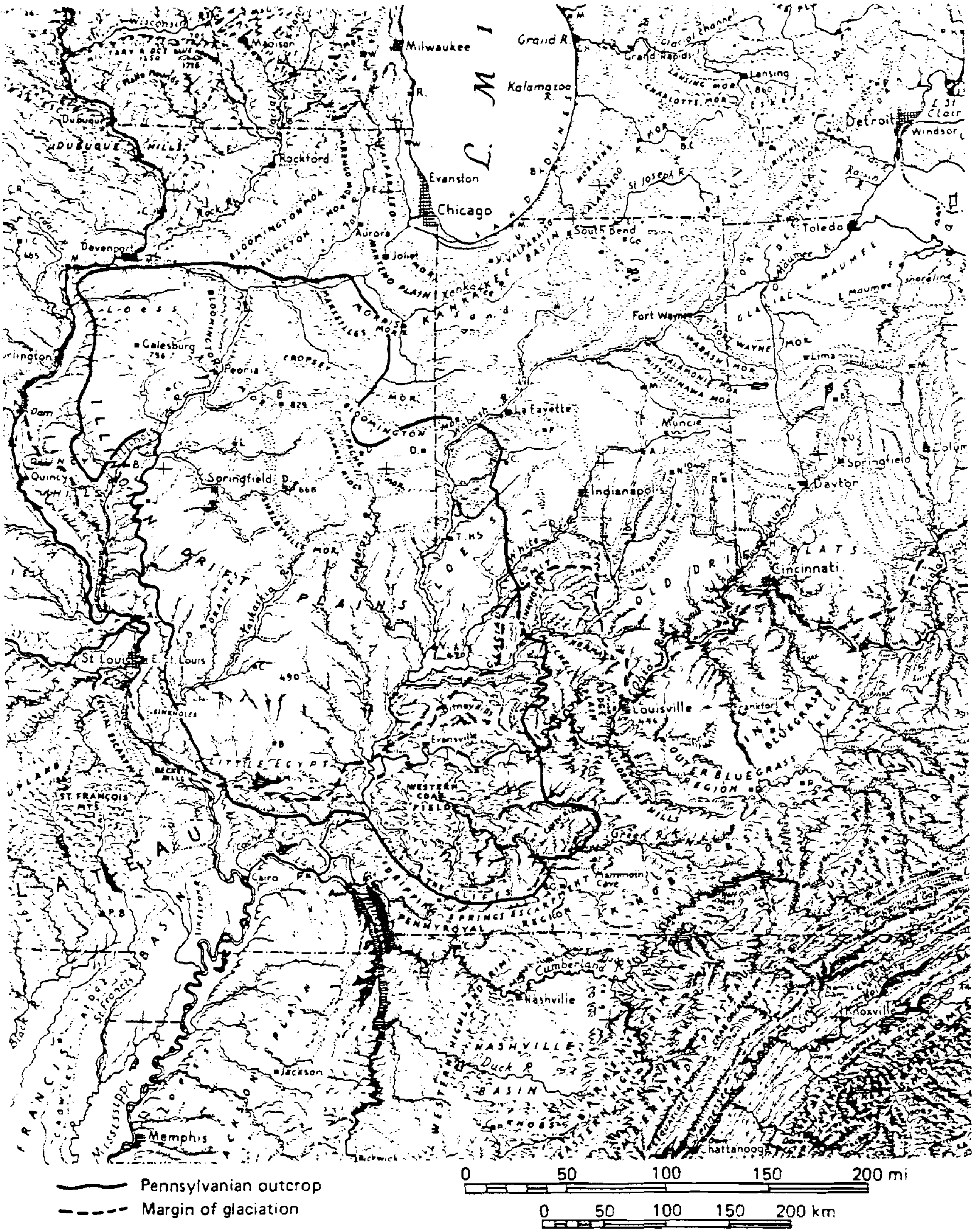


Figure 5. Physiographic diagram of Midwest showing major topographic features, Pennsylvanian outcrop, and margin of maximum glacial advance (after Raisz 1954)

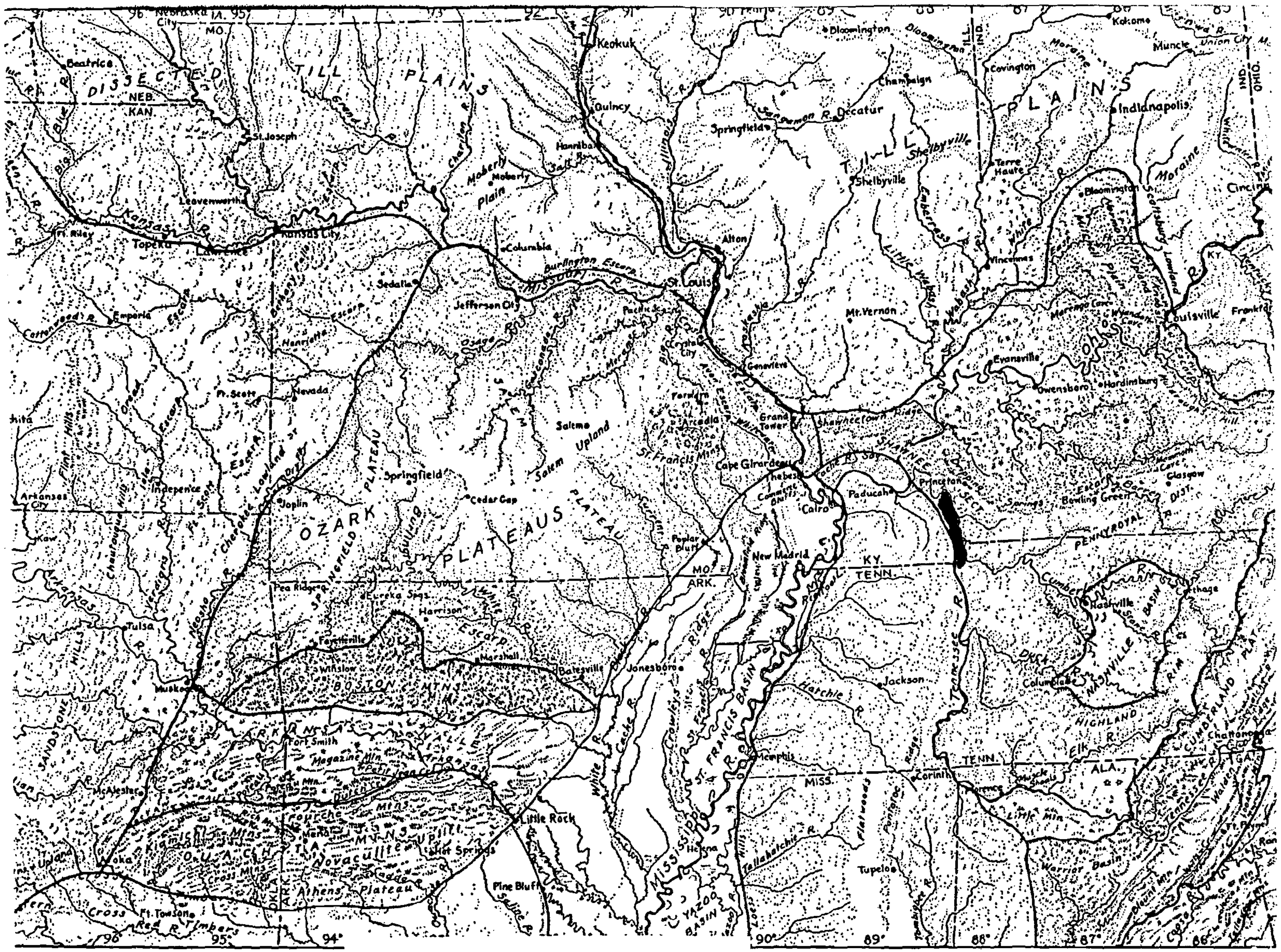


Figure 6. Physiographic divisions of Midwest (from Fenneman 1938)

The generalized geologic map of central U. S. (figure 3) indicates the age of the bedrock. Figure 4 shows the main structural elements which will be referred to in this report. Note that LBL lies on the flanks of the Eastern Interior Basin to the north and the Nashville Dome to the southeast. As will be shown below (figure 7) it is also marginal to the faulted zone of the Wabash and Rough Creek arm of the failed Reelfoot Rift.

The Tennessee and Cumberland valleys are the dominating elements of LBL. They extend parallel to one another for about 65 km in a north-south direction, and are 11 to 14.5 km apart. The rivers formed topographic trenches 1.5 to 3 km wide. Closely-spaced tributary valleys enter the trench at nearly right angles. The depth of the master streams determines the depth of erosion of the tributaries. Likewise, when the rivers aggraded during the late Pleistocene, the lower reaches of the tributaries in LBL also aggraded. The resulting bottomlands were broad, but subject to frequent floods.

The Tennessee and Cumberland both flow into the Ohio River less than 16 airline km to the northwest of LBL. From there it is about 65 km downstream to the confluence of the Ohio with the Mississippi (figure 5).

During the Pleistocene Epoch glaciers did not reach the Tennessee and Cumberland valleys, so there are no glacial deposits in LBL. Maximum advance occurred during the Illinoian Stage when glaciers pushed up the backslope of the Shawnee Hills of southern Illinois, but did not reach the crest (figure 5). Later the maximum advance of the Wisconsinan Stage reached only to central Illinois approximately 22,000 years ago. However, there have been successive climatic changes during the two or three million years of the Pleistocene Epoch. Repeated changes in vegetation and intensity of geomorphic processes must have resulted. Indirect effects on the LBL region were: 1) deepening of the valleys, 2) ponding and aggradation of the valleys, and 3) deposition of windblown silty and sandy loess mantling the uplands.

Finally, LBL lies within the region affected by Reelfoot Rift system (figure 8). The extent and age of this system are presently being investigated. The structural weakness apparently dates from the late Precambrian, and has been intermittently active ever since. Modern earthquake epicenter distribution indicates movement in the basement complex mainly along the Mississippi River, but elsewhere as well. Land Between The Lakes would be affected in any major earthquake, and lesser earthquakes could occur very close to, or even in, LBL.

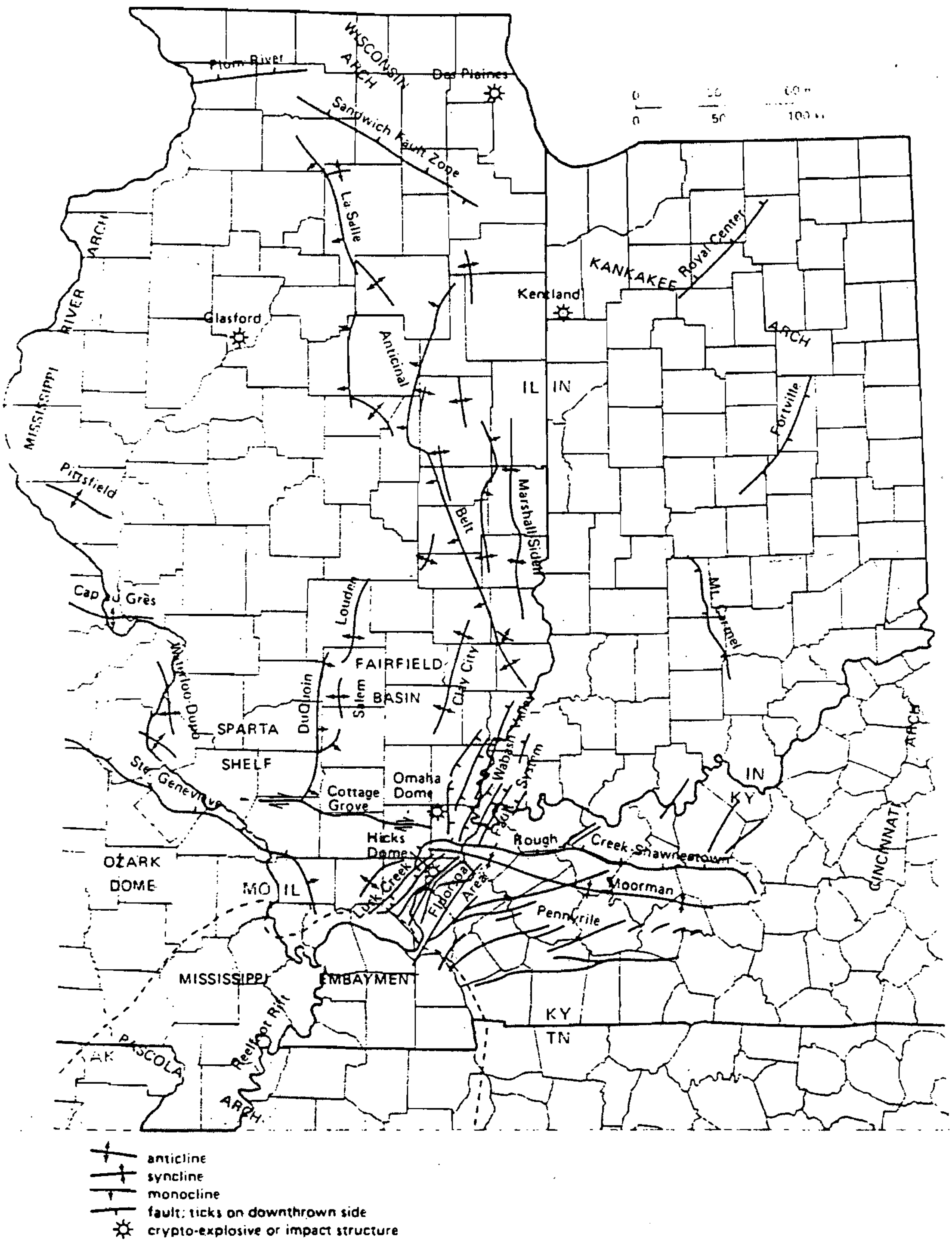


Figure 7. Structural features of the Illinois Basin and adjacent areas (from IBUD 1987)

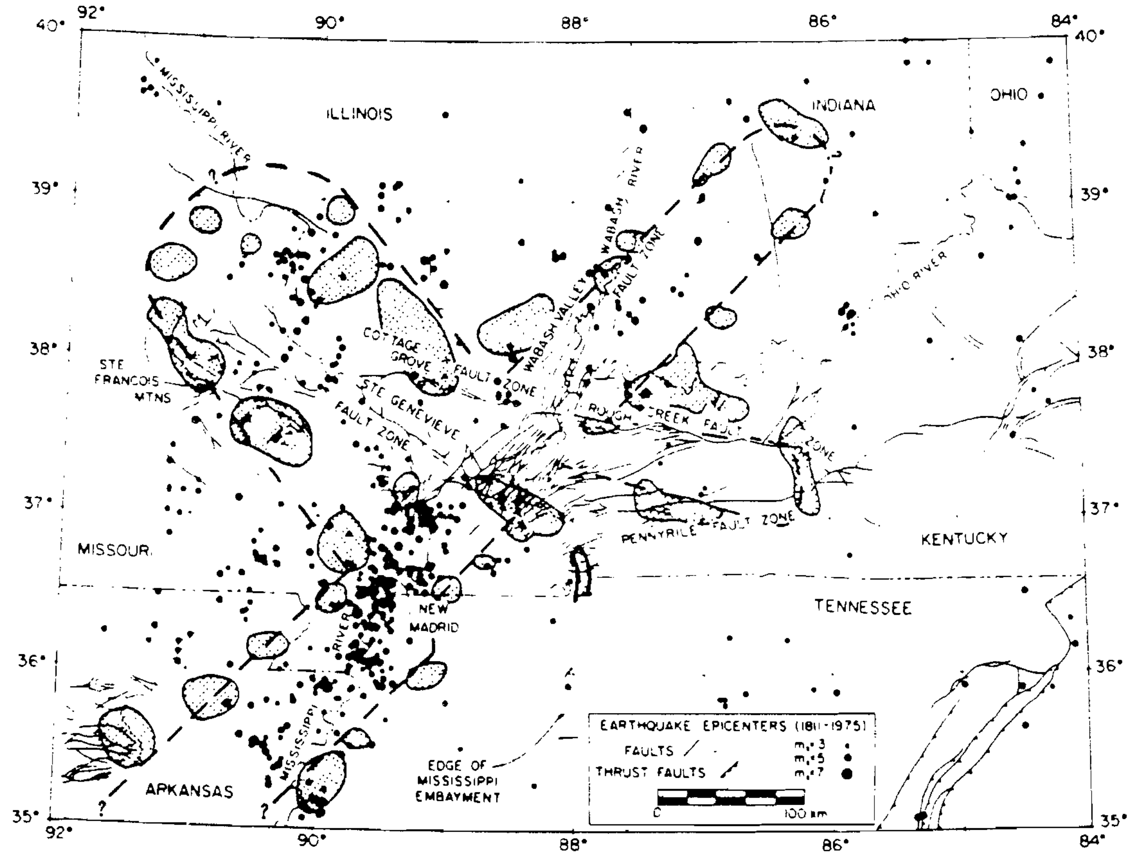


Figure 8. Map of inferred rift complex in New Madrid area showing earthquake epicenters (dots), correlative gravity and magnetic anomalies (shaded), and inferred boundary of the rift complex (from Braile et al. 1982)

TOPOGRAPHY

Land Between The Lakes was called "land between the rivers" before the high dams were constructed on the Tennessee River (to form Kentucky Lake) and on the Cumberland River (to form Lake Barkley). The topography is greatly dissected by the numerous tributaries of each river. These head against each other so as to form a narrow drainage divide. The divide between the rivers is somewhat closer to the Tennessee than to the Cumberland valley.

The elevation of this divide is relatively even, ranging from about 150 to 180 m above sea level. However, the entire area is maturely dissected, in William Morris Davis' terminology (1954); valleys and their tributaries are so close together that most of the area is in slope. There is somewhat more bottomland than flat upland. Original maximum relief before the lakes were formed was little more than 90 m. Presently, lake elevation is generally 109.4 m A.T., reducing the relief somewhat. The central divide is highest at the extreme south where it reaches 201 m A.T. Northward the ridge crest undulates above and below 180 m to the vicinity of highway 68; from Jenny Ridge northward the crest declines gradually until at the north end of LBL the elevation drops below 150 m. Most of the streams tributary to the major river valleys are roughly parallel to each other and spaced about 1-2 km apart. They reach the valleys (lakes) nearly at right angles. They have a very steep gradient in the headwaters but their lower course has a low gradient and a relatively broad valley floor (see later section for explanation). Today these valleys are drowned at their mouths by the lake waters. Divides between these secondary valleys are also narrow and complexly dissected with a generally reticulate pattern.

Some valleys have only one main stem while others have two, three, or even four forks of nearly equal size. A few valleys are somewhat longer. Their upper course extends nearly parallel to the major rivers, flowing in a northerly direction and then curving toward the east to the Cumberland Valley (Lake Barkley). Crooked Creek and Laura Furnace Creek are the best examples. They also have the largest drainage basins. The longest valleys are tributary to the Cumberland River.

GEOLOGIC MATERIALS

Land Between The Lakes owes its homogeneity of bedrock and topography to the fact that the rivers parallel the strike of the bedrock and the rocks are nearly flat-lying. The same formations make up the bedrock throughout the entire length of LBL. Though faults cut the area diagonally in a number of places, the displacement is not great.

The bedrock beneath Land Between The Lakes is limestone, some very cherty. Limestone is a soluble rock, while chert is resistant both to solution and to abrasion. Some of the limestone units contain thin shale layers and/or disseminated clay and silt. Disseminated or layered silt or clay, together with the chert, form the residual weathered product. Practically no soil would be formed by weathering of pure limestone.

In current usage the bedrock of LBL is divided into five formations (figure 9). They belong to the Mississippian System, part of the great accumulation of carbonate rocks deposited in the center of the North American continent during the mid-Paleozoic Era. Poorly-exposed shales of Devono-Mississippian age occur at the extreme southern part of the area.

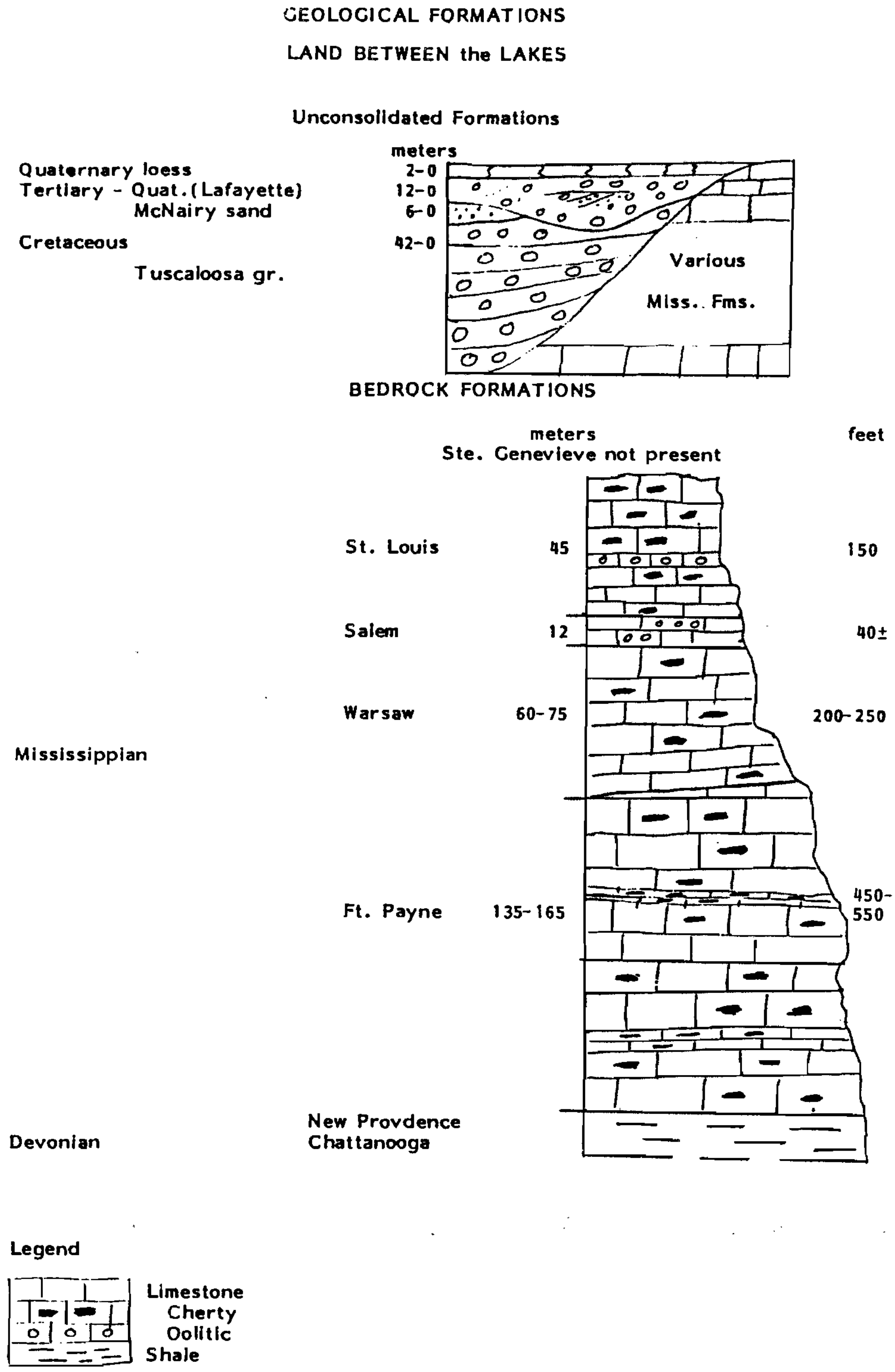


Figure 9. Bedrock formations which outcrop in Land Between The Lakes area

Surface exposures of the bedrock are uncommon in LBL except along the shores of the lakes where in many places wave action has removed the overlying unconsolidated sediments and residuum. Otherwise exposures are mainly where streams have undercut the base of slopes. Some exposures have been made by cultural excavations, as at the north end of the dam at Energy Lake and the vicinity of the old quarry on the south side of Hematite Lake.

The best descriptions of the bedrock accompany the published geologic maps prepared by the U. S. Geological Survey in cooperation with the Kentucky and Tennessee state geological surveys. These were published in the 1960s on a scale of 1/24,000. The base maps are the U.S.G.S. topographic maps. A Kentucky Geological Survey bulletin concerning limestone resources of western Kentucky gives detailed lithologic and chemical descriptions of several quarry sections in the area (Dever and McGrain 1969).

The limestones and cherty limestones of the entire sequence are similar. Variations exist due to changing depositional and subsequent environmental conditions. However, the variations are repetitious, so that isolated exposures cannot be easily identified by formation name. Their identification rests primarily on their fossil content and certain distinctive lithologies. Furthermore, several faults interrupt continuity of units. From the viewpoint of a biologist, correct identification of the bedrock formation probably makes little difference. The bedrock formations all weather to a cherty residuum and few exposures are present. Nevertheless the soil materials are the weathering product of specific bedrock units, and future research may discover unique or significant properties. So far as the writer is aware, no such properties have yet been recognized.

CONSOLIDATED FORMATIONS

Devonian-Mississippian Systems

Chattanooga-New Providence formations: The oldest rocks in LBL are represented by a few exposures of dark brown laminated Chattanooga shale of Devonian age. Overlying this shale is a gray-green shale which is assigned to the New Providence shale of Mississippian age. The sequence probably represents continuous deposition, but under changing environmental conditions. These formations underlie the Ft. Payne Formation at the base of the thick column of Mississippian limestones.

A considerable thickness of gray-green shale is exposed on Shaw Branch in the northeast corner of the Fenton Quad. It is laminated and noncalcareous, and presumably belongs to the New Providence shale. In the Eddyville Quad similar gray-green shale contains interbedded dark brown to black carbonaceous shale.

The black shale is thicker below and is considered to represent the Chattanooga Formation.

Shales of similar nature occur throughout the midwest in that particular stratigraphic position. A great deal of literature about them discusses both their origin and age. The black shale is believed to have been formed under anaerobic conditions in a sea with poor circulation. Abundant spore carps are commonly present in the Chattanooga; they are considered to be of Devonian age. The black shale contains enough uranium to be of some strategic interest, and is possibly radioactive enough to affect the environment.

The overlying gray-green shale is generally considered to be lower Mississippian in age. Better conditions of circulation provided sufficient oxygen so that carbonaceous material was decomposed. The age controversy has little or no interest in this report. Furthermore, the shale occurs in very few places and leaves no impress on the land.

Mississippian System

The Mississippian System was so named because of its extensive outcrop distribution in the mid-Mississippi Valley (figure 3). The outcrop extends from southern Illinois southeastward, forming the surface bedrock of most of the Highland Rim Section of the Interior Low Plateaus. The upper Mississippian Chesterian Series, composed of alternating sandstones, shales, and limestones, underlie the hilly topography of the Shawnee Hills. The mid-Mississippian series is dominated by limestones including the formations composing the bedrock of LBL (figure 6).

These formations were deposited in a shallow inland sea. Calcium carbonate muds formed by direct precipitation, and bioclastic sands consisting of shell fragments were deposited in the clear seas. Also, chert accumulated. In some cases silica, in the form of chert, chemically replaced some of the limestone; some may have accumulated with the sediment as gelatinous masses, later dehydrated. The source of the silica and the exact manner of formation of chert is not fully understood.

Ft. Payne Formation: The Ft. Payne Formation is the lowest limestone formation exposed in LBL. It is gray, generally fine grained, and thin bedded. It is sparsely fossiliferous, a feature which distinguishes it from the overlying Warsaw, Salem, and St. Louis formations. The limestone has a fetid odor when freshly broken. This formation lies at the base of Mississippian limestone sequence which forms the bedrock of most of LBL.

Chert is a major component of the Ft. Payne. It is generally interbedded in irregular layers with the limestone. As much as 50 percent or even more of the formation consists of chert especially where some solution of the limestone has taken place. The chert is gray or dark gray, dense (in places porcelaneous), and commonly banded.

The formation is best exposed in bluffs along the shores of Kentucky Lake; other exposures occur along Panther Creek and at Ferguson Springs.

The residuum appears as a "float" of angular chert fragments on the hill slopes. The chert is light gray, even yellowish, in a matrix of very light gray to pinkish gray, silty clay.

Warsaw Formation: The Warsaw Formation overlies the Ft. Payne but contact between the two is not exposed. The limestone of the Warsaw Formation is generally light to medium gray. Commonly the beds consist largely of fossil fragments of crinoids and bryozoans reworked into thin layers in the warm, shallow Mississippian sea by waves and currents. Cross bedding is common. When broken, the matrix appears as shiny, sparry calcite. It is 80-95 m thick.

The Warsaw contains less chert than the Ft. Payne. However, in the middle section of the Warsaw up to 50 percent of the rock may consist of chert. Some of the chert is nodular with concentric bands, but most chert occurs as irregularly bedded, discontinuous layers from 2-25 cm or more in thickness. The chert is generally dark or nearly black on a freshly broken surface.

In the lower part of the formation, chert is less abundant. The limestone is light to medium gray. Many beds are 60 cm or more of dense limestone, coarse- to medium-grained, and consist of crinoid and bryozoan fragments. Many beds are cross bedded. When broken, the rock has a crystalline appearance and the fossils are not visible. Some limestone units are very pure carbonate, without chert. Zones of very high calcium limestone of chemical quality occur in quarries on the east side of Lake Barkley near Canton (Dever and McGrain 1969).

The residual soils are a rubble of chert fragments in a matrix of yellowish or reddish clay and silt. The chert ranges from sand-sized particles to porous blocks 30 cm or more across. It is commonly fossiliferous; rounded chert nodules are also present.

The Warsaw Formation crops out beneath the St. Louis-Salem, commonly occupying the lower slopes. On these lower slopes exposures of the rock are seen in many places where streams impinge against the valley slope. The best exposures are undoubtedly along the lake shores.

Salem Formation: St. Louis and Salem formations are shown with a single symbol on the several geologic maps prepared for the region in the 1960s. Separation of the two formations is difficult because lithologies are so similar. However, these names are in use throughout the midwest and separation may be relatively clear in some areas. Fox and Seeland (1964) describe the Salem in the Canton Quad, but do not separate its outcrop from that of the St. Louis. Where separated, the Salem is about 12 m thick.

Beds in the upper part of the Salem contain a light gray oolitic limestone; this lithology is a pure calcium carbonate. The oolite is interbedded with gray to brown, medium- to coarse-grained limestone. Brown, very thin-bedded, argillaceous limestone also occurs. Fossils include crinoid columnals and plates, horn corals, and Lithostrotian colonial coral masses.

The lower unit is a dark gray limestone of very fine texture, argillaceous and laminated; a few chert nodules and geodes are present. A second interbedded lithology consists of medium dark gray bioclastic limestone; i.e. the rock is composed of fragments of fossils reworked and deposited like a sand.

St. Louis Formation: The highest bedrock unit mapped in LBL is the St. Louis Formation. North of LBL it lies stratigraphically directly beneath the Ste. Genevieve without any obvious discontinuity. Agreement on the zone of separation is sometimes difficult to obtain among different geologists and geological organizations. In fact, the upper St. Louis as mapped by geologists in the quadrangles covering LBL appears to be equivalent to that designated lower Ste. Genevieve in the quarries of Christian and southeastern Trigg counties, Kentucky. Preferred usage now places these units in the upper St. Louis (Dever and McGrain 1969).

The uppermost part of the St. Louis is missing from LBL, but total thickness is estimated at 30 to 45 m. The formation consists of light gray to dark brown limestone. Many zones are quite fossiliferous, consisting of crinoid plates, columnal fragments (Indian beads), and bryozoans. The large colonial coral, Lithostrotian, is characteristic. Oolitic beds are an important lithology of the St. Louis, as they are in the Salem and the Ste. Genevieve. The term oolite refers to small spherical particles, of sand size, which somewhat resemble fish eggs. They occur in layers from several, to 30 or so cm in thickness and are very pure carbonate. They form on very shallow marine banks such as those found in the Bahamas. Calcium carbonate is precipitated around small particles due to loss of CO_2 during warming and evaporation of agitated water. They are commonly white with a chalky matrix.

Chert is generally sparse in the lower member of the St. Louis but is locally abundant. Dense nodules of chert are apparently more characteristic than lenses or beds of chert.

The darker limestones are commonly dolomitic, i.e., magnesium replaces some of the calcium in the carbonate radical. The dark color usually indicates impurities of clay or silt. In the St. Louis Formation dense nodules of chert are apparently more characteristic than lenses or beds of chert. The upper member is very cherty both at the base and the top just below the Ste. Genevieve.

One limestone lithology consists almost entirely of fossil fragments in rather thick beds. The fossils are readily seen in relief on weathered surfaces but few are entire. When broken, the fresh rock has a crystalline appearance and the fossils may not be recognizable. Crystal-lined vugs and geodes are present in the lower member, and gypsum is occasionally found in thin layers.

The weathered residuum is commonly even thicker than that over the Salem, Warsaw, or Ft. Payne, but is distinctive enough to allow identification of the formation anyway. It has a reddish or yellowish color, and contains abundant chert masses, commonly in nodular form.

The St. Louis Formation forms the bedrock in much of the upland of LBL beneath its residuum, younger gravels, and mantling loess. In the south the loess and unconsolidated gravels are thin or remain on the ridge crest. On the other hand the residuum is thick nearly everywhere. Thus, bedrock exposures are few.

The uppermost Mississippian formations belonging to the Chester Series and the Ste. Genevieve limestone are nearly all eroded at LBL. They outcrop to the north and northeast of LBL. Only the Bethel sandstone is mapped in LBL in a small area within a down-faulted block in the Eddyville Quad. Farther north the sandstones of the Chester Series are ridge formers but the topography is not affected by the small Bethel exposure in LBL. The St. Genevieve provides the limestone of greatest economic importance. Reed's Quarry, traversed by U. S. HWY 62, produces mainly from the Ste. Genevieve.

UNCONSOLIDATED MATERIALS

Cretaceous System

Tuscaloosa Formation: The Tuscaloosa Formation is characterized by white, rounded gravels. Bedding is poorly developed except where fine-grained layers occur (U. S. Geol. Survey GQ maps). The pebbles which are composed of chert have been rounded by impact against one another during transport. In some well exposed sections white clay and sand layers are seen to be interbedded. However, mass wasting and erosion carry these fine particles away and make the pebbles more prominent so the formation is often called a "gravel". It seems to reach a thickness of 6 to 9 m in LBL, though it must have been much thicker where it is now exposed at low elevations, as in the vicinity of Golden Pond.

The pebbles are poorly sorted in texture, ranging up to about 18 cm in long dimension. The chert pebbles in the gravel vary greatly in character. Some are smooth, dense, and very well rounded; others are grainy, or tripolitic. Tripolitic chert looks as though it might be soft and chalky, for it is easy to scratch apart. However, the scraped particles are silica, hard enough to abrade a knife blade. Some tripolitic pebbles are nearly spherical in shape. A small percent of the pebbles are silica-cemented quartz sandstone. Scattered quartz pebbles do occur but their near-absence is a significant compositional difference from the younger Tertiary-Quaternary gravel. The Tuscaloosa does not contain waterworn ironstone pebbles.

The interstitial and bedded sands are composed mostly of chert grains which were derived both from the parent residuum and the small fragments broken by impact during transport. The clay constituents are mainly montmorillonite and kaolinite, similar to the clays found in the source rock. Some of the kaolinite may be a secondary weathered product.

Good exposures of the Tuscaloosa are not found on the upland ridges. In some places the brown chert gravels of Pleistocene age overlie them, and in addition the veneer of Pleistocene loess, though partly eroded, still mantles the upland. The best exposures are in gravel pits. There is an excellent exposure in the road cut, ditch, and vertical drop where the Jenny Ridge road comes down to Crooked Creek.

The Tuscaloosa Formation rests on a profound unconformity; underlying rocks are Mississippian in LBL and as old as Cambrian beneath embayment deposits. This unconformity represents a period of uplift and erosion which probably started in late Permian and continued through Triassic, Jurassic, and early and middle Cretaceous periods. However, downwarping at the edge of the continent probably began during the Jurassic Period. Simultaneously, the broad Mississippi Embayment extended gradually northward from the Gulf of Mexico.

At the beginning of the Late Cretaceous a highland known as the Pascola Arch extended southeastward from the Ozarks (figure 10). Modern drill records through the coastal plain deposits have been used to construct the accompanying pre-Cretaceous geologic map (figure 10). These Paleozoic carbonate rocks are very cherty and contain some interbedded shales; several sandstone units are also present. The gravels and associated sediments are derived from these rocks. Some material had a local origin, but much had been carried a considerable distance. They seem to have been deposited as coalescent alluvial fans in a terrestrial environment. Marcher and Stearns (1962) believe the source of the Tuscaloosa was from the west--the Pascola Arch. Evidence for this is the abundance of distinctive gray chert pebbles clearly derived from Devonian cherty formations. Those formations outcropped only around the eastern periphery of the Pascola Arch that is now buried beneath post-Tuscaloosa Coastal Plain deposits.

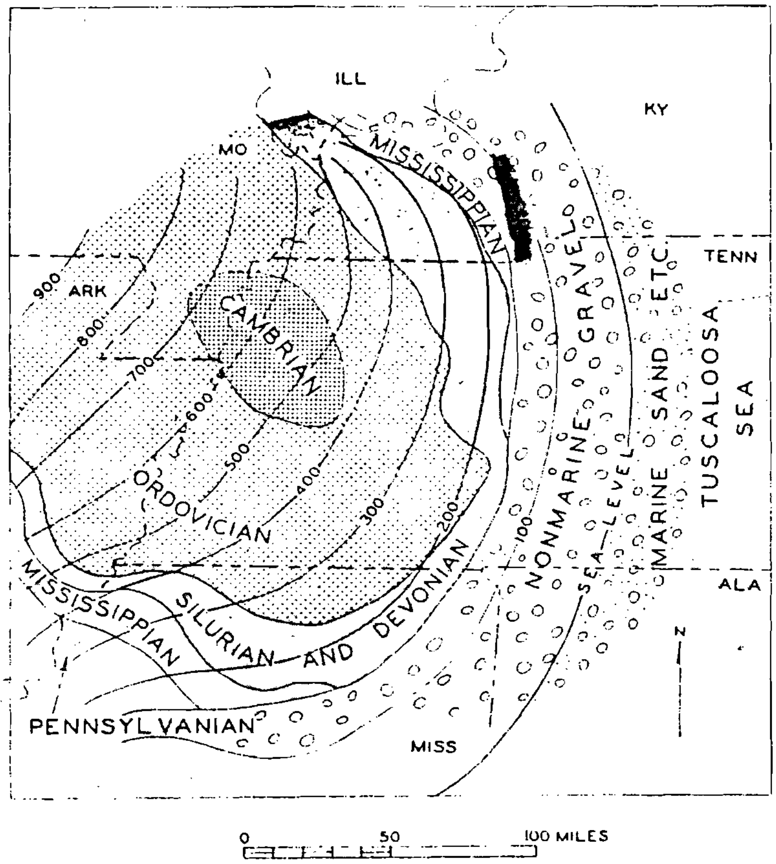


Figure 10. Geology and geography of the upper Mississippi Embayment during deposition of the Tuscaloosa Formation (from Marcher and Stearns 1962)

The gravel was deposited on a very irregular surface as revealed by the fact that these gravels are found at low elevations in some valleys--apparently in their original position--though the main gravel body occurs on the upland above the Mississippian bedrock. Some of the irregularity may have resulted from solution and collapse of the ancient surface. Preservation of the Tuscaloosa and the overlying McNairy is due to the subsequent downwarping of the head of the embayment.

McNairy Formation: The McNairy Formation is a fine-grained, reddish brown sand. It overlies the Tuscaloosa gravels on some of the higher ridges.

The sand is composed of sub-angular quartz grains in a matrix of reddish brown, argillaceous silt. Mica grains are distinctive in this formation, and easily seen when sunlight is reflected from them, although mica makes up no more than 1 percent of the particles. Thin streaks of gray clay are irregularly distributed through the sand; these are parallel to the bedding. Discoidal, gray, clay pebbles up to 2 cm across also occur. Ferruginous concretions of secondary origin are found in some places.

Original thickness is unknown. Drill holes have encountered as much as 23 m, but it appears thinner in exposures.

The McNairy sand is not very prominent, but it is susceptible to severe gully erosion. Good exposures may be seen in the old erosion control demonstration area on Jenny Ridge. Erosion is more or less stabilized today, but the old "badland" gullies are still visible. Rainsplash and sheetwash are active on bare surfaces, and gullies 1.5 m or so in depth are also active.

The McNairy sand once covered all of LBL, but, like the Tuscaloosa, has been dissected by stream erosion. It is more extensive to the west across Kentucky Lake from LBL. The same name is applied to similar sands in southern Illinois. The name "Coffee Sand" is used in the Tharpe Quadrangle in Tennessee. Similar sands are traced far southward at the margin of the Coastal Plain.

Cenozoic System

Tertiary-Quaternary Gravel (Lafayette Gravel of former usage): Remnants of this younger gravel body underlie the loess on the crests of some of the higher and broader ridges. They are believed to be late Tertiary to very early Quaternary in age. No diagnostic fossils have been found and no successful geophysical dating has been made.

The gravels are yellowish brown to reddish brown. Pebbles are composed of chert, as they are in the Tuscaloosa; they are sub-angular to sub-round rather than rounded in shape. In size, pebbles most commonly range up to 8 cm in diameter, and there are scattered cobbles up to 30 cm across. Well-rounded quartz pebbles, yellowish or pinkish in color, and water-worn ironstone pebbles distinguish this gravel from the Tuscaloosa. The gravels have a matrix of reddish sandy clay. Lenses of reddish brown sand, commonly argillaceous and pebbly, are interbedded.

When a cross section is well exposed, as in a gravel pit, the bedding is seen to be prominent, though irregular. Cross bedding is characteristic, and shows regional directional trends (figure 11). The gravels are generally unconsolidated. However, irregular zones of dark brown to black iron oxide form a dense conglomerate. Erosion may yield large conglomerate boulders.

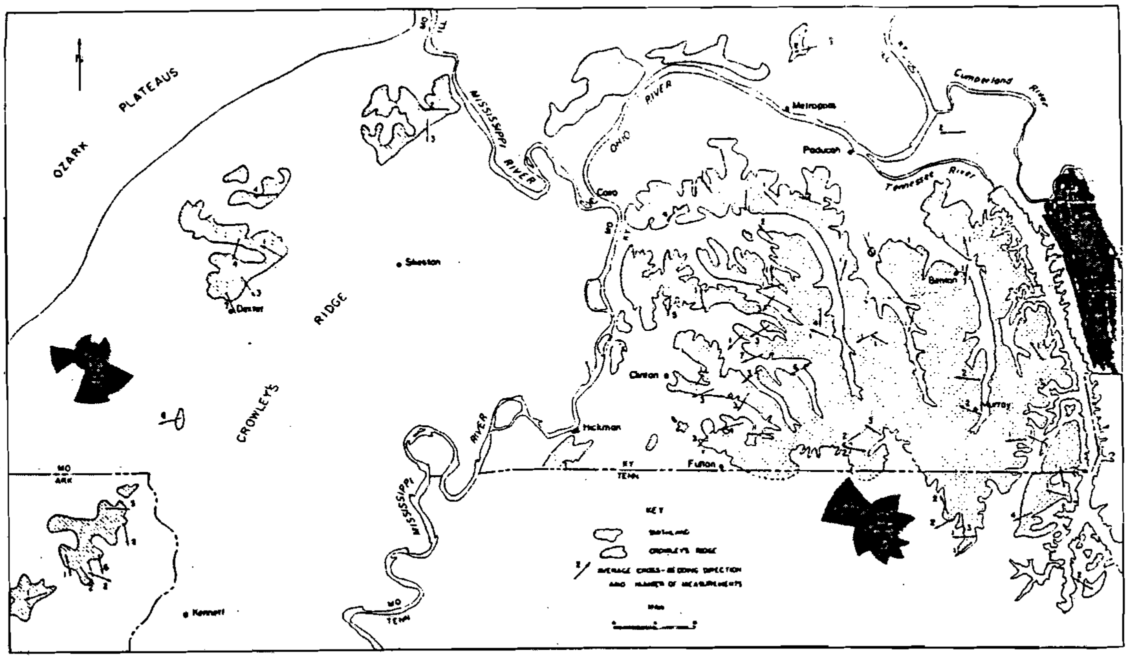


Figure 11. Present distribution of Lafayette gravel (west of Tennessee River) and direction of cross bedding (from Potter 1955)

The gravels are well over 30 m thick west of Kentucky Lake and may be that thick in places in LBL. Once, the deposit was continuous across LBL and all of the Jackson Purchase area. Figure 12 illustrates the post-depositional erosion of the this gravel. It was a part of a broad aggrading lowland extending the length of the ancient Mississippi River and along its major tributaries. Perhaps the greatest accumulation was at the junction of the Mississippi and Tennessee-Cumberland-ancient Ohio rivers.

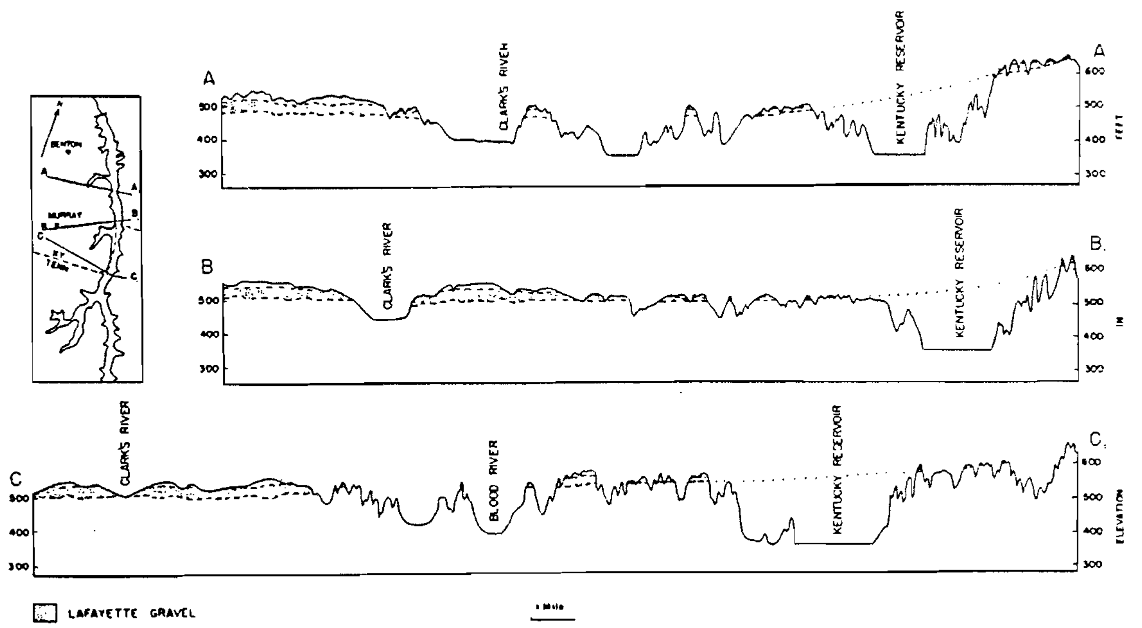


Figure 12. Topographic profiles along the Tennessee River illustrating post-Lafayette dissection (from Potter 1955)

The brown color of the pebbles is due to an iron oxide patina which penetrates the surface to a depth of about 1-2 mm. When broken, the inside of the pebble is white or cream colored. The smooth patina is not evenly distributed over the surface. The rounded corners are roughened by abrasion and are a paler color. Many pebbles have concave surfaces which have a smoother, darker patina.

The Tertiary-Quaternary gravel is distinguished from the older Tuscaloosa gravel by the patina, the presence of quartz pebbles, and scattered, discoidal, waterworn, ironstone pebbles. The quartz pebbles range up to 2 cm in diameter. They are smooth and well rounded and yellowish or pinkish in color. They may represent 5-15 percent of the pebbles. Most of the sand-sized fraction is quartz, unlike the Tuscaloosa, though perhaps 15 percent of the sand grains are chert.

<u>Quaternary series</u>

<u>The Loess</u>: The upland is veneered with a mantle of tan- to buff-colored loess. This body of silt has a massive structure

showing no stratification. Where freshly exposed, vertical jointing is apparent. Brown iron oxide nodules occur in some places, though the writer has not seen these in LBL. Where present, these are a secondary effect of weathering. Some loess contains a high proportion of very fine sand; for example, that mapped on the Tennessee Valley slope in the Birmingham Point Quadrangle.

Loess is generally believed to have a wind-blown origin because:

1. It is a mantle of even-textured, dominantly quartz, silt.
2. It is broadly distributed over upland and slope.
3. Its composition is not related to the substrate.
4. Contact with the underlying material is generally sharp.
5. The deposit is thickest and coarsest close to major, broad river bottomlands, especially on the eastern side of the valley.
6. Loess is related especially to the valleys which have an aggraded fill of glacial valley train sediments.
7. Where very thick (not in LBL) primary calcareous grains and pulmonate snail shells are present beneath the leached zone of weathering.

In LBL the loess is rather thin, rarely more than 1.6 m on the ridge tops. It was originally deposited on upland and slopes alike. The loess body represents more than one period of deposition during the Pleistocene. Near the Mississippi River where the deposit is as thick as 7.5 m, at least three bodies of loess are recognizable by the weathered and/or soil zones between them.

The loess in LBL is dominantly coarse silt to very fine sand; clay is present especially in the B-zone of soils. The silt and sand grains are mostly quartz. It is noncalcareous, probably because leaching of calcareous constituents occurred about as rapidly as the wind blown particles accumulated. Maximum original accumulation is most nearly represented by the thickness on the upland. At such places the soils are free of stones. Loess tends to be thinner on the slopes because of more rapid erosion than on flat upland. Transported silts are incorporated in the chert rubble of the soils of the steep slopes. On the valley bottomlands the silt-textured materials forming the surface sediments are mainly derived from loess.

On steep, north-facing slopes, even where considerable loess is present, pebbles and chert fragments from the underlying units have been incorporated in the soil. This implies dynamic downslope movement, digging by animals, or windthrown trees.

<u>Modern Sediments</u>: The geologic materials of LBL yield abundant coarse fragments. These are ubiquitous, occurring in most physiographic environments. Rounded chert gravels of

Pliocene-Pleistocene and Cretaceous age mantle the uplands, especially in the Kentucky portion. Chert is an abundant constituent of the limestone bedrock. It is a major residual product of weathering of the soluble limestone. Angular chert fragments of all sizes are present in the soil profile, and loose on many hillside slopes.

Chert from all three sources reaches waterways by mass wasting or direct scouring of stream channels. Therefore chert gravels constitute a major portion of the sediment within the active stream channel, and also beneath finer surface materials of the bottomlands. Streams transport a surprisingly large volume of sediment, from clay to boulders in size. During floods the water is turbid with silt and clay; sand may be partly in suspension; and cobbles and boulders may be rolled or shoved along the bottom. Flood waters may overflow the banks carrying fine sediments, sand, and even cobbles onto the floodplain. During decline, flood waters return to the channel, and coarse materials form gravel bars. They come to rest on the inside of the bends, in backwater areas, or in scour depressions. Some fines settle or are washed into the interstices of the coarse materials of the channel bars.

The broader bottomlands typically have a surface layer 0.6 to 1.2 m thick, composed of fine-grained sediments, generally silt and sand. Pebbles and cobbles may be irregularly incorporated. Beneath the fine-grained material, coarse material of varying thickness rests on the bedrock. This material is poorly sorted, containing boulders, cobbles, and pebbles whose interstices are filled with finer-grained sediment. Organic substances, including tree trunks, may be incorporated.

The processes which produce this bottomland sequence are more complicated than might initially be deduced. The natural bottomland stream channel is generally meandering. On the outside of the bends, where scouring and collapse occur, one may observe the profile of fine sediment above coarse. On the inside of the bend sediment accumulates, coarse low in the channel, fine higher up. Over time one may note erosion on the one side and encroachment of sediment on the other. Thus, the cross section area of the channel remains constant, and stream flow capacity is maintained. As the channel shifts laterally, a depositional fill follows behind, with coarse sediment on the bottom and finer material above.

In short term the channel location may seem relatively permanent. It has been noted that gravel bars maintain their position in the channel, even after gravel has been excavated for structural material. More gravel from upstream is deposited in the next flood and the previous configuration is restored. Removal of too much gravel eventually alters the stream regimen, as has been discovered on some of the Ozark canoeing streams.

GEOLOGIC STRUCTURE

Land Between The Lakes lies on the southwest flank of the small structural feature known as the Kuttawa Arch, nearly parallel to the axis which extends from near Kuttawa southeasterly between Barkley Lake and Cadiz toward the Kentucky-Tennessee line. Thus the same Mississippian limestone formations outcrop for the entire length of LBL. The rock units are offset by several faults of moderate displacement, which form a series of down-dropped blocks, or grabens. One such graben in the Eddyville Quadrangle contains a sliver of Bethel sandstone of lower Chesterian age. Strike of the faults ranges from N 60° E to N 85° E. The faults do not displace the Cretaceous gravels. They represent the period of tectonic activity at the end of the Paleozoic Era extending into the early Mesozoic. The faults are related to the Pennyrile system as described by Schwalb (1982). Perusal of the structure maps, figures 7 and 13, show a more complex regional relationship. Land Between The Lakes is near the junction of several major structural elements of east central U. S. Eastward the strata rise gently onto the Cincinnati Arch-Nashville Dome. Northward the strata dip into the Illinois Basin. Westward lies the downwarp of the Mississippi Embayment containing unconsolidated Coastal Plain sediments. Very complex fault systems characterize the region across the north, extending from the west flank of the Cincinnati Arch westward to the east flank of the Ozark Dome.

Land Between The Lakes is situated just east of the New Madrid Seismic Zone, locale of high-intensity earthquakes in 1811 and 1812. Though no destructive quake has occurred since then, modest quakes occur frequently. The map diagram (figure 8) of epicenter distribution (Braile et al. 1982) indicates that LBL is outside the zones of major activity, though it would be within the area of potential damage. Focus of modern earthquakes is at a depth of several kilometers in the "basement" complex. In spite of the many earthquakes, surface displacements have been minor and occur only in alluvial deposits. The ancient Paleozoic fault systems apparently have not been reactivated.

In recent years intensive studies have been undertaken to determine the cause of the modern earthquakes, using advanced geophysical techniques to determine subsurface structures. The development of the concept of plate tectonics has provided a framework which serves as a guide in exploration, and in the interpretation of results.

New Madrid Rift Complex

In summarizing the most recent interpretations of work being done on the New Madrid earthquake problem, the writer refers most particularly to the article by Braile et al. (1986).

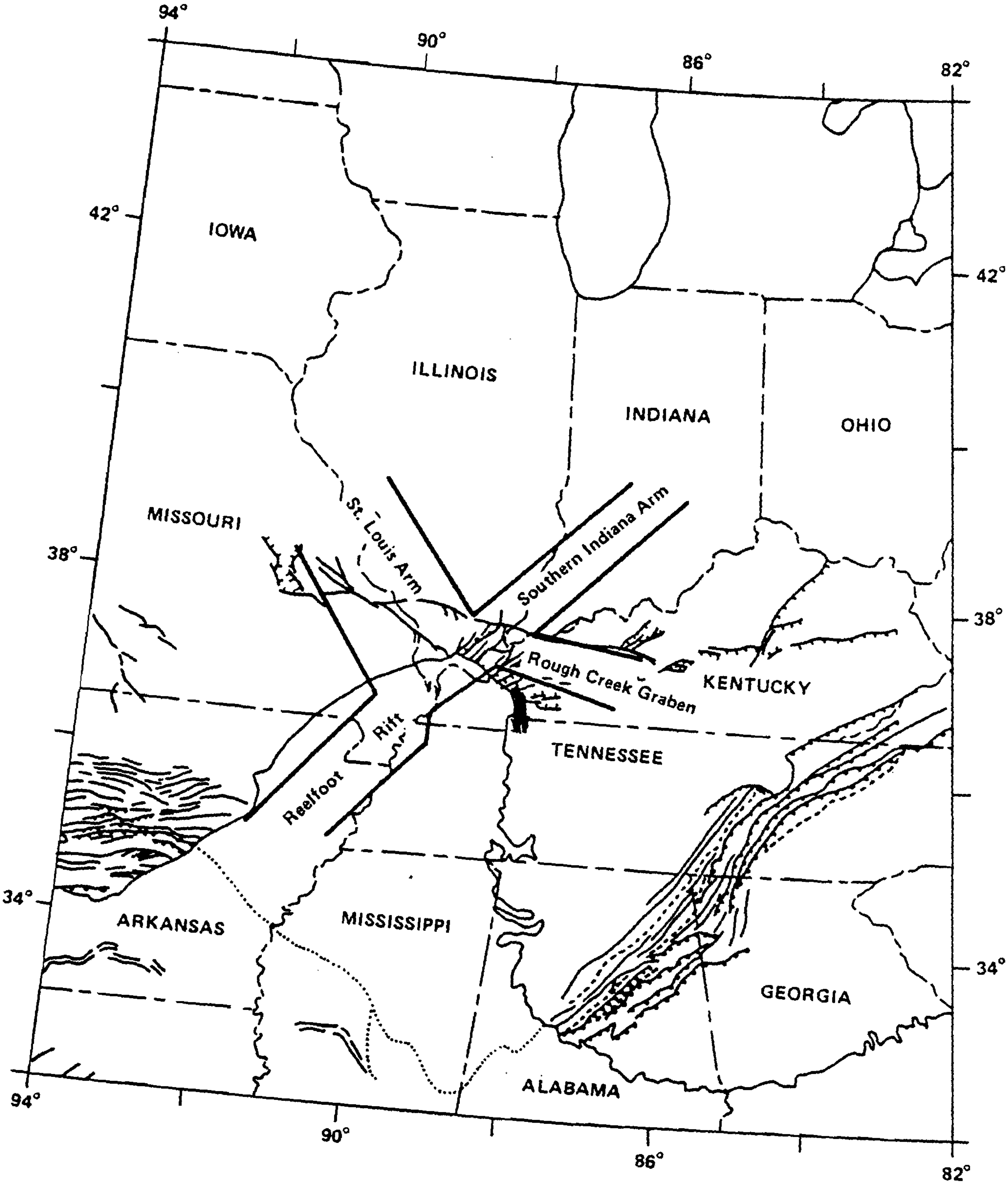


Figure 13. Reelfoot or New Madrid Rift Complex (from IBUD 1987)

It synthesizes the results of deep drilling and stratigraphic information, gravity, magnetic, and seismic data to develop a mode consistent with plate tectonic theory. Reference should be made to the accompanying maps and diagrams.

Ervin and McGinnis (1975) first suggested the presence of an upper crust feature which might represent a "rift". A rift is an elongate zone of gravity faults caused by tensional forces tending to pull apart the earth's crust. Ancient sedimentary rocks several hundred meters thick fill the rift (figure 14) and lie below the Mt. Simon Sandstone which generally rests on the Precambrian crystalline rocks over most of the Midwest. Thus, the rift seems to have been active in late Precambrian to early Paleozoic time.

Positive gravity and magnetic anomalies are found to be associated with the rift. Furthermore they seem to outline extensions, with their junction very nearly at the head of the Mississippi Embayment. These anomalies are interpreted as mafic igneous intrusions localized by the faults of the rift.

This ancient rift system failed to sunder the continent and apparently became inactive. However, the excess mass resulted in subsidence and a thicker accumulation of Paleozoic sediments than in the surrounding area. At the end of the Paleozoic Era and through most of the Mesozoic the continent was uplifted and the resulting interval of erosion has left no record.

By the mid-Mesozoic Era the margin of the continent was downwarping, and an embayment to the Coastal Plain extended northward along the axis of the ancient rift (figure 14). Perhaps the influence of the ancient rift may also be seen in the courses of the major rivers (Potter 1978). The lower Mississippi River follows the axis of the Reelfoot Rift (Mann and Thomas 1968), the modern mid-Mississippi River follows the St. Louis Arm, and the late Paleozoic Michigan River followed the Southern Indiana Arm. The writer suggests in a later section that the course of the Tennessee River may also have been "directed" to the triple junction of the rift.

Finally, in modern times the pattern of frequent earthquakes is focused along the arms of the rift complex. Perhaps they are due to the reactivation at depth of the faults of the rift complex. The focus of the quakes is several kilometers below surface. The stresses appear not to be similar to those which produced the shallower Paleozoic faulting which we can map in the rocks now exposed at the surface.

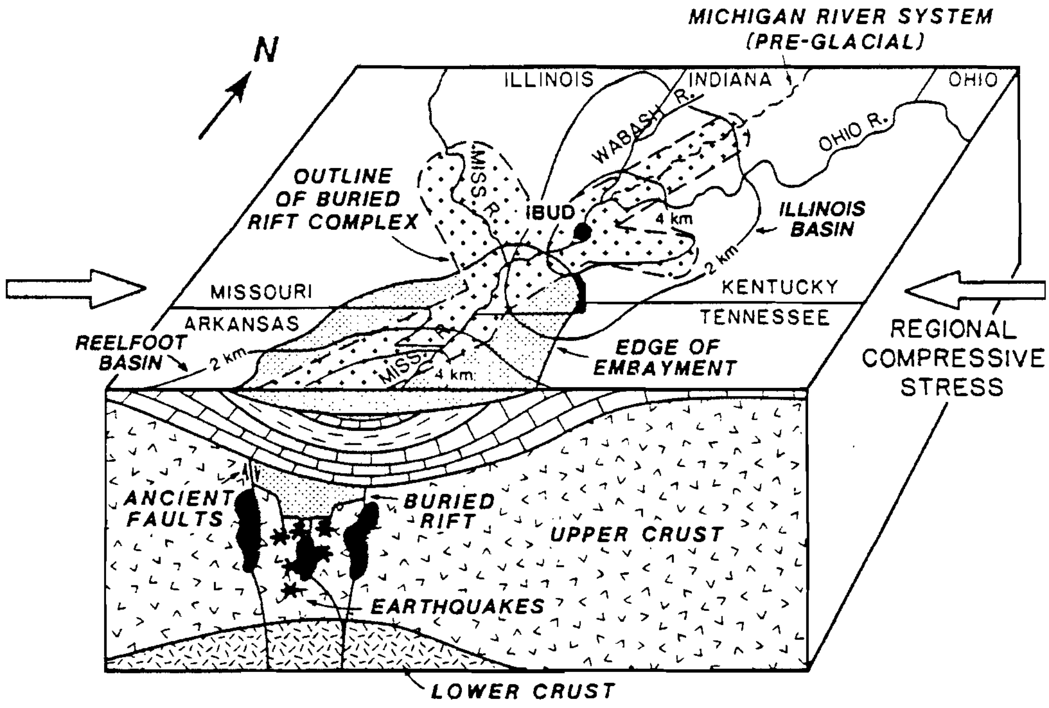


Figure 14. Schematic block diagram of the structure of the crystalline crust and Phanerozoic sedimentary beneath the Reelfoot Complex in the upper Mississippi Embayment and Illinois Basin (from IBUD 1987)

SOILS

Soil is the surface material of an area, the medium in which plants grow. It is the product of a number of on-going, interacting geologic and biologic processes. From the geologic viewpoint, soils are continually evolving, modified by every alteration of the many parameters which affect them. Cultural activities such as cutting of a forest and plowing of a prairie initiate changes which may be perceived in a few years and gradually evolve over decades.

Soils are commonly spoken of as "young", "mature", or "old." A young soil shows little evidence of the development of a soil profile, i.e. there is relatively little alteration of the parent material. An old soil has a strongly developed profile of several zones and subzones, commonly extending to a considerable depth. The lower weathered zones of such a soil grade into the parent material, but the near-surface zones have been completely altered. The changes are caused by chemical, biological, and physical processes. Young soils are generally found in recently deposited sediments such as alluvium, but may also occur where erosion has inhibited the development of a profile or has removed a profile. All soils are the result of a complex of "weathering" processes, but weathered materials are not considered, per se, to be soil. This brief consideration of soils is based on the "Soil survey of Lyon and Trigg counties, Kentucky" issued in May 1981. This is a valuable reference useful to everyone working in LBL. In a subsequent section, a discussion of soil morphology is related more closely to geology. A soil report and map for Stewart County, Tennessee was published in 1953 (Austin et al. 1953). It is very useful even though it is outdated.

The following section gives a brief description of the three mapping units of Lyon and Trigg counties. In addition, some of the main associated soil series are described. Two diagrammatic representations of the distribution patterns of some of the soil series are shown in figures 15 and 16.

Brandon-Lax

This unit includes the soils of the broad upland ridge extending the length of LBL. Lateral extensions occur on the broadest ridges between stream valleys.

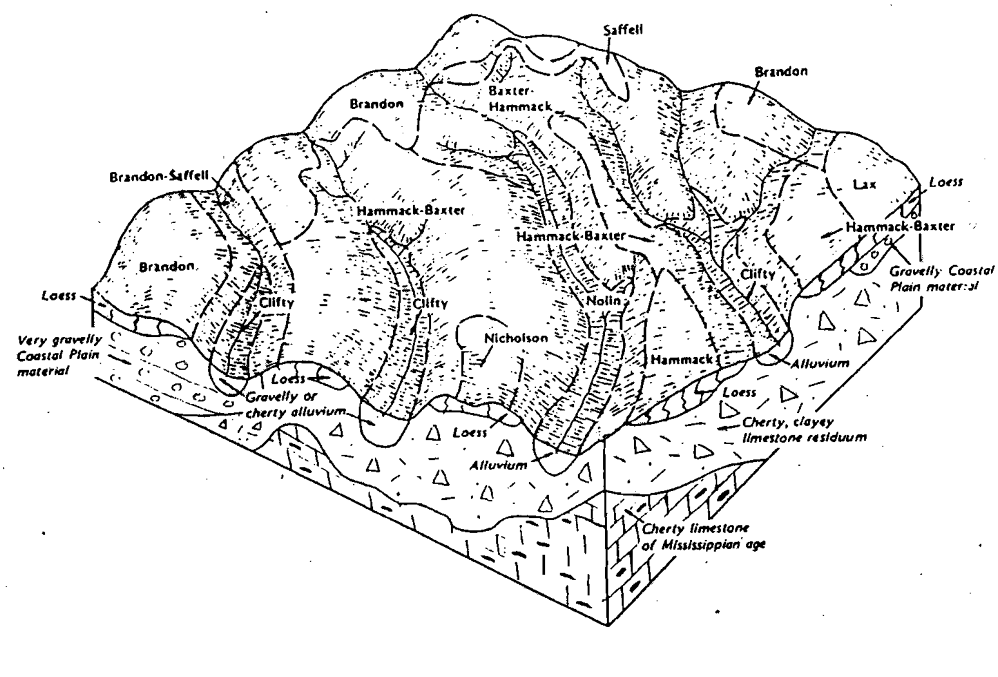


Figure 15. Typical pattern of soils and underlying material in the Baxter-Hammock-Brandon map unit (from Humphrey 1981)

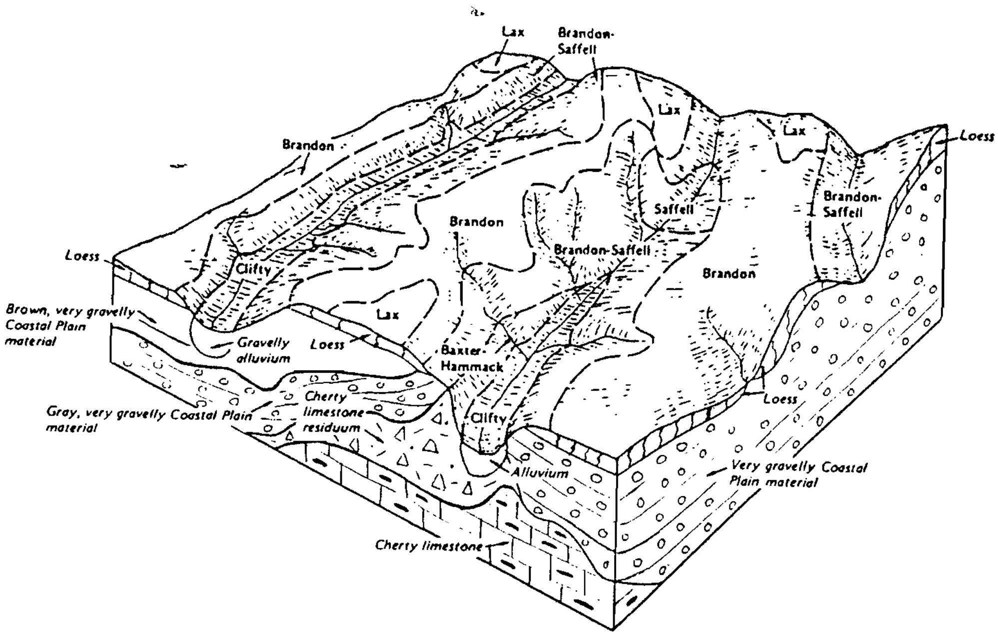


Figure 16. Typical pattern of soils and underlying material in the Brandon-Saffel map unit (from Humphrey 1981).

The Brandon soils are on the narrower ridges and upper side slopes. They are well drained. The surface layer is brown silty loam derived from the loess. The subsoil is moderately permeable and underlain by gravelly, loamy material, also permeable.

The Brandon series consists of four phases, all on sloping land; two are severely eroded. The soils are of medium natural fertility, but low in organic content. Tilth is good, the root zone deep, and water capacity high. However, reaction is strongly to very strongly acid, and the soil is subject to severe erosion.

The eroded phases have lost their A-horizon, so that the surface tends to be a silty clay loam with chert pebbles at or near the surface, especially on the steep slopes. In some places a surface crust inhibits the germination of seeds. Further, though roots may easily penetrate to depth, the parent materials are largely siliceous with little nutrient value.

Lax soils occupy the higher, broader ridge tops and the gentle side slopes. The parent loessal silt is thicker than in

Brandon soils. The surface layer is also a brown silt loam. The upper part of the Lax subsoil is a moderately permeable loam, but the lower part is a fragipan, only slowly permeable. Gravel, generally in a clayey matrix, lies beneath the subsoil.

Within the Brandon-Lax map unit are the headwaters of the streams which flow to the lakes. On the steep valley slopes Saffel, Baxter, and Hammock soils are present (see later sections). On bottomlands Clifty, Lindside, and Newark are present.

The parent materials of the associated bottomland soils are the sedimentary products of the erosion of the uplands. Characteristically these sediments are very gravelly where bottomlands are narrow and side slopes steep. This is the domain of the Clifty. Farther downstream the bottomlands are broader and gradient more gentle. During floods much gravel is carried along the channels and some is carried overbank. However, floodplains receive mainly the fine-grained material eroded from the uplands. This is largely silt from the loess, though clay and some very fine sand are present. As the channels shift their courses in the flood plain, a bottom layer dominated by gravel is formed. Above this the texture is dominantly silt. Sand may also be present where the Cretaceous and/or Quaternary formations occur on the upland. Nolin, Newark, and Lindside are developed in these floodplain sediments. They are soils most favorable for cultivation from the point of view of fertility, tilth, and drainage. All are subject to flooding which generally, but not always, occurs before planting season.

The Brandon-Lax complex provides the best upland soils. However, they are subject to severe erosion if not protected and carefully used.

Baxter-Hammock Complex

These are deep, well-drained upland soils on sloping to steep topography. They are formed in the residuum of cherty limestone. On less eroded surfaces a thin loess covers the residuum.

The Hammock soils are developed on narrow upland ridges. The surface soil is developed in loess while the upper part of the subsoil may also be a silty loam. Beneath this the soil is cherty and clayey, and only moderately permeable.

Baxter soils are on the steep side slopes. Even the surface is cherty loam, though silty because of the incorporation of transported loess. These profiles have poor profile development because weathering and erosion proceed at about the same rate.

Present in small areas in the appropriate geomorphic position are: Brandon, Saffel, Lax, and Nicholson soils on the upland and slopes. Clifty occurs in the headwater valley bottoms, while Nolin, Lindside, and Newark occur where gradient has decreased and the valley floor broadened.

Baxter soils are also found on knolls on narrow secondary ridges of the upland. Loess has been removed and the ground is very stony. This is the domain of the chestnut oak (*Quercus prinus*).

Brandon-Saffel

The Brandon-Saffel mapping unit consists of deep, well-drained soils on sloping to very steep slopes. It is developed in areas where gravelly materials of the Tuscaloosa or Pliocene-Pleistocene are present. Loess is the parent material at the surface on the ridge tops. Included within the mapped area are Lax soils on the flatter ridge tops and patches of the four bottomland soils in the valleys.

The Brandon and Saffel soils may form an intimate complex where the individual units occupy too small an area to be mapped on the scale of 1/20,000 used on the photo map base. In general the Brandon occurs on the less severely eroded north and east slopes. Saffel soils occupy the steeper and more exposed south and west slopes from which the "original" loess cover has been removed; transported loessal silts are present as part of the rather mobile soil.

The Brandon soils occupy the ridge crests and upper slopes where loess deposits remain. Their surface layer is brown silt loam about 20 cm thick. The upper loamy subsoil is moderately permeable on top of a yellowish or reddish more clayey zone to a depth of about 65 cm. Beneath this, much gravel is incorporated in a silty clay loam; sand may also be a constituent where available.

The Saffel typically has a 15 cm surface layer of gravelly silt loam, grayish brown above and more yellowish in the lower 12 cm. The subsoil may be up to 2 m thick composed of gravelly clayey silt. Some zonation is present. In some places gravel pebbles or cobbles are present at the surface, especially where erosion has been severe.

The gravels of this complex may be derived from either or both gravel bodies. Both soils on sloping topography are internally rather well drained. They are suited for woodlands and recreational (but not intensive) use. They are poorly suited for cultivation.

Bottomland soils

The bottomland soils have formed in alluvial sediments. These are derived from erosion of the upland; they consist of silty clay and siliceous fragments ranging in size from sand to boulders. Generally the surface material is silt loam, becoming more stony with depth.

The bottomland soils show much variation. They are classified into some eight units by the Soil Survey as shown on the soils map. They are all on rather level surfaces with slopes ranging from 0 to 3 degrees. Of course, flood plains are not truly level. Over-bank floods deposit sediment in the form of bars, and natural levees are deposited by over-bank flow; scour channels are also formed. Shifting of the channel leaves low areas on the inside of the bends. Here point bars accumulate and arcuate swales are left. Alluvial fans form at the edge of the bottomland where tributary ravines deposit debris. Side channels parallel to the main stream carry off run-off from the valley slopes and over-flow waters. In addition, higher segments of the bottomland may never, or rarely, flood because the modern channel has deepened.

Channel-ways, even at the headwaters, contain debris eroded from the steep upland slopes. Where the valley floor widens a little, the material is poorly sorted, consisting of silt, clay, sand, and chert pebbles and/or fragments. The name Clifty is applied to these very young soils. Horizon development is poor or absent. Clifty is mapped along the margins of the bottomlands where the steep valley slopes yield coarse debris.

Four soils are distinguished in close geographic association on the broader bottoms. They are deep soils with a silt loam surface layer, are subject to flooding, and have a rather high water table during wet seasons. They have relatively high natural fertility and are less acid than the upland soils. These soils differ in drainage and permeability and in the texture of the subsurface materials.

Of the four, Newark has the least profile development, and Melvin the lowest permeability, though water availability is high. The Lindside has high natural fertility and its acidity is near neutral; however, it may suffer from a high water table. The Nolin soil has a gravelly base, is well drained, and has a high natural fertility. It tends to occupy the midcourse of many waterways adjacent to the gravelly Clifty soil.

Bottomland soils are relatively young, with little horizon development. Sediments may be added or scoured as the result of flooding. In places, overflow from channels has deposited gravel and sand--even cobbles--onto the surface, making cultivation difficult.

It may seem odd, but in fact, soil of any given bottomland area is subject to more sudden and profound alteration than upland soils. Erosion adjacent to the main stream channel may scour away at a field year after year. Overflow from the channel causes both scour and deposition of sediment--sometimes cobbles. Close to the debouchers of ravines much coarse sediment may wash onto the lowland--and gullying may also occur during severe cloudbursts.

The establishment of the two great lakes drowned the lower portion of all valleys in LBL. Groundwater level was raised simultaneously. Similar effects have occurred upstream from the smaller impoundments. In Crooked Creek, beaver dams aggravate the problem, while the Ferguson Springs complex adds water year-around. The result has been formation of an extensive wetland.

Nevertheless, with all these hazards, bottomlands provide the most favorable sites for cultivation and pastures.

GEOMORPHOLOGY

Land Between The Lakes has a maturely-dissected topography with narrow ridge crests, steep slopes, and narrow bottomlands. This landscape has been etched mainly by the erosion of running water. The density of the valleys is due to the proximity of the two main through valleys formed by the Tennessee and Cumberland rivers. The dissection is in marked contrast to the Pennyroyal upland to the east. In addition to the processes associated with running-water-weathering, mass wasting and ground water action have played important roles in determining the aspect of the land. The filling of the lakes established a shoreline where waves and currents are now very active geomorphic agents.

Internal earth processes have determined the gross form of our setting. These have acted through many millions of years, but internal movements do not now seem to have an active geomorphic role. Land Between The Lakes is on the relatively stable continental craton. Yet continental warping has lowered or raised the region relative to sea level during the last 600 million years. Gentle warping produced the domes and basins shown on figure 3. In addition, LBL is on the periphery of the failed Reelfoot Rift, which is nevertheless responsible for the Mississippi Embayment and probably for the focus at Cairo of the major rivers of central U. S.

Climate

Climate is responsible, in large part, for the nature and intensity of geomorphic activity in a region. The climate at LBL is temperate continental. The latitude at the Kentucky-Tennessee state line is approximately 36^{o} 40′ N. Thus in the summer the sun is high in the sky but in winter it is rather low, even at noon. Average rainfall is 1173 mm per year, but the range for 1957-1986 was from a minimum of approximately 890 mm to a maximum of approximately 1600 mm (estimated from records at Louisville, Nashville, and Cairo).

Summers are generally hot and dry, even though total amounts of rainfall are as great in summer as in winter. Evaporation is so great in summer that streams and most springs cease to flow. July is the hottest month, with an average maximum daily temperature of 32.2°C. Thunderstorms occur at an average rate of 45-50 per year, and severe rains of 10 to 15 cm in a day may cause slope wash, scouring of waterways, and flooding. Winters are moderate, but leaves fall in October and emerge in late April; broad-leaved evergreens are not common in the wild. Several severe arctic storms penetrate the area in most winters. Temperatures of minus 17°C or below have been recorded. Nevertheless, mild intervals are the rule. Most precipitation during the winter months is in the form of rain. Stream flow increases because of low evaporation and little transpiration. The relatively permeable soils permit replenishment of groundwater, and percolation into the fractures and solution channels of the bedrock.

The effect of orientation of a slope to the sun's rays is significant. It is clearly reflected in the vegetational cover, the depth of soil, and the rate of erosion on the slopes. The south-facing slopes and north-facing slopes show striking contrasts in physical conditions and vegetation. South-facing slopes are subject to greater diurnal temperature changes and greater evaporation in all seasons. In summer the prevailing southwesterly winds may also be a factor. Erosion is particularly severe in the winter and spring. Freezing and thawing cause heaving of the silty loess or clay matrix of cherty soil. This lifts the surface materials during freezing and drops them downhill during thawing. Particles rest loosely and become subject to rain impact and slope wash. Alternate wetting and drying have similar effects, though not of the same magnitude. Loose particles and fragments on steep slopes are also subject to gravity sliding when wet or impacted by the weight of a falling branch or passing animal.

Erosion is less rapid on north-facing slopes, as is indicated by the fact that loess is generally still present. Freezing and thawing are much less frequent during winter, and moisture is retained longer during the summer. Vegetation clearly reflects these more favorable conditions.

Weathering

Physical processes of weathering are most evident in winter and spring. Alternation of wetting and drying of silts and clays cause expansion and contraction. The resulting cracks allow entrance of air and water. Under colder conditions freezing and thawing have similar effects. Frost heaving exposes plant rootlets and may cause them considerable damage.

Roots of trees penetrate fractures and bedding planes of the rocks. Growth pressures may expand the fractures and cause additional breakage, and open up passageways for air and water. Tree roots do have a stabilizing effect on slopes and stream banks.

Chemical weathering is of major importance because the bedrock is dominantly carbonate rock. Rainwater penetrating the soil causes solution of the rock, while acids derived from decay of organic matter increase the rate of solution. Since the limestone is dense, solution is concentrated on the rock surfaces, and along fractures and bedding planes. Solution is most rapid near the ground surface. However, large solution channels were encountered in drilling and excavations for the foundations of Kentucky and Barkley dams (Tennessee Valley Authority 1951). The extent and interconnection of the channels is indicated by the tremendous volume of grout required to seal them.

Leaching of the limestone leaves a residue of the insoluble materials. Chert and/or argillaceous material are abundant constituents of the St. Louis and Ft. Payne formations, and in parts of the Warsaw. The very pure carbonate zones of these formations yield very little soil-forming substance.

Residuum is very thick in some parts of LBL. It represents a very long period of weathering. The writer has not learned the relationship of this residuum to the Cretaceous deposits; it is possible that the residuum partly antedates Tuscaloosa deposition.

Three types of chert material veneer the hills of LBL. On the broader ridge crests loess forms the cover, but on most slopes cherty material is exposed. The Tuscaloosa and brown gravels are in the form of pebbles, with sand of chert or quartz composition. Residual chert is more angular and ranges in character from dense-nodular and porcelaneous to porous-tripolitic-grainy. The latter disintegrates to small pebbles, sand, and silty fragments.

Mass Wasting

Mass wasting includes a wide range of manifestations of downslope movements caused by the pull of gravity. The more obvious, such as landslides, are known here only as the result of human action. Slumps may be seen in roadcuts along the Trace and at the lake shores; both are due to oversteepening of the equilibrium slope. Small slumps are visible on the banks of streams, especially on the outsides of bends where scouring occurs.

Downslope movement on steep slopes is significant in the slow degradation of the landscape. On many slopes, especially those underlain by residuum, loose cherty fragments rest at or near the angle of repose. Lichens, moss, and scattered plants are present, but fragments roll and slide repeatedly. They accumulate above the boles of trees or other obstructions. Twigs and branches also lie against the uphill side of trees. (When fires sweep the woods floor, severe burns at the base of the trunk may be caused by firing of this accumulation.) A very large volume of material is moved every year by this process, especially during late winter and early spring.

No doubt rain impact and drip from trees also moves fine material downslope. This process is especially severe on bare (particularly cultivated) slopes at times of heavy rain.

Overland Flow

Rainfall on the uplands and hill slopes tends to infiltrate the organic cover and the soil. Run-off occurs only after the surface pores become saturated. If the ground is very permeable, surface run-off is infrequent, but in tight soils run-off may be almost immediate even during a moderate rain. A permeable soil ultimately results in 1) more seepage downslope at some impermeable zone or along the valley bottom, and 2) more springs. Clearly, then, soil porosity and permeability affect both surface run-off and groundwater recharge.

Overland flow is generally a film of water moving without turbulence; the water may be essentially clear. On bare soil raindrop impact causes splash which raises loose particles. The particles fall into the moving film of water causing "sheet wash". Even if there is no water film, raindrop impact causes spatter which displaces particles of soil and organic matter. The result is a shifting of material downslope.

As a film of water moves downslope it gathers volume and velocity until turbulence is initiated. The water begins to concentrate into linear flow lines. In a cultivated field this may be seen in the formation of small, closely-spaced rills, which coalesce farther downslope into gullies. This process is much less obvious on a grassy slope or a woods floor; the erosional process there is very much slower.

In LBL the ridges are dissected by closely-spaced valleys and ravines. The upper ridge slopes may show no sign of concentrated flow, though they are commonly steep. However, as one walks downslope, amphitheater-like topographic forms appear, generally without any waterway. Farther downslope run-off has been concentrated along a linear trend; eventually a definite waterway appears. Most waterways are then marked by a definite channel. Commonly, the head of the channel is a gully marked by a low, retreating waterfall. In some cases the gully reveals the first large bedrock fragments, though in LBL bedrock is rarely exposed at this upland elevation.

Discontinuous Gullies

The retreat of discontinuous gullies is, perhaps, the most active (or most obvious) erosional process within LBL. Discontinuous gullies are present in the upper reaches of most waterways. These features are paired in that they consist of both a retreating waterfall and gully, and a deposit of the eroded material. A succession of more than a single pair may occur.

The waterfall is not the result of a resistant ledge impeding the deepening process. Rather here the waterfall is incising unconsolidated sediment or residuum. Retreat of the fall produces a gully generally narrow, straight, and up to a meter deep. It may be only a few meters long, followed by a deposit in the form of an elongate alluvial fan occupying the floor of the waterway. The deposit is composed of material eroded from the collapsing fall, and debris from the gully sides. A little farther down-valley another falls and gully may be dissecting this deposit.

This tandem feature may be analogous to the scour and riffle (or bar) sequence characteristic of larger stream channels. Sediment is transported down-valley, but there is some question whether the valley is actually deepened. In fact, it may be a process of dynamic equilibrium. Material from the hillsides, which has reached the waterway through mass wasting, slope wash, and gullying, is removed, but without incremental deepening of the valley.

Stream Channels

In LBL, flow of water is intermittent in the stream channels. Drainage basins are too small to retain enough water to maintain year-around flow. In the wet seasons, when rains fall on saturated earth, floods overflow the channel banks onto the floodplains. Even low-order waterways carry a good flow from late fall to early summer.

Occasionally, heavy rains fall on frozen ground. The immediate run-off results in flooded stream channels and transport of great quantities of gravel. Some gravel is carried over-bank onto the floodplain. Some piles up against obstructions such as logs, culverts, and bridges. Stream beds are scoured and gravel bars shifted; at decline of the flood the gravel bars may be re-established in the same places.

As summer progresses the small waterways dry up. In most years, even in the larger drainage basins, there is no surface flow by early fall. Periodically there are long droughts, when rainfall is insufficient to cause run-off. Ground water no longer yields springs or seeps. Droughts may occur at any time of the year, though they are most frequent in the warm seasons.

The typical channel has a bedload of chert gravel and sand. In the larger valleys the channel has eroded from one to a few meters below flood plain level. The banks are steep, and scouring exposes the typical floodplain sequence. Rocky sediment is at the base, covered by finer layers of sand and silt. The bed of the channel varies in character depending on the material brought to it.

At the bridge to The Home Place the channel of Prior Creek has a large bedload of coarse debris up to cobble size, occupying essentially the entire visible reach of the stream. In other channels, such as Crooked Creek, where bedload is not quite so great, the alternation of scour and riffle, or pool and gravel bar, is characteristic. Even when surface flow is not apparent, base flow may be present. The coarse gravel allows percolation of water through the pore spaces. Sometimes this can be seen if the downstream end of a bar is disturbed; clear water flows out of the gravel into the muddied pool.

The gravel bed of a stream serves as a filter. Muddy water after a storm percolates through the gravel bars which filter out the fine suspended sediment; the water soon becomes clear. The filter system is constantly reactivated. During floods, part of the filled portion of a gravel bar is scoured and eroded. Loose gravel accumulates on the downstream end of the next bar and the filter is rejuvenated.

Wherever the bottom of a valley becomes wide enough to include more than the main channel, secondary channels also form (see figure 17). Such channels form 1) to carry flood waters back to the main channel and 2) to carry run-off from hillslopes and ravines on the opposite side of the valley from the main channel.

When flood waters overflow the banks of the main channel, sediment, even of cobble size, is quickly dropped. Deposition occurs because velocity and volume decrease, and the carrying capacity of the water is suddenly reduced. Flood waters cannot return immediately to the channel because of the previously-formed natural levee. Water flows down the floodplain, generally to a place where the main channel impinges against the valley slope. The water may move in a sheet at first, but soon flow concentrates into a channel. This channel also carries away local rainfall.

Such a floodplain channel commonly joins a channel of the second type, which tends to develop parallel and close to the valley slope. The size of such a channel is determined by its length before joining the main channel and by the amount of water it carries.

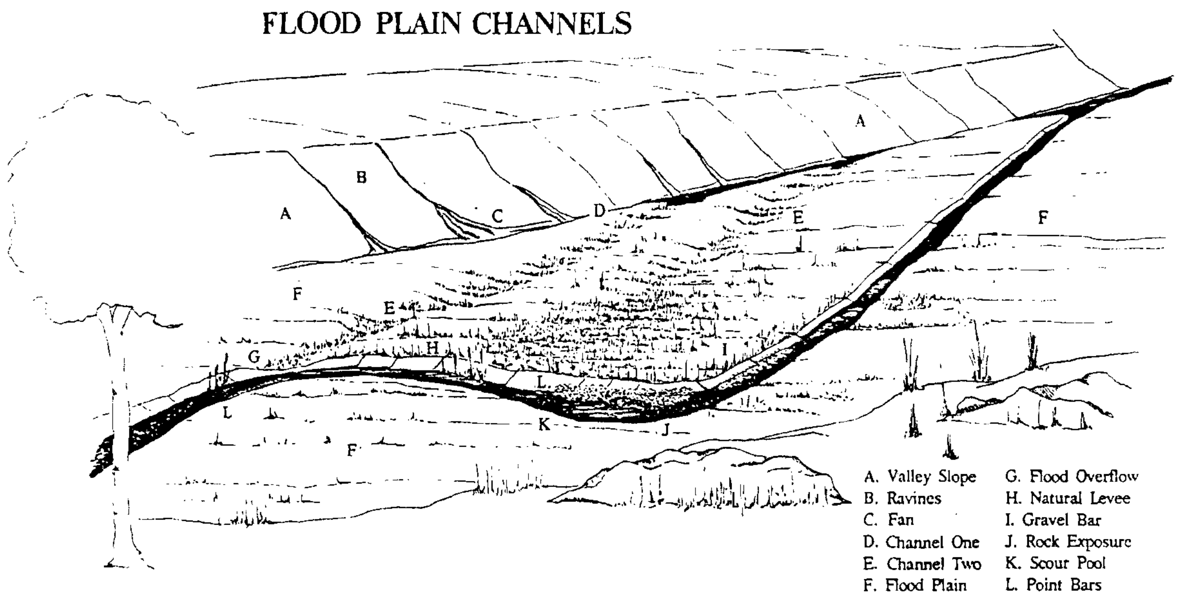


Figure 17. Diagrammatic representation of a floodplain, showing main and secondary channels

In valleys with steep gradients, but with a narrow floodplain, overflow is frequent and secondary channels may be gully-like. A retreating waterfall may develop at the head of such a channel. Apparently, the present regimen in LBL is such that much bottomland sediment is being removed. The main channels have active gravel bars, and seem to be widening. Erosion against the valley slopes and across the mouths of tributaries is also causing deepening of the tributary channels.

Depositional Fans

Large depositional fans are an interesting feature of many of the larger tributary valleys. The fan is located at the junction of a higher-order valley. At the head of the fan the channel becomes shallow. Overflow waters carry abundant debris onto the fan. Rock slabs may be seen resting against the trunks of trees on the fan. Shallow waterways marked with freshly deposited sand and gravel may bifurcate at some obstruction. The fan is a depositional surface, and channels tend to form, and then be abandoned when filled with sediment. A small main channel may persist across the fan.

At the lower ends of some fans, gullies are working headward into the fan. Erosion of the lower end of the fan is most marked if the higher-order stream channel happens to be meandering against the fan. Some rather casual observations suggest that the fans have especially favorable growing conditions.

Sediment Train

Every stream system in LBL contains a train of sediment. This train begins near the head of every waterway and extends downstream to one of the lakes. Some small percent of this sediment is present in the stream channel, where it is subject to transport at every high water. The remainder of the sediment train is temporarily stationary, forming the floodplains and terraces in the lower course, and the narrow bottomlands upstream. At each storm some small amount of this sediment is loosened and enters the channel; some additional debris enters from the upland slopes. An approximately equivalent amount is carried out of the channel, either onto the floodplain, or downstream into the lake where it may form a delta. Most stream systems maintain a dynamic equilibrium, though this means that the upland is gradually being worn away and the lake is gradually being filled. At a river's mouth this process is rapid enough to be observed and measured in a few years' time.

In LBL most of the sediment is siliceous. The coarse material is dominantly 1) rounded chert pebbles derived from the two gravel bodies on the upland and 2) more angular chert derived from the weathered cherty limestone bedrock. Limestone fragments may be found just downstream from a bedrock outcrop, where a channel impinges against the valley side. Generally, limestone fragments soon disappear, due to abrasion and solution.

Quartz pebbles can be found in the sediment of valleys which head in the outcrops of the Lafayette (of former usage) gravel of Tertiary-Quaternary age.

Sand-sized sediment is abundant. Chert grains are derived from the Tuscaloosa and the bedrock residuum, and quartz grains are derived both from the Lafayette and the McNairy formations.

Silt particles are probably derived from all formations, but the loess is probably the main source. These, too, are largely quartz.

The clays are derived from all formations and are of diverse mineralogic composition. Some of the bottomland sediments contain considerable clay, especially in the subsurface of the soil. Channel-scour exposures show abundant clay as part of the filling of the gravel interstices.

Ground Water

Many springs and seeps are present in LBL. Most appear to be seasonal, although two or three had maintained a good flow even after the rather dry summer of 1987. The limestone terrain stores considerable water during the rainy season. This ground water is released slowly, provides clear water, and extends the period of stream flow. However, the drainage basins are small, and the storage capacity of the uplands not very large. As the growing season progresses, evaporation and transpiration exceed rainfall. Ground water is not recharged, so seepage and flow from springs decline. By midsummer ground water makes little or no contribution to stream flow.

The springs on Panther Creek, near the southwest corner of LBL, yielded an excellent flow of water in October of 1987. A scum with iridescent colors was observed just downstream. It suggested oil, but the scum fragmented when poked, and hence was more likely due to iron bacteria. Limestone is exposed close by. It is possible that the water is derived from some depth, perhaps along a fault zone.

Underflow of water through the gravels in stream channels is considerable; perhaps also beneath the entire flood plain. In October of 1987, water was noted emerging from the base of gravel bars into scour-channel pools of Crooked Creek. No measurements were taken.

The limestone bedrock is subject to solution along fractures and bedding planes. Since few bedrock exposures exist, the extent and effect are not readily observable. However, springs and seeps in every valley offer a clue to the extensive ground water network which must exist. Exposures of the bedrock along the shoreline of the lakes offer the best view of the "honeycombed" nature of the bedrock. Solution is most extensive near the bedrock surface, and at a higher elevation than the bedrock floor of the adjacent valleys. Slowly, moving groundwater may sink beneath the upland to depths far beneath the valley floors, then rise and emerge in the valleys. The intricate, interconnected labyrinth of solution openings is clearly shown in the records of drilling and excavation for the dam foundations (see figure 18).

Nevertheless, caves and caverns are unknown, and sinkholes are uncommon in LBL. This seems strange because in many areas the St. Louis limestone is famous for these features. Their absence in LBL is probably due to two factors: 1) much of the upland has a cover of unconsolidated sediment and/or a thick accumulation of residuum and 2) the proximity of the two large valleys and the resulting dissected nature of the area. In the former case the sediment and residuum inhibit the flow of groundwater, and in the latter case surface run-off is rapid; much less water circulates underground than in the Pennyroyal plain to the east. Stearns (personal communication) suggests that there may have been insufficient uplift to expose caverns above the deeper, water-filled cavities.

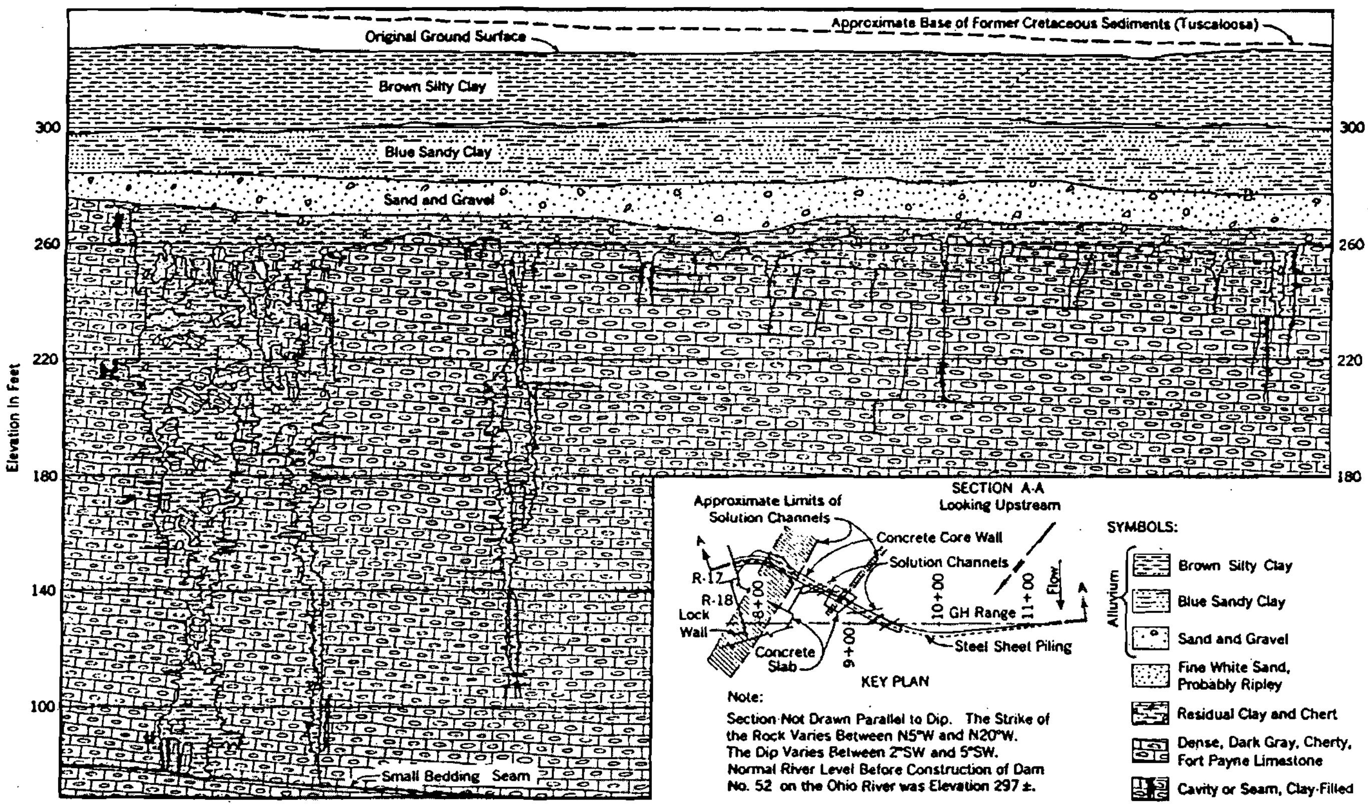


Figure 18. Geologic section under east embankment of Kentucky Lake dam, showing deep solution channels adjacent to the locks (from Tennessee Valley Authority 1951)

Lake Shorelines

Shorelines are undergoing the most rapid geomorphic changes in the LBL landscape. The lakes have been set onto a topography which had been formed mainly by the work of running water. The two master streams had cut deep valleys, with many short tributaries which had steep gradients. That topography is being rapidly modified at and near lake level.

Kentucky Lake was first impounded during the 1940s. Subsequently Barkley Dam was completed and its lake filled by 1966. A canal connects the two lakes near Grand Rivers, so the "normal" pool level is the same for both lakes--at 109.4 m A.T. However, water level is modified for flood control and for equalizing flow of the Ohio River. Water level is lowered during late summer to provide storage capacity against probable high waters on the Ohio River in late winter and spring. Low water in winter is also desirable to minimize wave erosion caused by winter storms with strong winds from the northwest. Water level is allowed to rise during late spring, and generally reaches a maximum in summer.

The floodplains and channels of both the Tennessee and Cumberland rivers are submerged. The lower reaches of all tributaries are "drowned", resulting in a succession of bays. The interfluves are now headlands more exposed to wave and current action than are the bays.

Headlands

The headlands have suffered a great deal of erosion. The resulting bluffs differ, depending on the steepness and elevation of the interfluve and the nature of the bedrock and overburden. All headlands have an erosional bluff. Some are cliffed with cherty limestone bedrock. The rock may be bedrock in place, or consist of many large, loose blocks which have been exposed by removal of soil and regolith. In other places neither bedrock nor large blocks are exposed.

The regolith forms bluffs 3-6 m high on the Kentucky Lake shore. A good example is at the east end of the U. S. Hwy. 68 bridge across Kentucky Lake. The regolith is a dense mass of unstratified material. It somewhat resembles glacial till, but all the material is of local origin. It consists of a heterogeneous mix of cherty fragments residual from the bedrock, and rounded pebbles and cobbles from the overlying gravels--these enclosed in a matrix of clay, silt and sand. This heterogeneous debris has been subject to downhill creep from the time the major rivers incised their valleys and the mature topography of LBL was initiated. The debris covering the slopes has been in dynamic equilibrium. Movement is slow and vegetation is a stabilizing element.

The advent of lake waters against the slopes brought new conditions and processes which are making profound changes. Wave action is undercutting the slopes, removing material, and forming bluffs. The stabilizing trees and their root masses collapse, and ground cover of small plants, mosses, and lichens is carried away. Ground water has risen, increasing pore pressure and decreasing friction. Slumps of the oversteepened slopes result. The hillslopes above the wave-cut bluffs have been little affected, so far. Active movement on the original slope is apparent, but probably in the same way as before lake shore action began.

Wave action against the debris easily causes disintegration of the unconsolidated material. The fines are taken into suspension and carried to deeper water. Coarser sands are also removed from the shore front, while pebbles, cobbles, and boulders remain to form a coarse shingle beach.

Beaches

The abundance of coarse fragments has resulted in rapid development of the beaches. When water level is low the beach protects the bluff against further wave erosion. However, at high water level most of the gravel beach is submerged, and storm waves pound against the bluff debris, releasing more sediment. Longshore currents are formed when wind and waves strike the shore at an angle. Even cobble-sized fragments are transported. Breaking waves shift material diagonally, then returning water carries material directly downslope off the beach. A considerable lateral movement may occur in a single storm. Transport direction reverses with change in wind direction, but the prevailing storm waves and currents result in dominantly southward movement. Thus, the beaches extend outward in spits and bay-mouth bars. Some shallow bays are completely shut off from the lake, though water may migrate through the bar.

Beaches of reddish-brown sand are present in places on Kentucky Lake shores. The writer has not learned the source of this sand. Birmingham Point geologic map shows sand veneering the topography in the area, similar to a mantle of loess. However, the beach sand seems to be too coarse for such an origin. The beach sand looks like the Cretaceous McNairy. It might be from a Pleistocene slackwater lake terrace. The sandy beaches will persist as long as a source remains.

Bays

Bays occur in the mouth of every stream valley. This is because tributaries have eroded to the depth of the master streams. The length of a bay depends, then, on the extent to which the tributary had deepened its valley in its lower reaches before impoundment of the two large lakes. Width of the bay likewise depends on the width of the drowned valley.

All valleys a kilometer or more in length had a flood plain and a relatively wide valley floor. Lake waters now cover only the lower end of the flood plain, so a valley flat lies at the head of every bay.

The bays, like the headlands, are undergoing rapid change. However, they are receiving sediment rather than suffering erosion. The sediment is derived from two directions: 1) from streams at the head of the bay and 2) from longshore transport of sediment eroded from the headlands.

Sediment from Streams

The streams transport a great deal of sediment. The coarse, cherty bedload is most obvious, but large quantities of finer material are also transported. When fast-flowing, sediment-laden streams reach the bay, velocity is suddenly reduced. Sediment is deposited. The coarser material is dropped immediately; the finer particles are carried farther, settling out farther into the bay, or even out into the lake. Air photos show plumes of cloudy water originating at the bay heads and at the mouths of ravines entering bays. These deposits are a form of delta. Fluctuations of lake level modify the form so that the appearance is not comparable to that in a textbook example. Coarse gravels are spread farther out into the bays at times of low water than would be true if "normal" pool were maintained. At high water, fine-grained sediment covers the more distant gravels. At low water, mud flats may be extensive. These muds seem very dark considering the source material. They bear study for composition and content.

PHYSIOGRAPHIC HISTORY

Traditional physiography is a study of the modern landscape, and the evolutionary history which produced it. William Morris Davis (1954) nearly 100 years ago identified four major elements determining the character of a landscape:

Materials and structure--rocks and soils and their arrangement

Climate--past as well as present

Processes--both internal and external

Time--particularly the length of time during which given conditions have persisted so as to permit physical and chemical alterations, such as development of a soil profile.

River Systems of Central U. S.

The focus of river drainage at the Mississippi-Ohio confluence is both striking and puzzling. See the physiographic map of the U. S. (figure 5). At first sight the northern rivers seem to follow obvious routes: 1) Missouri River and its tributaries originating in the Rocky Mountains and flowing generally eastward across the high plains to the structural and topographical low of the Mississippi Embayment, 2) the upper and mid-Mississippi River, also flowing toward the embayment and entering it along the east flank of the Ozarks, to the west of the resistant Pennsylvanian sandstones (Harris 1979), and 3) the Ohio River extending westward from the Appalachians, with its tributaries from north and south, to the embayment where it joins the Mississippi River.

This picture is deceiving, but this is not the place to review the physiographic literature of the river systems of central U. S. Suffice it to say that preglacial drainage of northern U. S. was quite different from modern drainage. The upper Missouri River flowed northward into Canada, and the Ohio River Valley, as we know it, existed only west of Louisville, Kentucky.

A master stream did exist from north to south along the east flank of the Ozarks. However, the major drainage way from the Allegheny Plateau was the ancient Teays, now filled and buried with glacial deposits (Horberg 1945). It extended from southeastern Ohio, across central Indiana and Illinois north of the resistant Pennsylvanian sandstones (Harris 1979), to what is now the Illinois River Valley where it joined the ancestral Mississippi. The Cumberland and Tennessee rivers joined the ancestral Mississippi at the head of the embayment; the Ohio was only a minor tributary. Glaciation did not directly affect the Tennessee and Cumberland rivers.

Cumberland Valley

The course of the Cumberland River is very ancient. Its headwaters flow westerly from the Appalachians, but a southwesterly trend carries it into the Nashville Basin--the basin eroded from the center of the structural Nashville Dome. It leaves the basin plunging into and through the resistant escarpment of the Highland Rim. From there the Cumberland River takes a northerly course toward the head of the embayment. The Cumberland River at LBL lies on the east side of the Tuscaloosa gravels. The gravels are resistant to erosion so that the lower course of the Cumberland may have formed to the east of them. The valley gradually approaches that of the Tennessee River, but their valleys do not quite join before their confluences with the Ohio River.

Tennessee Valley

The course of the Tennessee Valley takes a much more complex route. It originates in the Smokies, and follows the Appalachian Mountains southwestward as if headed for the Gulf of Mexico. Its course follows an anomalous route, turning westward around the south end of the Interior Low Plateaus, and then sharply northward along the west side of the Nashville Dome. In this report we are concerned only with this latter segment.

Paleozoic and Mesozoic periods

During the Paleozoic Era central U. S. was dominated by extensive inland seas. Highlands of the Canadian Shield and the proto-Appalachians were distant during the early and middle Paleozoic. Their fragmental erosion products did not reach what is now the Interior Low Plateau. However, vast accumulations of ex-solutional sediments were deposited. The Mississippian sediments in LBL are a small segment. The Appalachian system was growing westward, presumably under stresses against the east side of the North American continental plate. Through the late Paleozoic Era the southern Appalachian Mountains trended westerly through Alabama and Mississippi. The system may have continued westward to join the Ouachitas of Arkansas. A stable shelf with sedimentation basins of the craton lay to the north in what is now East Central U. S. River systems drained into this center from south, east, and north. Broad coastal plains were marked by a number of great deltas (see Potter 1978).

At the end of the Paleozoic Era the craton was raised above sea level. The rivers from the Appalachians extended their trends downslope. Some 1500 m of sediment were eroded from what is now the Interior Low Plateaus and the Central Interior Lowlands.

Mann and Thomas (1968) have shown that the Mississippi Embayment had begun to form by the Jurassic Period; they postulated an ancient Mississippi River flowing to it. It now appears that by mid-Cretaceous the region was affected by tensional forces which re-activated the Reelfoot Rift so as to form a north-south downwarp. The seas advanced in a broad embayment. They spread across the beveled Paleozoic bedrock onto the flanks of the Nashville-Cincinnati Arch on the east and the Ozark Dome on the west.

When the downwarp began, the Ozark and the Nashville domes were connected by the Pascola Arch. The earliest Cretaceous deposit in this region is the Tuscaloosa gravel, remnants of which are present in LBL on the ridges. The gravel is a terrestrial deposit formed by coalescing alluvial fans. The gravels were carried eastward from the Pascola Arch and laid down at the edge of the advancing sea. East of LBL, on the flanks of the Highland Rim, remnants of the Tuscaloosa Formation are finer grained and appear to be shallow marine in origin (Marcher and Stearns 1962).

Soon afterward the Pascola Arch (over the Reelfoot Rift) subsided, and later Cretaceous and early Tertiary marine and deltaic deposits extended into western Kentucky and southern Illinois. The ultimate extent of the coastal deposits is unknown. Some isolated remnants are found along the Ohio and Mississippi valleys; others, more numerous, occur on the flanks of the Ozarks and the Highland Rim.

Confluence of the Rivers

The confluence of rivers of Central U. S. is at the head of the Coastal Plain Embayment. From the viewpoint of physiographic history it is more appropriate to refer to the confluence of the Mississippi-Tennessee-Cumberland than to the Mississippi-Ohio, since the Ohio River dates only from the Pleistocene. This confluence lies at the ancient structural junction where the north-south trend of the New Madrid Rift System appears to split into two arms. The Southwestern Indiana Arm extends to the northeast and the St. Louis Arm to the northwest.

It seems to the writer that this structural zone has been a centripetal focus of river drainage, perhaps since before the end of the Paleozoic Era. The major drainage lines from the Appalachians have persisted: 1) an "ancestral" Tennessee flowed northward along the west flank of the Nashville Dome, 2) an ancestral Cumberland and "Teays" flowed westward, and 3) an ancestral Mississippi River flowed southward from the Canadian Shield.

During the latter part of the Tertiary Epoch, the seas of the Mississippi Embayment withdrew toward the Gulf of Mexico. The Coastal Plain developed an integrated drainage system of rivers. However, the trend of the Tennessee River had been established and it remained near the contact of the Paleozoic formations with those of the Coastal Plain. Only a few enigmatic sediments exist to represent this interval.

Lafayette or Tertiary-Quaternary gravels

Then, a rather remarkable sheet-gravel deposit covered the Tertiary topography of the lower Tennessee Valley. Brown chert gravel spread across the entire Jackson Purchase of Kentucky. Similar, though less extensive, gravels are known in other valleys of Kentucky, the upper Mississippi Valley, and on Crowley's Ridge in the lower Mississippi Valley. The gravels are derived from the Paleozoic cherty limestone formations of the Interior Plateaus and Interior Lowlands.

Release of such a flood of gravel may have been caused by a climatic change or regional warping. The source of the gravel was a very thick residuum much like that found in some parts of LBL. Much fine material was released at the same time and not all was carried away, because the gravels contain interstitial fillings of clay, silt, and sand; sandy layers are also present. The gravels eroded from the upland were deposited in the lowlands.

The work of Paul Potter (1955) shows that the gravels were deposited across the entire upland surface of the Jackson Purchase of Kentucky. Sedimentational features show a curving depositional trend from the Tennessee River to the Mississippi Valley (figure 11).

Pleistocene

Soon thereafter the regimen was again reversed, due to some combination of climatic change, sea level change, or perhaps structural movement. In any case rivers and streams eroded through this gravel mantle. The Cumberland River seems to have established its position at the eastern margin of the gravel body, while the Tennessee River deepened its valley a short distance to the west. Both rivers flowed northward to the Shawnee Hills of southern Illinois where they turned westward to the Mississippi.

Near the confluence of the two rivers with the Ohio the map (figure 5) shows two large, parallel, east-west valleys. The southern valley is occupied today by the Ohio-Cumberland-Tennessee rivers. Just to the north lies an abandoned valley of similar size; it is known as the Cache-Bay Creek Lowland. It continues to be an overflow route during major Ohio River floods (as in 1927 and 1937). This valley has a fill of glacial valley train sediments extending to a depth of 60 m. The physiographic history of the formation and occupancy of the two valleys is uncertain. Some physiographers think that the Cache is the older valley, once occupied by the Cumberland, Tennessee, and "Ohio" drainage west of Louisville. Others believe that the Tennessee, and perhaps the Cumberland, have "always" occupied their present position; the Ohio did not join them until its full glacial meltwater flow was attained. According to this view valley train aggradation raised the valley floor until the meltwaters overflowed into the lower Tennessee Valley. Presently, insufficient data have been assembled to determine the history.

Pleistocene glaciers did not reach the drainage basins of the Cumberland and Tennessee valleys. The region was probably affected by climatic changes as the glaciers waxed and waned. The lower ends of the valleys were ponded by aggradation of the late glacial floods of sediments on the Ohio and Mississippi rivers. The legacy is the veneer of silty loesses mantling the upland.

The last event is the intervention of man, the building of dams, and formation of the lakes.

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History of Land Between The Lakes

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ABSTRACT

This study provides a general overview of the history of the people in the southern part of the region between the lower Tennessee and Cumberland rivers, from the prehistoric period to the time when the Tennessee Valley Authority purchased the land and removed the people. A general chronological outline is followed, summarizing major events and providing a general analysis of the economic, social, and cultural activities which affected growth and development in the area. This study focuses on the history of the southern part of the land between the rivers (as the area was known in the days before Land Between The Lakes) although some events affecting the entire area are discussed in order to clarify events in the southern region. In particular, the period of time during which the Tennessee Valley Authority acquired the land is emphasized.

THE PREHISTORIC ERA

Prior to European colonization, three different cultural groups of Native Americans inhabited the land between the rivers area. The most ancient of these cultures, the Archaic, lived in the river area from about 5000 to 500 B.C. Very little evidence is left to indicate how these people lived.[1] Succeeding the Archaic Culture was the Woodland Culture, or "Mound Builders", who lived in the region from about 500 B.C. to 1200 A.D. This group built many ceremonial mounds, which are still found throughout the region.[2] Indians who lived or hunted in the area from 1200 to 1600 A.D. belonged to the Mississippian Culture. They were present as European explorers moved into the area and took control.[3]

PRE-SETTLEMENT EUROPEAN PERIOD

Recorded history of the region began with the Spanish explorers, who came as early as 1540. Seeking gold, some of these explorers led expeditions into areas adjacent to the land between the rivers. Explorer Juan Pardo, for example, led a group of treasure hunters into the Cumberland River region as early as 1566 or 1567. As these early explorers searched for riches they developed an extensive fur trade with the Indians. When it became apparent that there was no gold to be found, the Spanish established trading posts in the South, and traded with the Indians who lived in the Tennessee and Cumberland river region.[4]

Unlike the Spanish, who were interested primarily in gold, French explorers came to the river area eager to obtain furs from the Indians. French trading posts were established on the Tennessee and Cumberland Rivers as early as 1692. In the early years, Indians and whites maintained a cordial relationship. This soon deteriorated; in less than fifty years open hostility was common. One well-documented incident illustrates this: Antoine Bonnefey and Martin Chartier (the latter married to a Shawnee woman) were trading with Indians on the Cumberland River in 1741. By this time most of the Indians were hostile to outsiders, and when Bonnefey and a group of hunters and traders came into contact with a group of Cherokee they were attacked. Only Bonnefey was able to escape and find his way to a French fort at the present site of Montgomery, Alabama.[5]

EARLY EUROPEAN SETTLEMENTS

England was the last of the major European powers to come into contact with the Indians in the land between the rivers. Although last, English contact was the most influential; permanent settlers were primarily English and the original English names of places are often still used today. After the London Company received a charter from James I in 1606, and Charles II granted lands to a group of his supporters in 1663, English traders established contact with the Indians in the land between the rivers.[6] The first of the English settlers came into the region, cleared small plots of land, and built cabins. Evidently they did not remain long; settlers who arrived in the 1770's found remains of cabins, but no people. Curiously, they could find no evidence indicating the reason or time that the first English settlers left the area. One theory is that these people were the "cutting edge" of the English westward migration, settling an area for a few years and then moving further into the wilderness.[7]

In 1748, Englishman Thomas Walker of Virginia, with a company of hunters and fur traders, made an expedition to the west. Upon reaching a river that had been known to the Indians as the Shawnee or Louisa, Walker renamed it the "Cumberland", in honor of the Duke of Cumberland. The "Tennessee" River, however, retained its original Indian name.[8]

As newcomers moved into the region they found that Indians had been using the land for centuries. They left behind many war and hunting trails, and there was evidence that animal life had once been abundant. Settlers found animal "traces" -- pathways worn into deep ruts by migration--some of which were sixty to two-hundred feet wide. These formed as the various species, especially buffalo, moved from salt licks to watering holes over the years. When settlers followed hunters and traders into the area, they often tracked these paths to locate rivers and creeks by which to site their new homes.[9]

FIRST PERMANENT EUROPEAN SETTLEMENTS

Permanent settlements in the land between the rivers area were founded between 1779 and 1800.[10] People who settled the region were a cross-section of the American population during the Revolutionary War period. Some were poverty-stricken and moved westward with little but what they were able to carry on their backs; because many were uneducated and unskilled, the wilderness offered their only real hope of land ownership. Others came because they had a sense of adventure and wanted to explore new territory or hunt wild game. And some families came because their men had been granted land by North Carolina or Virginia as recompense for service in the Continental Army.[11] Whatever the reason for moving to the frontier, all settlers faced equal difficulties once they arrived at their destination.

Early settlers lived in makeshift tents and brush arbors until they had cleared land and planted gardens. The first cabin was often one small room, crudely built from trees that had been cut and stripped of limbs. The rough logs were laid horizontally and spaces between the logs were "chinked" with a mixture of mud and straw. Food was cooked on an open fire outside the cabin until a fireplace could be added to the structure. Then, with simple implements such as spits, pothooks, and kettles, cooks were able to prepare more palatable food on the open hearth. The chimney for the fireplace was usually made of small slabs and sticks of wood, plastered together with a mixture of clay and animal hair. Usually several years passed before settlers could add a stone chimney to the cabin, and the stone chimney thus provided the signal that a settler intended to make the land his homestead.[12]

EARLY LAND SURVEYS AND BOUNDARY DISPUTES

People often settled the land without clear title to the property, and boundary disputes became common among the settlers. Determining the lines between farms was especially difficult because the two adjoining states could not agree on a common boundary, and thus people were never certain whether they were occupying land in Virginia or in North Carolina.

In 1779, Thomas Walker and Daniel Smith of Virginia, and Richard Henderson of North Carolina, began a much-needed survey of the border between the neighboring states. Unfortunately, the two commissions could not agree on a boundary, and separated into two groups. Walker and Smith proceeded from the Clear Fork of the Cumberland to a point at which Virginia and North Carolina reached the east bank of the Cumberland River. They then continued the survey westward to the Tennessee River.

Virginia and North Carolina eventually transferred their western lands to the federal government. When Kentucky and Tennessee entered the Union (in 1792 and 1796, respectively) the two states were faced with internal ownership disputes and a continuing disagreement over boundaries. In 1797, the new states of Kentucky and Tennessee agreed to discuss the Walker line and work out an acceptable compromise. The boundary issue, however, would be debated for the next sixty-three years; people living in the lands between the Tennessee and Cumberland Rivers during that time were never quite sure of they were residents of Tennessee or Kentucky. Because of this ambiguity, and because transportation was difficult and communication slow, many of the river residents identified with community and local units of jurisdiction rather than with the government of any one state.

The land between the rivers proved to be fertile farm land, with rivers providing transportation into the region. Therefore the population increased rapidly, and as it did, the boundary issue became even more troublesome. In 1819, the Kentucky legislature appointed a commission, headed by Robert Alexander and Luke Munsell, to study the Walker line and make some determination on its legitimacy. (Prior to this, Andrew Jackson and Isaac Shelby had negotiated a treaty with the Chickasaw Indians which included a provision that the 36 degree 30 minute line set the boundary between Kentucky and Tennessee).

As the Kentucky commission studied the problem, Tennessee officials made clear their desire to leave the boundary east of the Tennessee River unchanged. They requested a meeting with Kentucky officials to fix the exact divisions between the states. At the conference, the officials from both jurisdictions elected to accept the old Walker line, from the Tennessee River eastward. Included in this compromise was a provision giving the state of Kentucky the authority to dispose of all unappropriated land in the region between the rivers, while Tennessee retained political control of all acreage within her boundaries. People in the land between the rivers were not satisfied with the agreement, however, and forced further discussions in the Kentucky and Tennessee legislatures in 1827, 1831, 1844, and 1858. The matter was not settled finally until 1860, when Kentucky ceded 2,500 square miles--some of it in the land between the rivers--to the state of Tennessee.[13]

I. Stewart County

Between 1803 and 1854, Stewart County in Tennessee and Trigg and Lyon counties in Kentucky were organized as units of government in the land between the rivers.[14] On November 1, 1803, the state legislature of Tennessee, in session at Knoxville, passed an act which divided Montgomery County into two separate counties. The division began at the Kentucky line, thirteen miles west of the meridian of Clarksville, and ran south to the Tennessee-Alabama state border. The newly created territory was named Stewart County in honor of Duncan Stewart, a prominent citizen of the area.

At the first session of the Stewart County Court, the court authorized the purchase of thirty acres of land and planned a town, to be named Monroe, as the county seat. Records show, however, that the town was referred to as Dover from the beginning. A story is told that the first settlers in Dover saw a resemblance between their little village, perched atop the limestone bluffs of the Cumberland River, and the town of Dover, England. If the story is true, those settlers were gifted with vivid imaginations.[15]

James Elder was appointed surveyor to run the boundary line between Stewart and Montgomery counties, and James Huling, James Elder, Amos Bird, Harry Small, and John Blair were appointed to serve as commissioners to choose the site of the permanent county seat. The state legislature appointed George Petty, Caleb Williams, and James Tagert as commissioners to acquire the property for the county seat. Meanwhile, the first session of the county court was held at the home of William Martin, who lived near Bald Island, and the court authorized the purchase of thirty acres of land and planned Monroe. The court agreed to reserve one and one-half acres of land for the public square which would contain a courthouse, jail, and stocks. The land around the public square was to be divided into lots, sold to individuals, and the revenue used by the county government.

In 1803, Stewart County included today's Houston, Humphreys, Perry, Wayne, and parts of Hardin and Lewis counties. When the Western District was added to Tennessee, the jurisdiction of Stewart County was extended to the Mississippi River. The reorganization of the counties in Tennessee in 1821 resulted in the creation of thirteen new counties, and Stewart County was stripped of all of its southern and western regions, and reduced in size to some 425 square miles, or about 270,000 acres of land.[16]

II. Trigg County

Just as Stewart County began its history as part of another county, Trigg County, Kentucky, was originally a part of Christian and Caldwell counties. By an act of the Kentucky legislature in the winter session of 1819-1820, Trigg County was created and a commission appointed to choose local officials. The county was named for Stephen Trigg of Virginia, who had come to the district of Kentucky in 1779 as a member of the Court of Land Commissioners. He decided to remain in Kentucky, and built a home which became known as Trigg Station, on Cane Run Creek. (Stephen Trigg was killed in a fight with Indians on August 19, 1782, at the battle of Blue Licks.)[17] Trigg County officials chose land on the Main Little River for the county seat, and named the town Cadiz.

An anecdote about Trigg County indicated that the land retained its frontier flavor even after the town was well established. In October, 1820, as the Trigg County Court was in session to discuss taxes, the people heard the sound of a gunshot. County officials were not overly surprised at this, but they were sufficiently alarmed when a wounded bear staggered into the courtroom. All the county officials, with the exception of the county clerk, scrambled for safety. And although the bear did not attack anyone, some of the people did suffer injuries when they jumped through a window to escape the beast. The stalwart county clerk, William Cannon Jr., thus became famous for taking his job so seriously that he would risk death rather than abandon his notes.[18]

III. Lyon

Matthew and Chittenden Lyon's Legacy. Lyon County, Kentucky, the last of the counties in the land between the rivers to be organized, was a part of Caldwell County until 1854. But by 1791, settlers had moved into the area and established homesteads. In 1798, Matthew Lyon--who later became instrumental in the development of the region, and one of the most important business leaders in the land between the rivers--was a resident of Vermont, and serving in the United States Congress. Lyon had become uncomfortable with many of the activities of the Federalist Party and was very critical of John Adams, the President of the United States. Matthew Lyon delivered a series of speeches and wrote several letters criticizing the Federalist-sponsored Sedition Act. Lyon continued his verbal and written denouncements even though he was warned that he was violating the Sedition Act. He referred to Adams as an individual "in a continual grasp for power." Unsurprisingly, Lyon was arrested and charged with several violations of the Sedition Act. He pleaded not guilty and posted a one thousand dollar bond.[19]

In 1797, Lyon considered moving to the frontier. He visited Andrew Jackson in Nashville, Tennessee, and made contacts with land owners in the land between the rivers. While awaiting trial, Lyon decided he was ready to leave Vermont, and purchased 5800 acres of land between the Tennessee and Cumberland Rivers. At his trial, after about an hour's deliberation the jury returned a verdict of guilty. The court sentenced Lyon to four months in prison, and fined him one thousand dollars. The trial and verdict caused an uproar in Vermont. Lyon was not a man to delay after making a decision to act, and spent the time in jail planning his settlement in Kentucky. He contacted his sons-in-law--John Messenger, who had married his daughter Ann, and George Catlett, who had married another daughter named Pamela--and asked them to move to the land he had purchased. Lyon recruited a number of skilled artisans and persuaded them to move to his settlement at Eddyville, Kentucky. Lyon planned to leave for Kentucky and join his daughters and their families as soon as he had served his jail sentence.[20] Then he and ten other families left for Kentucky in a flotilla of thirty flatboats. Each canvas-covered flatboat was approximately sixty feet long and loaded with tools, household goods, and guns. These people would join those already living in the land between the rivers in several developing communities.[21]

Because his property touched both the Tennessee and Cumberland Rivers, Lyon recognized the possibility of establishing businesses along the rivers, since it would be easy to transport merchandise to his business operations by way of the rivers. He established several farms, and shipped pork, bacon, lard, corn, venison, hams, and cotton to New Orleans and Philadelphia. With his success as a merchant and farmer, and because he had political connections in Washington, D.C., Lyon was appointed Commissary General of the Western Army.[22]

Lyon went into partnership with Matthew Carey, a prominent book dealer, publicist, and economist, and they began a business which they referred to as a moving book store. Books were shipped up and down the Cumberland and Tennessee rivers, and people came to the river landings to purchase them. The book selling business became so profitable that several more boats were purchased, and Matthew Lyon invested the extra income in land.[23]

Lyon used his political connections to obtain contracts from the federal government to build barges, sloops, and gunboats. He organized a shipbuilding company and hired workers from Vermont to come to Eddyville and work in the industry. Soon the business prospered; Lyon was meeting his government contracts, and had expanded his business to include selling boats to merchants in the river area.[24]

Chittenden Lyon, Matthew's son, took over his father's business enterprises in Kentucky in 1803, when Matthew was elected to the United States Congress from Kentucky. Chittenden was as successful as his father, and expanded the family business operations by building a grist mill, a cotton gin, and a paper mill. Chittenden was especially interested in the iron industry, and when his father died in 1821 he began to expand the iron operations.[25]

COUNTY BOUNDARIES BUT COMMUNITY FEELINGS

From 1803 to 1854, Stewart, Lyon, and Trigg counties served as the units of government in the land between the rivers area. Although all offices of government in the region worked to resolve boundary and citizenship questions, the years of ambiguity and uncertainty left a legacy of doubt.

For several decades then, the people in the southern part of the land between the rivers had been unsure of their state citizenship and the local authorities had never clearly understood whether or not to include these people on their tax rolls. Often, people simply chose the county government they thought controlled their land and voted in that county's election.

During this period the people in the southern part of Trigg and Lyon counties and the northern part of Stewart County operated, socially and economically, as a single community. Even though the people were aware that they were citizens of different states and different counties, their isolation sparked loyalty, and caused them to interact with one another more than with others outside the river area.

The three counties that controlled the land between the rivers had several things in common: most of the settlers moved into the region from North Carolina and Virginia, they were faced with the problem of Indian raids, they were dependent on neighbors for help in times of crisis, and they developed a strong sense of independence and loyalty to family and community. In addition to close cultural and social affiliations, the physical environments were much alike. Soil and mineral deposits were similar; the region was covered with virgin forests and fertile river bottom land; the topography was uneven, with many hills and valleys throughout the area; and the climate was mild, with a mean summer temperature of 75 degrees, a mean annual temperature of 58 degrees, an average of 189 days between killing frosts, and an average annual rainfall of 46 inches. Finally, all three counties began as parts of a larger county.[26]

EARLY COMMERCE AND INDUSTRY

Early communities in the land between the rivers were similar in that most of the people traced their ancestry to Ireland, Scotland, or England. The people moved into the region and farmed and developed various other industries because they had access to the Tennessee and Cumberland rivers. Those waterways allowed the people to ship and receive goods from distant markets. As the population increased, there developed an interesting mix of settlers from other states and immigrants from other countries. By 1840, immigrants from Prussia, Spain, Germany, Bavaria, Switzerland, Africa, and China were living in the land between the rivers. Many of these people were skilled craftsmen who purchased land and opened businesses. They designed and made furniture, hats, saddles, shoes, barrels, clothing, and iron products. Immigrants from Switzerland ran a dairy farm, and an immigrant from China, Jon Gibb, was a butcher.[27]

Agriculture was basic to the economy in the land between the rivers. Corn and cotton were the primary crops for most farmers until the 1840's; secondary crops were tobacco and hemp. By 1849, tobacco began to replace cotton as a primary crop, with farmers raising cattle, hogs, mules, and horses to supplement their income.

Farmers raised corn for food as well as for the production of whiskey. Whiskey production by farmers was to become the longest-surviving industry in the land between the rivers. By 1804, whiskey was being produced in the region for sale in markets all over the country. The earliest settlers had brought with them the knowledge, techniques, and equipment to produce a superior whiskey. If the Indians referred to corn as the giver of life, the farmers in the land between the rivers could have referred to corn as the means of acquiring money which would be the giver of a better life. Great pride was taken in the quality of whiskey produced, and family recipes were a zealously-guarded secret. A sharp distinction was made between pure corn whiskey and whiskey made with sugar or yeast. Pure corn whiskey, referred to as "corn squeezins", "white mule", or "white lightning", was the preferred drink, and all family members drank it from early childhood on. Still houses were built as soon as a few families moved into an area. The county courts licensed the still houses and set rates on the price of all alcohol sold to the public. Most people considered the production and consumption of whiskey an inalienable right, and no law enforcement official or minister could change their minds.[28]

THE IRON INDUSTRY

The iron industry was the most important industry not connected directly to agriculture. When the first settlers arrived they found brown iron ore, and soon realized that large deposits existed in Stewart County near the settlements of Model and Tharpe, and smaller deposits extended from Bailey's Creek and south of Fort Henry along the western edge of the Tennessee River into Trigg and Lyon counties. Northwest of Model there were deposits of quartz gravel at an elevation of about 600 feet, and a terrace of chert and limonite from about 560 to 600 feet. Limestone deposits were exposed in the valleys at elevations from 500 to 525 feet. In fact, it was discovered that low-grade iron deposits were located in beds throughout Stewart, Trigg, and Lyon counties. Iron ore, limestone, and virgin forests were the ingredients needed for the cold-blast production of iron. By 1820, people with sufficient capital were interested in refining the ore.[29]

Investors realized that the iron deposits were large enough and close enough to the surface to make iron production very profitable. The ore was located near large forests that could produce charcoal for cold-blast furnaces, and limestone was readily available for processing the ore. The Tennessee and Cumberland rivers provided easy access to markets in Philadelphia and New Orleans. Montgomery Bell, Anthony Vanleer, William Stacker, William Kelly, Thomas Yeatman, and Matthew Lyon were some of the first businessmen who realized the potential of the iron industry; they began to buy timberlands and ore sites as early as 1814.[30]

A community soon developed around the industry, with the largest settlements located near the furnace sites. Each iron production site was dominated by its furnace. The cold-blast furnace was usually in the shape of a truncated pyramid with its height equal to the length of one leg of its base. The body of the furnace was made of three layers. The interior wall section consisted of five brick walls. The first wall, made of fire brick, was laid as headers with the bricks forming circles. Bricks of the outer four walls were laid lengthwise in concentric circles. The brick walls served as the core of the furnace, and a space between the core and the outer masonry wall was filled with sand to insulate the outer wall from the core. Some later furnaces had metal jackets around the core to further protect the outer walls from the heat of the furnace. The outer masonry wall, made from limestone, was built to form a truncated pyramid. An average furnace had side walls about twenty-seven feet long, which tapered to about twenty-two feet at the top. An eight foot stack surmounted the structure.[31]

The core, or "bosh", of the furnace bulged in the middle and was narrower at the bottom and top. At the base of the core was the hearth, often fitted with an iron base. At its widest point the bosh was about ten feet across, from where it began to taper as it rose to the top of the stack. Heat to melt the ore and separate impurities from the iron was generated by using charcoal produced near the furnace site. Charcoal was needed in large amounts to produce a temperature of roughly 3,500 degrees F, and to keep the blast at a constant temperature. An iron notch, for removing the molten iron, was located on one wall of the stack. About three feet above the iron notch was the slag notch, used to drain extracted impurities which floated above the molten iron. To load the furnace core the workers had to load the charcoal, dump in the limestone, and finally add the iron. To facilitate loading, most furnaces were built near a bluff or hill, so that a ramp could be constructed to the opening at the top of the furnace.[32]

After the charcoal was lighted, a bellows forced air into the furnace. Oxygen combined with the hot charcoal to form carbon monoxide. As the hot gases rose to the top of the stack, the ore was liquified and drained down through the limestone filter. The limestone and impurities from the ore combined to form an impure glass called slag. As slag floated to the top, the flushing operation began. The liquid slag was drained through the slag notch and a trough carried it into a container, or "hot-pot". When filled, the hot-pot was hauled to a nearby field or road and dumped. The greenish-blue slag was either crushed and used as road gravel, or simply allowed to form a pile in the field.[33]

The iron notch was then opened to allow the molten iron to drain into a sand mold called a feeder trench, or "sow". Smaller sand molds along each side of the sow were called "pigs", and as the molten iron drained into the sow it was directed into the pigs. The iron workers often referred to the molds as the pig bed, and the iron was known as pig iron. The molds were usually arranged into twenty-two rough squares, and each of the squares was a bed. Each bed had pigs that varied from four to six feet in length, and a bed usually would hold at least two tons of iron. After the pig iron had cooled in the molds, the bed was broken into pieces and loaded on wagons for transportation to river ports. Some furnace owners built clay molds to produce hollow ware at the furnace site. Molds for kettles, pans, pots, stoves, anvils, hammers, and cannon shot were constructed, and as the liquid iron came from the furnace it was poured into the molds. Rolling mills and forges were built to work the pig iron into finished goods such as fenders, boiler plates, horseshoes, and nails. Initially, river transportation allowed the manufacturers to send their merchandise to various ports. But railroad lines would eventually be needed if the industry in the land between the rivers was to remain competitive. By 1850, the industry's biggest handicap was the lack of adequate railroad transportation.[34]

The demand for charcoal to fuel the furnaces was immense. The forests provided wood for the charcoal pits, which were located near each furnace. Each charcoal pit contained approximately sixty cords of wood, and skilled workers were needed to construct it. Each mound-shaped pit was about twelve feet tall, and covered over with damp leaves and clay. Extra layers of leaves and clay were packed on the top of the pit, because if it did not fire properly it could literally blow its top and destroy fifty to one hundred surrounding pits.

The firing process--the most complicated part of charcoal production--was begun by carefully breaking a hole in the top of the pit and lowering kindling into the hearth. The kindling was ignited and the hole covered. When the fire had caught properly, two six-inch-diameter holes were made, one on each side of the pit to allow gas and smoke to escape.[35] Watchmen kept a continuous watch on each pit, and if it appeared that any pit was not burning properly, they sounded an alarm.[36]

The iron industry required a large, constant labor supply. Workers were needed to cut and haul wood, work in the charcoal pits, dig and haul iron ore and limestone, and produce food for the furnace community. On the census records, many men listed their occupations as farmers even though most, if not all, of their income came from the iron industry. Iron masters hired local workers, purchased slaves, and encouraged immigrants to move to the region. A furnace community included boarding houses, cabins, tool and storage sheds, and shops for carpenters, blacksmiths, and harness makers. A general store was provided either by the iron company or by independent merchants. Stables for horses, mules, cattle, hogs, and sheep, and pens and houses for poultry were built. The furnace community was a bustling center of activity. The furnace owners organized their own farming operations nearby to provide food for their employees and slaves. Iron masters were typically the largest slave owners in the region, and often hired additional slaves from local farmers. Contracts with the farmers provided that the slave was to work for a designated number of months, and that the furnace owner was obligated to provide food, shelter, clothing, and medical care.[37]

In the land between the rivers, Lyon (Caldwell) County was the first to develop iron industries, when Matthew Lyon built a furnace at Eddyville in 1815. Stewart County followed in 1820 and Trigg County ironworks began in 1832. The industry peaked in the 1850's, but survived until 1927. Between 1815 and 1927, Stewart County had eighteen furnaces operating at one time or another, and became the largest producer of iron in the land between the rivers. Trigg and Lyon counties each had two furnaces. One reason Stewart County led in the production of iron was that the Tennessee Legislature passed three acts between 1807 and 1815 which offered land bounties to investors interested in establishing furnaces in the state. Stewart County also had more extensive deposits of both limonite and brown hematite than did Trigg or Lyon counties and that ore was relatively free of impurities and more concentrated in banks or beds.[38]

In 1820 the Dover Furnace began production on Cross Creek, only a short distance up the river from Dover. Woods, Yeatman, & Co., which had been involved in the iron industry in Montgomery County, expanded its operations into Stewart County, and by 1818 had built a second Dover Furnace. John and Samuel Stacker built the LaGrange Furnace on Leatherwood Creek in 1830. By 1840 several other furnaces were completed and operating. These included the Eclipse Furnace on Hurricane Creek, Brunson Furnace on Wells Creek, Randolph Furnace on Lick Creek, Bear Springs Furnace on the Cumberland River, and Byron Forge on Wells Creek.[39]

During the 1840's the Rough and Ready Furnace was built and began operations on the Cumberland River. Further expansion of existing furnaces, construction of the Peytona Furnace on Bear Creek, and plans for new furnaces along the Cumberland and Tennessee Rivers made Stewart County one of the most important iron producing sites in Tennessee and Kentucky.[40]

The peak period of furnace construction was during the 1850's. Bell Wood Furnace was built to enlarge the holdings of the Cumberland Iron Works. The Ashland Furnace on Wells Creek, Clark Furnace on Leatherwood Creek, Union Furnace on the Cumberland River, Saline Furnace on Saline Creek, Cross Creek Furnace near Indian Mound, Great Western Furnace at Model, and Randolph Furnace near the Cumberland Iron Works all appeared during that decade. By 1856 Stewart County could boast of fourteen active furnaces. Two bloomery forges were producing three thousand tons of blooms, bars, and other iron products annually. About twenty thousand tons of pig iron was produced per year, amounting to at least seven percent of all iron produced in the United States. The rolling mills were producing more than twenty-five hundred tons of bar, plate, and sheet iron annually. The furnaces were also producing thousands of iron items such as kettles, pots, pans, irons, and other utensils.[41]

The iron industries in Stewart, Trigg, and Lyon counties were connected because many individuals had shares in several furnaces at the same time. These businessmen bought and sold furnaces to one another. They encouraged farmers, doctors, lawyers, and merchants to invest in the industry. Because so many people were involved, it affected the total economy of the area. Anthony Wayne Vanleer, the son of Samuel Vanleer, is an example of an iron master who sought financial backing from others. In 1820, he purchased the Cumberland Furnace from Montgomery Bell, and in 1831 he formed a partnership with Daniel Hillman, who owned several iron industries, including the Empire and Fulton furnaces. They organized the Big Richland Creek Company, and purchased interests in the Tennessee Rolling Mills in Nashville and the Steam Forge in Betsytown, Kentucky. They moved these operations to the land between the rivers where they owned large tracts of land and built the Mammoth Furnace. Vanleer soon bought into the Empire Furnace and the Trigg Furnace, both in Trigg County.[42]

Daniel Hillman, once an investor in the Vanleer enterprises, formed a partnership with John and Samuel Stacker, and Thomas Watson, and purchased large land holdings in Trigg and Lyon counties. They enlarged the Empire Iron Furnace, the Mammoth Steam Furnace, and the Center Furnace. The Center Furnace remained in operation during the Civil War and used slaves, Chinese, and white laborers. The town of Hematite grew up at the furnace site, and the community was large enough to have a post office, a public meeting hall, and houses for the workers. The trail from Hematite to the Cumberland River was known as the Silver Trail because the paymaster used the road to bring the wages, paid in silver, to the workers. When Daniel Hillman died in 1884, his wife, Mary, took over the operations of the furnace until 1895. She sold the industry and the furnace was eventually purchased by the Hillman Land & Iron Company which produced crossties for the railroad. The company operated until 1919. Later the lands were turned over to the state of Kentucky and declared a wildlife refuge. The refuge gained national attention when it was stocked with the English fallow deer and the English stag deer.[43]

The cold-blast iron furnaces could only show a profit by producing at least ten tons of iron per day. When the hot-blast coke furnace, which could produce more than sixty tons per day, was introduced in other parts of the country, the iron industry in the land between the rivers had to increase production to remain profitable. Ore had to be mined at a cost of less than one dollar and ten cents per ton. Limestone had to be abundant, easily obtained, and less than seventy five cents per ton in cost. Charcoal had to be produced for less than four and one-half cents per bushel. Even when these conditions were met, the iron masters had to keep labor costs at a minimum. Immigrant workers were brought into the industry in larger numbers by 1840, but labor costs continued to rise. The iron industry was not keeping pace with outside competition, and the destruction of furnaces and rolling mills during the Civil War was a blow the industry never recovered from.[44]

BLACK/WHITE RELATIONS BEFORE 1860

One effect of the iron industry was to increase the number of slaves and free people of color who lived in the land between the rivers. As more and more black workers moved into the area, competition for jobs increased between the slaves and free workers. White residents were especially upset that free blacks were allowed to compete with them for jobs. They believed slaves working in the iron industry were likely to start a rebellion.[45]

This fear of slave insurrection created a flammable situation; rumors of black atrocities ran rampant throughout the white community. In 1850 the January session of the Stewart County Court, in order to keep the peace, ordered all free persons of color to register with the county court, and make bond. In the February session the county court expressed concern that only five free persons of color had complied with their order, when at least a hundred should have. The court ordered justices of the peace to check each district, and compile an accurate list of all free persons of color living in the county. In April 1851, the court ordered its clerk to notify all free persons of color to appear at the July session of the court and make bond as the law required. In July and August of that year, thirty-two men and women appeared before the court and made bond for themselves and their children. Court records did not indicate the number of free blacks in the County in 1851, but the record for 1852 is 155.[46]

Fear that slaves and freedmen might unite to form a rebellion peaked in 1856 and resulted in a change in the policies of the Stewart County Court. The county no longer felt secure in simply requiring black males to appear before the clerk and make bond for themselves and their families. A new policy required a responsible white male to cosign the bond with the free person of color. Eighty-five bonds were signed in 1856, but only forty the following year. Some freedmen may have left the area when they were unable to find someone to cosign their bond. Or perhaps they feared the danger and violence they faced during those turbulent years. Nevertheless, it seems likely that the number of freedmen actually in the area was approximately the same as the number of bonds signed.[47]

Another indication of deteriorating race relations during the period from 1852 to 1856 is the attempt of the local governments to force more and more children belonging to freedmen into indentured service. More black children were indentured from 1852 to 1856 than for the preceding ten years.[48] The number of white children bound out as servants in the same period declined.[49]

The courts in Stewart, Trigg, and Lyon counties reacted similarly to the rumors of slave uprisings. Laws restricting the actions of freedmen and slaves had been previously enacted, but stricter enforcement was begun in 1852. Any merchant caught selling liquor to blacks was arrested, fined, and had his license to sell liquor revoked. In Stewart County several men were arrested for allowing slaves to meet on their property. The cases were tried and the men found guilty. It was illegal for blacks to gamble. A number of white men caught gambling with blacks were prosecuted, convicted, fined, and jailed.[50] No records indicate that blacks were charged with the same crime.

Racial tensions climaxed in 1856. A rumor circulated that slaves were holding secret meetings at the iron furnaces to plan a rebellion. Secret messages were supposedly being sent from furnace to furnace in an attempt to unite all slaves and free blacks in Stewart County into one rebellion. The local authorities warned slave holders to not allow their slaves to assemble in groups, because such meetings would allow the slaves to plan a rebellion. The rumors triggered violent reactions, and men formed secret organizations to control the blacks. A group calling itself the Committee of Safety was formed in Dover. On November 28, 1856, the committee began to ferret out and capture all blacks suspected of being involved in planning the rebellion. By December 5, 1856, the Committee of Safety had compiled a list of all blacks they considered suspect. Some of these slaves were whipped. One was beaten until he confessed that he and several others had actually been planning to lead an uprising.[51]

Records indicate at least nine slaves were killed by the Committee of Safety on December 5, 1856. The other slaves accused of conspiring with the rebellion leaders were brought to jail in Dover. Though the exact number of prisoners held in the jail is not known, an item in the January, 1857 county court records provides a clue. The county court ordered that O. P. Thomson be given $140.00 for boarding Negro prisoners during the "excitement in the county from November to December, 1856." If the average cost for boarding a Negro prisoner (fifty cents a day) was paid for Negro prisoners in this incident, then approximately forty-six slaves were held in jail. At the same session of the county court it was ordered that E. P. Lancaster be paid the sum of $7.50 for making three coffins for Negroes who had been executed by the county in December, 1856.[52]

Apparently no action was taken by law enforcement officials against any member of the Committee of Safety for killing suspected leaders of the rumored rebellion. Yet some county court members did express concern, during the January, 1857 session of the court, about the possibility of further violence among the slaves and a county patrol was established to keep the slaves under control.[53]

Some slave owners reacted to the rumored rebellion by attempting to free their slaves and remove them from the area. One example was Samuel Elam, whose will provided for the emancipation of his slaves upon his death. He died in 1855, his will was executed, and the Stewart County Court assumed the responsibility of placing his slaves in jobs for two years. The slaves were then to be sent to Liberia, with the passage fee for the journey provided by Elam's estate. The court was to hold all money the slaves earned during the two years they worked, and that sum was to be used to help them settle in their new homes. The county court accepted the will and recorded plans to find jobs for the slaves, but no record shows that the court ever did transport the slaves to Africa.[54]

During this period it was not uncommon for slaves living in the land between the rivers to be kidnapped, and sold in other parts of the country. Several charges were brought against individuals for such crimes from 1840 to 1860. In 1854, Robert Lee was convicted in Stewart County for kidnapping and selling five slaves belonging to Albert Wallace.[55]

Most citizens of the land between the rivers did not own slaves.[56] Fear of rebellion and competition for jobs, however, fostered a negative attitude toward Negroes. Many believed that slaves should not be allowed in the area because of competition for jobs. Others were opposed to the institution of slavery because of moral or religious beliefs. A few citizens opposed slavery by aiding slaves in their attempts to leave Tennessee and Kentucky. It is difficult to determine how many individuals aided the slaves in their attempts to escape, but it did occur. In November, 1856, Thomas W. Gately of Stewart County was charged with harboring runaway slaves. But slaves could not be found on Gately's property, and the case against him never came to trial.[57]

Fear of a possible slave rebellion affected the iron industry in the land between the rivers. The Great Western Furnace was closed in 1856 because of the rumored slave rebellion, and was never put into full production again. Research has failed to produce any real evidence that a rebellion was ever planned by the slaves. The violent actions taken by the white citizens were based on fear rather than factual evidence.[58]

COMMERCE AND COMMUNITY BEFORE THE CIVIL WAR

From 1830 to 1860, the iron industry and good farm land drew many immigrants into the land between the rivers. Irish settlers were so numerous by 1839 that Bishop Miles of Nashville, Tennessee sent a missionary priest, Reverend Aloysius Orengo, to celebrate Catholic Mass with workers in the area. Soon afterward a church was established in Clarksville, and mass was held in the land between the rivers each Sunday.[59]

Another sign of prosperity was that by 1850, Stewart and Trigg counties had made provisions for pauper, or "poor houses", for the destitute.[60] Prior to this, the county's indigent poor were auctioned off to whoever bid the lowest sum for caretaking. Also by this time the insane were made wards of the court, although still, unfortunately, housed in jail before transfer to an asylum. The insane were usually sent to an asylum in Clarksville, Tennessee, or Cadiz or Eddyville, Kentucky.[61]

Before the Great Western Furnace closed, the settlement around it had grown into a small town. Its residents were determined to develop a small utopia, which would serve as a model for other towns in the area. They often referred to their settlement as the model, and soon that name was accepted for the town. As Model grew, the people invested in homes, and acquired a post office and community center. They planned to pave their sidewalks and perhaps even build a town square. When the Great Western Furnace closed in 1856, however, the dreams for Model began to fade. There were fewer jobs, and many merchants considered closing their businesses before they lost even more money. Sidewalks were never paved, and the town square never constructed, but many of the people remained and struggled to maintain their town. They kept their post office and school. The churches continued to hold services. It was a small town, but it was still the model community to its residents.[62]

Though the rivers provided much of the transportation needed by the people in the land between the rivers, it was still necessary to connect the inland communities with roads. Each man in the area was expected to maintain certain sections of the public roads. If he did not keep his section of the roads clear and passable, he was arrested and fined.[63] From the early settlement period until the Civil War, counties in the land between the rivers continued to build roads and ferries along the Tennessee and Cumberland Rivers. The county courts set the ferry rates, which were always higher on the Tennessee River. The rates were increased on both the Tennessee and Cumberland during the winter season. Ferries transported people, horses and wagons, carriages, carts, cattle, hogs, and chickens in ever increasing numbers. After nine p.m. the rates doubled, but the ferries were usually operated around the clock, especially during warmer weather.[64] The land between the rivers prospered from 1803 to 1860, but growing tensions between the North and South soon led to many drastic changes.

THE CIVIL WAR PERIOD

The year 1861 marks a turning point in the history of the land between the rivers. The Civil War was beginning, and the Tennessee State Legislature enacted a law authorizing all county courts to appoint a home guard, to serve for a period of three months. The guard was to disarm all slaves, and ensure that slaves did not assemble in large numbers. The slave population was to be kept in proper subjugation in order to maintain the peace.[65]

Stewart County was the only county in the land between the rivers to become part of the Confederacy. But both Trigg and Lyon counties were beset by many of the same problems that plagued Stewart County because of the difficulty outsiders had in determining the exact boundaries of the counties in the land between the rivers.

The Stewart County Court appointed Henry H. Erwin as General Commander of its home guard. One hundred twenty-three men were chosen from the twelve districts in the county, and a special tax of seven dollars and one-half cent was levied on each one hundred dollars of taxable property. The revenues were to be used to support the families of men who had volunteered for the

Confederate Army. In order to meet the financial needs of the county, the court issued bonds.[66]

The home guard needed supplies and, as soon became apparent, the men needed training. The county court purchased guns, powder, lead, and ten copies of Hardie's Rifle and Infantry Tactics for the guard. The books were to be distributed to the officers of the guard, and the men were to study the books so they would be ready to defend the people of the county.[67]

By July, 1861, the Stewart County Court was flooded with requests for aid for the families whose men had volunteered for the Confederate Army. Though the court tried to review each case, it was clear that not enough money was available to care for all the people who requested aid. In January, 1862, the Court levied a special tax of thirteen cents on each one hundred dollars of taxable property, but the additional revenue was still insufficient.[68]

In January, 1862, Stewart County had 1,613 adult white males considered fit for service in the Confederate Army. Many of these men, according to court records, wanted to volunteer for the Confederate Army because they did not wish to serve in the home guard. They thought the guard a waste of time, and they did not like its officers. The independent spirit of the men became apparent when appointed officers were often unable to organize them and get them to follow orders. In a letter written by J. C. Cook, an officer in the home guard, to Major N. Brandon, who at the time was stationed at Big Springs, Virginia, Mr. Cook complained: "I wish the legislature would make them all officers and then we would have a fit army."[69]

On June 6, 1861, the Fourteenth Tennessee Infantry Regiment, made up of volunteers from the land between rivers, was sent to Camp Duncan near Clarksville, Tennessee. The Regiment later fought in the Battle of Seven Pines, Chancellorsville, and Cold Harbor.[70] As the men left home to join the army, rumors were spreading that a Federal force was preparing for an immediate attack on Stewart County. People were convinced that the enemy would use the Tennessee and Cumberland rivers as invasion routes. The county court issued a plea that all available men train for the defense of the area. All available weapons had to be stockpiled, to defend Dover should a surprise attack be made. A special home guard was stationed at Dover. Because there were not enough guns available for the Dover guard, the court ordered special agents of the court to go to each household in the county and ask the people to surrender their guns. Predictably, most of the people did not want to relinquish their weapons. They argued that they needed the guns for their own defense, and several men were arrested when it was learned they had hidden guns from the agents. Reuben Wallace, for example, was arrested after an agent, watching his house, found that Wallace had been hiding his guns in a bucket which he lowered into a well when a visit from the agent was expected.[71]

The strategic geographic location of Stewart County did not escape the attention of Isham G. Harris, Governor of Tennessee. Harris was also aware of the iron industry's significance to the strength and preparedness of the Confederacy. When Governor Harris learned of a large Federal force in Kentucky and Illinois, and it appeared that Federal supply depots were under development at Cairo, Illinois and Paducah, Kentucky, he realized that the Tennessee and Cumberland rivers made Tennessee and the Confederacy vulnerable. Governor Harris sent messages to the leaders of the Confederacy, and he and the legislature discussed the construction of forts on both the Tennessee and Cumberland rivers.[72]

General Daniel S. Donelson, a nephew of Rachel Jackson, was chosen to select the sites of the fortifications. Fort Henry was sited at the old Kirkman Landing on the east bank of the Tennessee River, and Fort Donelson on the high limestone bluffs on the west bank of the Cumberland River near Dover. Fort Donelson was due east of Fort Henry, and by land only twelve miles distant. Colonel A. Heiman and his regiment, the Tenth Tennessee, were assigned the task of constructing the fortifications at Fort Henry. As the work began, Federal gunboats were sighted and fired upon by Confederate soldiers and civilians. According to reports, at least one man on a gunboat was killed because he was so interested in the sights that "he had been looking out a window."[73]

The Confederates realized that Fort Henry could not be easily defended, because it was on low ground inundated by flood waters from the Tennessee River during springtime. But they felt a fort in a poor location was better than no fort at all.[74]

Until October 1861, the War Between the States seemed unreal to most of the people in the land between the rivers. Some wanted to believe that the federal government would never send soldiers to attack them, even though they had been warned to expect an invasion at any time. People in Trigg and Lyon counties soon realized that the Federal Army was unsure of the exact boundary separating Kentucky and Tennessee and they, as did the people in Stewart County, went to work too late to hide tobacco, cotton, grain, and valuables in order to keep the Federal soldiers from finding and confiscating them.[75]

The work on Fort Henry and Fort Donelson moved slowly, and in September, when General Albert Sidney Johnston took command of Department No. 11, he ordered General Lloyd Tilghman to assume command of, and complete the construction of, the fortifications immediately. It was then that the lives of the people in the land between the rivers began to change palpably, though most still did not realize they would never be able to reclaim their past. Thousands of soldiers, and hundreds of slaves and civilian workers, moved into the area. Housing was inadequate and food was scarce. Merchants were often unable to procure supplies for sale to civilians because all available boats were being used in constructing the fortifications. The Tennessee and Cumberland rivers were filled with all types of boats, traveling in convoys, trying to deliver goods not only to forts Henry and Donelson, but also to points upriver from those fortifications. The price of supplies was soon inflated, and economic conditions worsened daily as more soldiers and slaves were sent to work on the forts. General Johnston ordered five hundred slaves gathered in northern Alabama and western Tennessee sent to supplement the labor force at the forts. They arrived at Fort Henry on November 28, 1861.[76] An estimated two thousand slaves, and several thousand civilian workers, assisted the twenty thousand soldiers in the construction of the forts.[77]

Soldiers on Federal gunboats kept a constant watch over the construction at Fort Henry and Fort Donelson, and they knew that obstructions had been placed in the Tennessee and Cumberland rivers to impede any Federal advance. Trees had been chained together and sunk in the rivers. The butts of the trees faced upstream and the branches of the trees floated near the water's surface. Confederate soldiers had placed torpedoes in the rivers, and planned to sink boats to provide an even better defense against the Federal gunboats. But before this task could be completed, seven gunboats under the command of Captain Andrew H. Foote, and about eighteen thousand Federal troops under the command of General Ulysses S. Grant, were in position to attack Fort Henry.[78] Federal troops disembarked on the east bank of the Tennessee River at Bailey's Ferry. The Confederate torpedoes, floating on the surface, were easily pulled from the water by the Federals, who then went ashore.[79]

General Tilghman and Colonel Gilmer left Fort Henry on the night of February 3, to inspect the work at Fort Donelson. Colonel Heiman, in command at Fort Henry, sent a message to inform General Tilghman that Federal troops had landed. Tilghman and Gilmer left Fort Henry around midnight. On February 5, Tilghman sent a note to General Albert S. Johnston, informing him of the invasion and commenting that Fort Henry would hold against the attack. But later that day it was decided that the fort would not be able to withstand an assault, since the flood waters might allow the gunboats to float inside the fortification.[80]

Colonel Heiman was ordered to evacuate the main Confederate force overland to Fort Donelson. General Tilghman and fifty-four men from Company B of the First Tennessee Artillery remained at Fort Henry to resist the Federal attack, but they could offer little resistance, and Fort Henry fell.[81]

By February 6, the people in the land between the rivers were facing another problem: Federal soldiers began to loot the countryside. The soldiers were so blatantly destructive that General Grant issued a command to protect the lives and property of citizens in the area. A few days later on February 9, Jonathan A. Rawlins, Assistant Adjutant General, issued General Field Order No. 5, from Fort Henry. The order stated that all officers would be held responsible for the actions of their men, and admonished the officers to make examples of those men who disobeyed the order. It also cautioned the men that they were in enemy country and needed to be careful not to convince the enemy that the cause of the Union forces was unjust. The order expressed great surprise that "men can be found so wanton as to destroy, indiscriminately without inquiry."[82]

Confederate soldiers were as undisciplined as the Federals, and communications from the officers at Fort Donelson mentioned that it was impossible to control the activities of the Confederate soldiers. Soldiers slipped away whenever they wanted to leave, and it was a source of constant concern that the officers did not have an accurate count of the men in their commands.[83]

Immediately after the fall of Fort Henry, the land between the rivers appeared, to anyone traveling through, to be desolate and uninhabited. People had left their homes and tried to hide in the forests. When the Federal Army was sent through the area on February 9, to find slaves to work at Fort Henry, they found none. The slaves had been moved behind the Confederate lines above Fort Donelson.[84]

From time to time, Federal soldiers passed through the area and reported seeing no men at the houses, and that the women and children seemed sick and underfed. They could find little food in the houses, and few animals on the farms. The people were drinking a horrible brew, which they called coffee but which was made from ground acorns. Though the Federal soldiers could not drink it, the people seemed glad to have anything to drink.[85]

Confederate reinforcements arrived at Fort Donelson daily. Workers cut trees and built breastworks to strengthen the fort. It was understood that Fort Donelson was constructed primarily to provide field support for the water batteries. The Confederate leaders had not anticipated an attack by land, but when Fort Henry fell it was apparent that Grant's forces could easily move overland to Fort Donelson. The military leaders counted on the densely wooded hills and ridges, with intervening deep gullies and flooded hollows, to make the journey from Fort Henry very difficult. General John B. Floyd arrived and took command at Fort Donelson on February 13. His staff, which included generals Gideon Pillow, Simon Buckner, and Bushrod Johnson, and Colonel Nathan Bedford Forrest, was told that plans must be prepared to halt an immediate attack. But even as the staff meeting was in progress, an advance Federal force arrived at Fort Donelson and attacked its outer fortifications. The attack was repulsed, and General Floyd arranged another meeting with his entire staff. Years later, when Ulysses S. Grant reflected on the events of February 1862, he commented that General Albert Sidney Johnston had made a fatal mistake when he gave the command of Fort Donelson to General Floyd, because Johnston must have realized that Floyd was "no soldier even if he possessed the elements of one."[86]

General Grant's comment benefitted from the luxury of hindsight, but it is true that General Floyd lacked experience and was at a disadvantage when he took command at Fort Donelson. He did not know the size of his force and was unfamiliar with the geography of the region. There was also the emotional strain of believing that if taken prisoner he would be tried for treason. His messages to Johnston indicate he did not comprehend the exact strength of his fortification, and that he felt the fort would fall if attacked. He did not seem to appreciate that the loss of Fort Donelson would open the heart of the Confederacy to a Federal invasion.[87]

From February 13 to 15, General Floyd became progressively convinced that the fort would have to surrender. On the evening of February 15, he sent a message to General Johnston, saying, "The Fort can not hold out for twenty minutes."[88]. He then called a staff meeting to discuss the situation, and stated that he felt the fort would have to surrender. Colonel Forrest, arriving late for the meeting, heard discussion of surrender, and objected. Following heated debate, it was decided to surrender the fort. But Forrest and Pillow wanted to evacuate the fort before Federal forces arrived. Floyd maintained that the troops could not march up the Cumberland River bottoms because of the backwater. J. W. Smith, a resident of Stewart County, was asked to come to the staff meeting at about eleven p.m. He was sent to the road leading to Clarksville to determine if soldiers could use the road as an escape route. After scouting the area he returned and reported that men and horses could ford the water with little difficulty. But Floyd continued to argue that the men could not be evacuated, and that the fort should surrender.[89] Colonel Forrest announced that he was not going to surrender, and would escape with his men up the Cumberland River. Forrest began preparations to lead some 1,500 soldiers out of the fortification.[90]

During the meeting, soldiers at the fort, aware that surrender was being proposed, met in small groups to discuss whether to remain and surrender. In the meantime, generals Floyd and Pillow decided to leave by boat. As they prepared to leave, small detachments of soldiers quietly abandoned the fort. In an apparent frenzy to leave, General Floyd commandeered two steamboats at the Dover landing, (the steamboats were loaded with troop reinforcements) and ordered their captains to take him and his men to Clarksville. General Pillow joined Floyd and, with about 1,500 men, they speedily left the fort.[91]

Talk of the surrender of Fort Donelson caused panic in Stewart County. People came to Dover to find out if the rumors were true, and upon learning that the fort was ready to surrender, many tried to flee the county. Spot F. Terrell, of Company H, Forty-Ninth Tennessee Infantry, wrote in his journal about the fear and confusion evident among the people. He noted that many soldiers were disgusted that the officers would consider giving up the fort without a fight. Such men were determined not to be captured, and they took it upon themselves to find a way to leave the fort. According to Terrell, any soldier who wished to leave simply walked away.[92]

General Simon Buckner surrendered the Fort to General Grant on February 16, 1862, and the second stage of the Civil War began for the people in the land between the rivers. When Grant took command at Fort Donelson, he did not issue rules of conduct for Federal soldiers, captives, or civilians in the area. Federal soldiers proceeded to loot the town of Dover, and the people were near hysteria. For several days after the surrender, Confederate soldiers continued to vanish from the captured fort. Company H. of the Fifty-Third Tennessee, for example, simply walked away, unhindered by Federal forces.[93]

Late in the afternoon of February 19, Grant issued orders that Federal soldiers were to patrol the fort's perimeter and detain any Confederate prisoner trying to leave. On the same day Grant wrote that a number of local people had come to Fort Donelson from the vicinity to express their delight that Federal forces were in control. These people told Grant that Confederate sympathizers were leaving the area, and supporters of the Union cause feared for their lives and property. Grant told the people they would be protected if they came to the camp and swore an oath of allegiance before him.[94]

On February 22, in a message reporting on the large store of Confederate supplies captured at Fort Donelson, Grant mentioned that the town of Dover had suffered considerable damage as a result of the battle. Nearly every building had been damaged, and wounded civilians were in dire need of medical attention. Trees had been cut down, fences burned, windows broken, and a number of buildings left standing after the battle were being torn down and used as fuel against the bitter cold. From the day of surrender to the day of Grant's message, Federal soldiers had been destroying and stealing property. They were seen filling their canteens with molasses and their pockets with money. One soldier was seen walking down the street with a "looking glass" under his arm. Another was loaded down with "several brass candlesticks" and was wearing a "woman's bonnet." One soldier wrote that the Federal soldiers were "luxuriating like children in hogsheads of sugar."[95]

On February 22, General Grant declared martial law in Stewart County and West Tennessee. But even after that, soldiers wandered through the area at will and took anything they wished. The Confederate commander of Camp Porter at Paris, Tennessee reported "terrible depredations committed on the citizens between Fort Henry and Concord," after the fall of Fort Donelson.[96]

The Union Army planned to use Fort Henry as its base of operations, and to leave only a small garrison at Fort Donelson. In March 1862, Grant had about 63,500 men at Fort Henry, an additional 5,740 soldiers waiting to move there, and 2,328 men at Fort Donelson. During the spring of 1862 the land between the rivers looked like a large and busy depot. Federal soldiers were either stationed at the forts or they were passing through the area to Cairo, Illinois. Food and supplies were scarce for civilians, and the situation worsened each day as soldiers took supplies needed desperately by the civilians.[97]

By March 15, charges were being made that Union commanders could not control their men. Messages sent to Grant informed him of the charges. He tried to control the situation by issuing General Order No. XXI, which appointed Captain Clark B. Lagow and Colonel John Riggins as supervisors of a program to issue passes to persons and property entering or leaving the area. Then Grant received orders to leave Fort Henry. He reorganized his command, removed the Federal force at Clarksville, left seven hundred men at Fort Donelson, and placed the Fifty-Second Indiana Regiment at Fort Henry. Colonel W. W. Lowe was placed in command of both forts.[98]

The people in the land between the rivers were now entering the third stage of the Civil War. Most Federal soldiers left the area, and except for two later raids by Nathan Bedford Forrest, actual battlefield experiences had ended. People tried to resume their lives. But as farmers tried to plant crops in March and April the weather did not look favorable. Money was scarce, and most farmers had no seeds to plant, or work animals for cultivating the crops. A farmer fortunate enough to have money to buy a mule, found it nearly impossible to find one for sale. People were forced to rely on a barter system in order to exchange goods. Occasionally, farmers had been successful in hiding a few animals, and perhaps some tobacco and cotton, but they found it nearly impossible to get permission from the Federal authorities to ship their goods. Some who had left their homes began to return, but soon realized that they were faced with poverty. And it was impossible for them to sell their land for any profit. Some left the area permanently.

Before the people could breathe a sigh of relief at the departure of the Federal forces or rejoice that they had survived the fighting, new problems appeared. Guerrilla bands roamed the area in raiding parties. Those operating out of Eddyville and Hopkinsville, Kentucky threatened the people in the land between the rivers most. The guerrilla bands tried to force men to join their group, and those refusing were likely to be shot. Confederate raiding parties came, seeking men and supplies. The situation became so dangerous that in 1863 some people asked for permission to move to the perimeters of forts Henry and Donelson for safety. Permission was initially granted, but when the army realized it could not provide food, shelter, and clothing for the people, it was rescinded.[99]

The people were faced with a fight for survival in an area torn by war, fear, hunger, and crime. In 1863, typhoid, malaria, and small pox spread across the countryside, exacerbating already dire circumstances. Martial law aggravated the problems, instead of alleviating them. The disease epidemics could not be controlled effectively because of the difficulty doctors had in obtaining passes allowing them to enter the area, and it was nearly impossible to transport the sick to physicians outside the area.

The citizens could not arm themselves against either criminals or the soldiers. Federal authorities were aware of the people's plight, and Colonel Rodney Mason, Commander of the Seventy-First Ohio Volunteers, was sent to Fort Henry to supervise the soldiers' actions. One reason it was nearly impossible to control the situation was that most soldiers thought all the local people were spying for the Confederacy. When Federal forces containing both black and white soldiers were sent on patrols, the citizens were both amazed and outraged that black soldiers could order them around. On one occasion, such a patrol to Clarksville destroyed everything in its path.[100] Hostility between the civilians and the soldiers made life generally difficult for everyone concerned.

Because forts Henry and Donelson were of great importance in controlling the Confederacy, special attention was paid to a broad area around both forts for the duration of the war. The garrisons at both installations were increased, and patrols were sent out to keep communication lines open.[101] Anyone suspected of sympathizing with the rebel cause was arrested. Federal occupation troops had difficulty maintaining communication lines on the Tennessee and Cumberland rivers because Confederate sympathizers were quite good at disrupting river traffic and cutting telegraph lines.

RECONSTRUCTION

On July 5, 1865, the people of Stewart County saw the end of military occupation, and immediately made plans to establish a local government. Elections were held on July 15, 1865, and Isaac Williams, chairman of the county court, began rebuilding economic and political operations in the county. From 1865 until the twentieth century, people in the land between the rivers suffered the long-term effects of the Civil War. The iron industry never recovered, and agriculture remained depressed for many years. People in Stewart County endured the additional hardship of paying off old debts while trying to raise enough money to develop the primary institutions in the county.[102] They were too poor to pay heavy taxes, yet the county court had to build public buildings, roads, schools, and other facilities. The activities of the county court in 1865 were a re-enactment of the activities that organized the county in 1803.[103]

The years between 1865 and 1875 were especially bleak. The number of people on the pauper rolls continued to rise as widows and children of the men who had died in the Civil War were added. Disabled veterans were unable to provide for their families, and jobs for able-bodied men were scarce. When people became so destitute that they had to ask for charity, the need was critical indeed because these were people raised with the belief that every man ought to provide for his family and those who did not were considered irresponsible. Economic conditions were so bad that the county court issued vouchers as a substitute for money, and attempted to raise money to construct schools and other public buildings by issuing bonds. Still, five years passed before the court house in Dover was replaced.[104]

From 1870 to 1900 the three counties in the land between the rivers were unable to raise enough revenue to operate the counties, and the public debt increased in each county. A note found in the Walter's papers for the Walter and Scarborough Company, which sold merchandise by sending peddlers into the land between the rivers, indicated that most of the peddlers' goods were sold by barter. The merchants accepted tobacco, livestock, and other farm produce in exchange for merchandise. In most instances farmers tried to develop a subsistence farm, and purchased only those goods which could not be produced at home. People substituted readily available local goods for items that in better times would be bought. Honey was substituted for sugar, and corn meal for flour. Cloth of cotton, wool, or hemp was made at home. Very few people purchased clothing or shoes from merchants. Life was indeed hard, and people became further isolated from areas outside their communities. They tended to resent outsiders and interference from people who moved into the area.[105]

Census records indicate that between 1865 and 1900 several black families lived in Stewart, Trigg, and Lyon counties. The largest black settlement was near Dover. But apparently no blacks lived in the land between the rivers. A folk rule in effect during this period warned that any black person caught in the land between the rivers after dark would never be seen again. There is no record that any black was killed or hurt in the area, possibly because blacks had heard of the rule, and very few ventured into the region.[106]

EARLY TWENTIETH CENTURY

World War I had little apparent effect on the region. The men went to war if they had no other choice. When the war ended, most of the men returned home and tried to take up their lives as they had left them. A few left to work in the war industries, and never returned. Large land owners raised tobacco, corn, and livestock, and continued to acquire land. People attended their churches and community centers, discussed politics, and voted. They took their right of franchise very seriously, and exercised it at every given opportunity. They lived their lives quietly and resisted outside influences.[107]

School and church were focal points for the communities, for both religious worship and socializing. Church congregations were predominantly female. Under the leadership of their ministers, the women were involved in movements to aid education and limit the consumption of alcohol. Though their families had for generations been involved in the production and sale of alcohol, most women believed in a moderate temperance reform and thought people should not drink to excess.[108]

PROHIBITION AND THE MOONSHINE ERA

Prohibition affected people in the land between the rivers. Since earliest settlement days, many had viewed whiskey production a God-given right. Though from time to time community pressure had forced moderation among local producers and consumers, it was unthinkable that the government would dare deny their right to make, sell, and consume whiskey. The idea of prohibition offended the people, and most ignored the law. The law was considered ridiculous. The people did not talk in terms of their civil liberties being violated by the federal government; they simply denied the right of any government to tell them what they could or could not drink. But rather than voice their protest, they simply remained silent, took their stills to isolated areas, and continued to produce some of the best whiskey in the nation.[109]

Tucked away between the rivers, the sparsely-populated area was perfect for whiskey making. Three ferries provided the only means of crossing the rivers, and sentries, usually on horseback, were posted at the landings to spread the word when strangers made a crossing. When strangers--who could be revenue agents--were spotted on the ferries, the sentries would ride to the nearest farm house and ring the dinner bell. The alarm would be picked up and spread from farm to farm until the entire area echoed to the slow, metallic clang of the bells. Once the danger was past, the all clear signal would be sounded by three blasts from a shotgun. Any man coming in by road was watched carefully by each farmer and was likely to be stopped and asked what his business was in the area.[110] Very soon, word spread that good whiskey could be bought in the land between the rivers if you knew the right people. As the thirsty in other parts of the nation learned of the quality product being produced in the area, they began to seek out those men who had the reputation of producing the country's best drinking whiskey. Illegal deals were made with bootleggers in other states, and dealers came to the region from such cities as Chicago, Cleveland, and Detroit. Caravans of trucks, often protected by armed guards, drove in from metropolitan centers to transport the whiskey. Law enforcement officials were ineffective in their attempts to find and close down stills. When a still was found and destroyed, it took but a few days to construct another and resume production. Both the federal and state authorities soon realized they were fighting a losing battle against the producers of whiskey in the land between the rivers. The law simply could not be enforced if most of the people chose to disobey it and there was not enough money in the state and national treasuries to field enough law enforcement officers to control whiskey production.[111]

As the Great Depression began in 1929, people in the land between the rivers depended even more on the illegal sale of whiskey to supplement their income. It was common knowledge, although no one spoke openly of the matter, that whiskey was available at all times.[112]

Local legend says that Al Capone had whiskey buyers in the land between the rivers during the days of prohibition. Capone's agents came in by trucks, cars, and airplanes. The town of Golden Pond in Trigg County became an unofficial headquarters for the acquisition of whiskey. Purportedly, an air strip was built near Golden Pond so Capone's men could fly in, buy whiskey, and leave in just a few minutes. By 1930 the whiskey makers had become quite open in their illegal operations. One operator printed his own labels, which read "Genuine Golden Pond Kentucky Whiskey," and pasted them on jars and jugs used for bottling. A huge sign, with the words "Whiskey Ridge Distilling Co.--No Trespassing," stood along a hillside trail east of Golden Pond.[113].

There are several local versions of how Golden Pond got its name. Some say it may have been named for small gold fish found in the pond by early settlers. Another story is that if the sunset in the summer was just right, the pond appeared gold. But after 1929, Golden Pond came to mean that one could purchase a liquid there, and after a few sips of the brew everything took on a golden hue.

Whiskey was the real money crop for many people during the depression, and ingenious ways were devised for circumventing the law. For those wanting to purchase whiskey without the fear of being arrested, certain respected citizens sold whiskey only at night and only to those visiting the family on social occasions. These citizens did not want their names associated with illegal activities, and they were very careful to maintain an air of respectability. They attended church, donated to the poor, and professed prohibition a good thing for the country. They also built rooms in their homes with double walls for storing whiskey. When a regular customer knocked at the door, he was admitted for a short visit. Presently, the visitor would be handed a bottle, package, or bag, and would then leave. The package appeared to be a jar of jam, a cake, or other food, and the bag might contain anything from vegetables to a covered dish. But hidden in the package was the jar of whiskey that the customer had come to buy. So casual was the transaction, other visitors in the house might not be aware that a purchase of alcohol had been made.[114]

DEPRESSION AND THE NEW DEAL

The Great Depression so reduced the living standards of most of the region's residents that when Franklin Roosevelt promised the New Deal, they were ready to allow the government to experiment in order to end the poverty. (However, a few farmers with hundreds of acres of land were opposed to the New Deal programs; they had done well during the Great Depression because of the cheap labor supply.) One of the biggest boons to the average person in the land between the rivers was the electrification program provided under the Tennessee Valley Authority (TVA). The people had no electrical power because private power companies found it unprofitable to run their lines into rural areas. The rural electrification program allowed people at least to install electric lights, even though most were unable to afford all the electrical appliances they wanted. TVA promised to make life easy for farm women, but the promise was not made good until well after World War II.[115] In the land between the rivers it was common to see a farm house with electrical wiring running along the walls, and a naked light bulb hanging from the ceiling. The refrigerator was typically placed on a porch because the kitchen was not large enough to accommodate it.[116]

In 1933, Works Progress Administration programs in the land between the rivers used federally employed workers to develop Honker Lake, Hematite Lake, and Empire Lake. Kentucky Woodlands National Wildlife Refuge was established in 1938 to provide habitat for native small game and waterfowl. The region at that time was the only place in Kentucky where wild turkeys could be found, and one of the few places in the South where deer could be sighted. All the turkeys and most of the deer that went into Kentucky's statewide restocking program were trapped at Kentucky Woodlands. They were then released at Mammoth Cave, Beaver Creek Refuge, Pennnyrile Forest, and other areas. The wild turkey was so rare in 1938 that each bird was worth $1,000 in trade for wildlife with other states.[117]

When World War II began, the residents of the land between the rivers became very involved in the war effort, and many left the area to work in the war industries. Most of the men who joined armed forces probably intended to return to their homes when the war ended, and many did. But the environment they left had changed. There was new interest in developing different farming techniques. Industry was being encouraged to come into the area. And a special emphasis was now being placed on education as a means to enable children to make better lives for themselves. These changes did not mean that people had altered their views on the role of family, church, and community. They were still committed to preserving their traditions, but they were also now involved in a new economy, and they intended to make the most of their new lives.[118]

THE ARRIVAL OF THE TENNESSEE VALLEY AUTHORITY

In 1944, approximately 158,000 acres of land were surveyed by the federal government for TVA's development of Kentucky Lake. A year later 234,000 acres were impounded for the lake and an easement for flood control. Some 3,500 families had to be moved. Many people protested when forced to sell their land. But the promise that the area would benefit from cheap electrical power, tourism, and industry helped to reduce the sorrow of losing their land. Thus without extreme opposition, Kentucky Lake was formed. People waited for the promised industries but they did not come to the land between the rivers. TVA officials seemed unaware that cheap power alone was not a sufficient catalyst for industry to come to the area. Industries and businesses were also interested in the labor supply and cheap, rapid transportation. The region lacked adequate railroads and the connecting highways necessary to make it appealing to potential industries.[119]

THE BARKLEY RESERVOIR PROJECT

In 1955, residents of the land between the rivers felt threatened when they realized that the project to build Barkley Dam would affect many of their farms and homes. For the first time TVA became a threat to these people, and they expressed opposition to further development by the agency. The people stood to lose some of the best farm land in the United States to the Barkley project. Congress had appropriated the money to build a high dam on the lower Cumberland which when completed, would affect approximately 57,000 acres of land. The best farm land would be flooded and citizens and officials of Trigg, Lyon, and Stewart counties were worried about the loss of population and tax revenue. But the greatest protest was voiced by farmers who felt their land was appraised far below its actual earning power. Though opposition was strong and vocal, and local organizations were formed to protest the construction of the high dam, the project proceeded, with a projected completion date of 1958.[120]

The Barkley Reservoir Project began on schedule, but the completion date was moved forward to 1961. It was then decided that a seven-thousand-foot-long canal should be built to join Kentucky Lake with Lake Barkley. The completion date was set for 1966. By the time the canal project was accepted, the Corps of Engineers was nearing the completion of Barkley Dam, and construction of the canal assumed top priority. The canal was about two miles south of Kentucky Dam and people in the land between the rivers realized they would soon be surrounded by water on three sides. They were, at first, delighted by the opportunities that the new shoreline offered in prospective tourist trade. The area might become a recreational gold mine, and people planned to take advantage of this new avenue to prosperity. But within a few weeks they realized that federal authorities were also interested in the land near the lakes. The area included from 50,000 to 70,000 acres of land, with excellent sites for boat docks, restaurants, and camping facilities. The capital needed to develop such recreational facilities was readily available.[121]

THE CONCEPTION AND GESTATION OF LBL

In February 1961, President John F. Kennedy spoke to the U.S. Congress on the natural resources of the country. He expressed interest in establishing a comprehensive federal recreational lands program. The Secretary of the Interior, in cooperation with the Secretary of Agriculture and other appropriate federal, state, and local officials, and private leaders in the recreation field, were instructed by Kennedy to formulate a comprehensive federal recreational lands program. They were also to conduct a survey to determine where additional national parks, forests, and seashore areas should be proposed.

The Tennessee Valley Authority acted immediately, and by March its board of directors had concluded a preliminary study of the area which they referred to as the Land Between The Lakes (LBL). Herbert Vogel, Chairman of TVA's Board of Directors submitted a report entitled, "A Proposal for a National Recreational Area Between the Lakes formed by Kentucky and Barkley Dams." In the report, Vogel proposed that TVA develop the area under provisions of Section 22 of the TVA Act and Executive Order No. 6161, issued on June 8, 1933. He suggested that 140,000 acres of land between the Cumberland and Tennessee Rivers be set aside as a recreational area. The proposal was sent to the President on June 13, 1961. Included in it were several demographic maps and data showing that much of the nation's population was concentrated around LBL. National parks and forests were concentrated in western lands and millions of Americans had no national parks near them. The Land Between The

Lakes seemed a good spot for a new national park or recreation area of some kind. It would have at least three hundred miles of shoreline fronting both reservoirs. The land was described as having few natural resources suitable for economic development other than recreation. The area's principal asset was its cove-studded shoreline, the result of federal investments of nearly $300,000,000 in the Barkley and Kentucky lakes projects. The report concluded that a national recreation area could be established in the LBL region to serve Americans in the eastern and midwestern United States.[122]

Three days before the proposal was submitted, newspapers reported that U.S. congressmen, Tennessee and Kentucky state officials, and private citizens were studying the possibility of a new national park in western Kentucky and Tennessee. The articles stated that governors Buford Ellington of Tennessee and Bert Combs of Kentucky were involved in the study of the proposed park.[123]

On June 23, 1961, ten days after the proposal had been sent to the President, Vogel wrote a letter to the President in which he included an overview of the proposal for the creation of a park in the Land Between The Lakes. Vogel suggested that the park be about forty miles long and from six to twelve miles wide. According to Vogel, the land was not conducive to industrial development because of its rugged topography. He described the land as forested mainly with scrub timber of little economic value, and wrote that farming was confined to narrow creek bottoms between three-hundred-foot-high ridges. Vogel stated that the area had no exploitable mineral deposits, only about five thousand people lived there, and many farm dwellings had been abandoned. He reminded the President that the Kentucky Woodlands National Wildlife Refuge already included 63,000 acres, TVA owned an additional 2,000 acres along Kentucky Lake, and the Corp of Engineers was in the process of acquiring about 2,000 acres along Lake Barkley. The implications of Vogel's letter were clear: the land had little agricultural or economic value, the public already owned a substantial portion of the area, and it was feasible to purchase the land not already under federal control for the proposed park.[124]

Vogel's letter stated that the project would provide an economic stimulus to the area, and that construction of access roads, campgrounds, picnic areas, and other public facilities could begin immediately in the areas already under public ownership. He estimated that seventy million people lived within five hundred miles of the proposed park, and noted that the land was ideally suited to many of the outdoor recreational sports and activities that people enjoyed. Camping, boating, fishing, hiking, and water skiing would be available to citizens seeking relief from modern stress. The President was assured that TVA would be glad to cooperate in any way it could to see that the plan was implemented.[125].

Citizens of Trigg, Lyon, and Stewart counties had learned of the proposed park a few days before Vogel's report was submitted, when newspapers reported that the area was being considered. They now read in the newspapers that President Kennedy had received the proposal from TVA, and referred the matter to the Secretary of the Interior for further study. In the meantime, Pierre Salinger, White House Press Secretary, announced that congressional representatives from Tennessee and Kentucky had been discussing the matter with the Department of the Interior, and had agreed that the park would be an asset to their states.[126]

In July 1961, governors Burt Combs of Kentucky and Buford Ellington of Tennessee told the press that they had discussed the park proposal with TVA officials before it was submitted to the President. When reporters asked why the matter had not been discussed more openly with the people of both states, the governors said that they were in the process of planning a meeting with the citizens of the counties involved in the park project.[127]

Area newspapers began to speculate on the size and function of the new park. They reported that about thirteen hundred houses would be affected if the park were acquired by the federal government, and some five thousand people who lived in the area would be directly affected. The value of the land was estimated at $100 to $150 per acre, which was considered by most residents to be reasonable.[128]

On July 7, 1961, the White House released details of the Land Between The Lakes plan. The President had officially endorsed a study of the area to determine if it was feasible. The proposed park was described as the only one of its kind east of the Rocky Mountains, and ideally suited for outdoor recreation. Land for the park would cost approximately 10 million dollars, and would become an extension of an area that the federal government had already developed at a cost of 300 million.[129]

In the same news release, White House Press Secretary Salinger said that the Secretary of the Interior, Stewart Udall, would be making a recommendation to the President. If Secretary Udall recommended that the park be created, and the President agreed, the next step would be a presidential recommendation to Congress to create the recreational area. When asked why TVA had submitted the proposal, Salinger said that TVA had been encouraged by a number of agencies to study the area for the purpose of creating a park and that all those agencies had agreed the proposal was a good one.[130]

The people learned that representatives Ross Bass of Tennessee and Frank Stubblefield of Kentucky had planned to introduce a bill which would provide the funding for a national park in the Land Between The Lakes. A group of citizens from Stewart, Trigg, and Lyon counties met with representatives of other nearby counties and formed the Between the Lakes Development Association. At a meeting in Cadiz, Kentucky on August 2, 1961, Smith Broadbent Jr., from Trigg County, was elected president of the organization and Ira Atkins, from Stewart County, was elected vice president. The group adopted articles of incorporation and set up a board of directors. Broadbent opened the meeting with a statement expressing opposition to the formation of a national park, but stating that his group was in favor of a recreational area. He explained that he had been told that the formation of a park would allow the creation of a wilderness area, but a recreational area would provide facilities for the use of all the people who wished to visit. Broadbent was sure that a wilderness would draw few visitors.

When the meeting was opened for discussion of the park proposal, George Bleidt, acting as spokesman for representatives of the Golden Pond area, said, "We have the hottest spot in the United States," and added that the people should be allowed to develop their own lands. Representatives from Stewart County expressed concern over the impending loss of their lands, and said they felt their county had already lost too many acres to the federal government.[131]

People came out of the meeting solidly in favor of allowing private business to develop in the area, whether the government developed a park or a recreational area. Those at the meeting pledged to make every effort to protect the people who lived in the land between the rivers. It was the goal of the organization to protect the property of those not wanting to sell their land to the federal government.[132]

As soon as the Between the Lakes Development Association was formed, and newspaper accounts reported the opposition to the park, Vogel spoke to the press about the urgency of moving quickly to develop the park in order to forestall private development of recreational facilities in the area. If private developers came in, property values would increase, making the land procurement costs to the federal government even higher.[133]

On August 2, 1961, Conrad Wirth, Director of the National Park Service, endorsed the recreational park project. He proposed that 140,000 acres of land be purchased and turned into a national park. He estimated that at least four million people would visit the park annually, and that within eight years tourists would be described as the new "money crop" in the land between the rivers region.[134]

A meeting of the Between the Lakes Development Association was held at Kenlake Hotel, to develop a set of proposals for submission to federal and state officials. The proposals would suggest boundaries for the new park, and limits on the amount of land that could be purchased. The group wanted the proposals ready for the visit of Secretary of the Interior, Stewart Udall, who had just announced that he planned to visit the area on August 28, 1961. The members of the Between the Lakes Development Association did not attempt to stop the park project, but were very anxious about how much land the federal government would decide to take.[135]

On August 13, 1961, new information was leaked to the press. It reported that the recreational park would be named the Between The Rivers National Recreational Area, and would extend from a point two miles south of the canal connecting Kentucky and Barkley lakes to Paris Landing and Dover, Tennessee. The new plan was advanced by the National Park Service, and recommended the inclusion of 167,000 acres instead of the 140,00 recommended in the original proposal. The National Park Service suggested excluding the Kentucky Woodlands National Wildlife Refuge from the new park (some 63,000 acres), and continuing its operation under the United States Fish and Wildlife Service. The National Park Service wanted the southern boundary far enough south to allow inclusion of certain areas of significant historical value, thereby increasing the park's interest, and preserving those features for future generations. The Park Service wanted to include what was left of Fort Henry, and the two roads over which General Grant's army had advanced from Fort Henry to Fort Donelson.[136]

Conrad L. Wirth, Director of the National Park Service, announced that his agency's proposal was tentative, and certain parts of it could be modified. The National Park Service was already considering excluding some areas from the park. They intended to leave out Fort Donelson National Military Park, Fort Donelson National Military Cemetery, the town of Dover, the Pumpkin Ridge section of Stewart County, the towns of Golden Pond and Fenton, and a corridor along U. S. Highway 68. Wirth said that several boat docks, fishing facilities, and motels in the area would also be omitted. Also, along Highway 68 there were several sites already developed by private investors that might not be included in the final proposal. Further study, said Wirt, could identify other areas to be excluded. He pointed out that the National Park Service was considering permitting continued agricultural use of some of the land. These areas would be considered open places in the park, and could be privately owned. An alternate option in the plan was a suggestion that the government purchase the farm land and allow the residents to remain on the land for a specific number of years or for the duration of their lives.[137]

Major newspapers in Tennessee were in favor of the park. As one stated, "This rose by any name will smell sweet."[138] They believed the park would be an economic asset to Tennessee and

Kentucky, especially to those people living in the land between the rivers. Residents would find "legitimate employment" serving the sportsmen and tourists who would visit the park.[139]

The original proposal was to allow commercial recreational development to flourish side by side with public development. Several Kentucky newspapers pointed out that it had taken little more than a month for the park proposal to receive the endorsement of the President, and was currently being readied for submission to Congress. The proposal had moved quickly, with little opposition, because the National Park Service was receptive to the idea that private commercial development could occur in the park. At least one newspaper, however, wrote of its concern that the exact plans for the park had not been made public, and that people living in the land between the rivers could be hurt if forced to sell their land to the government.[140] Other writers suggested that no one could stop the development of the park because projections indicated that the annual gross income to the area would be at least twenty-five million dollars, and a few individuals must not be allowed to stand in the way of such prosperity for so many people.[141]

Residents learned from newspaper accounts that the invitation to Secretary of the Interior Udall to visit the proposed park site had been extended by Herbert Vogel, Chairman of the TVA Board. After Udall accepted the invitation, Vogel sent one to Undersecretary of the Interior, John Carver, who also accepted. Governors Burt Combs and Buford Ellington told the press that they would attend the meetings. The press reported that the visit would include a dinner at Kentucky Dam Village State Park, where a speech would be delivered by Conrad Wirt, Director of the National Park Service. On the following day a meeting would be held at Paris Landing State Park, with Governor Ellington presiding at a noon luncheon. Following a press conference, the group would tour the area by car and plane.[142]

As details of the meeting were arranged, it was decided that Udall would fly from Washington to Fort Campbell, Kentucky, attend the opening session at Paris Landing at ten a.m., then hold a press conference in the afternoon. All state officials involved in the parks and recreational services in Kentucky and Tennessee were invited to the meetings. Local civic leaders were invited to attend the press conferences and general meetings arranged in Tennessee and Kentucky.[143]

By this time several members of the Between The Lakes National Development Association had already gone to Washington, D.C., to discuss the proposed park with their congressional delegations and Secretary Udall. At one of those meetings Ira Atkins, County Judge in Stewart County, voiced opposition to the proposal which would remove seventy thousand acres from his county's tax rolls. He told Secretary Udall that Stewart County had lost forty-five percent of its population, and the assessed value of its property had decreased by fifty percent, all because federal installations had already appropriated thousands of acres from the county. If another seventy thousand acres were lost to the government, he feared the county would dissolve.[144] Although no public announcement was made at the time, Atkins and Udall reached a compromise on the location of the southern boundary of the park.[145]

Neither area residents nor public officials in Tennessee and Kentucky were sure of the exact plan the federal government intended to follow. When Governor Buford Ellington was questioned in detail about what Tennessee wanted included in the park, he admitted that he was waiting for the meeting with Udall to find out what the federal government intended to do. Ellington said he was a bit confused about whether the facility would be a park or a recreational area, and that he still thought it possible the federal government would not develop the park at all.[146]

Even as state officials were expressing doubt that a park would be created, Secretary Udall announced that he had no such doubts, because there was a pressing need for the facility. He said that the country had too few national parks in the eastern and central portions of the country, and LBL's central location made it quite attractive. Udall went on to say that his upcoming meeting with people in Tennessee and Kentucky, scheduled for August 28, was to determine the exact nature of the proposal.[147]

Looking back on the speeches, interviews, and discussions of August 1961, it seems clear that TVA officials understood President Kennedy when he talked in terms of obtaining land for the preservation of natural resources and the protection of the beauties of nature. Kennedy clearly was not concerned with creating resort areas or playgrounds, but with establishing several protected areas.[148]

Announcements from state officials continued to create misunderstandings. Secretary Udall promised (on August 28, 1961) that the Kennedy administration would work to have a concrete recommendation for establishing a park ready for the next session of Congress. He emphasized that if plans were completed and accepted, the federal government would use every means to soften the impact on landowners. When questioned about his attitude toward the proposed park, Udall said he supported it, and would recommend that development be turned over to the National Park Service. When asked about the type of facility he favored, he said that certain standards had to be observed and they must guard against the "honky-tonk type of private development."[149] Though obviously vague about the developing plans, it was clear that Udall would not recommend that people in the land between the rivers be allowed to develop recreational facilities in the park.

At the August 28 meeting at Paris Landing State Park, Smith Broadbent, Jr., submitted questions to Udall about the extent of private development to be allowed in the park, and asked if the government would permit landowners to remain in the park area. Udall said that the general tenor of the questions was "good and constructive" and he saw nothing in the Association's policy of protecting people in the land between the rivers that would be a stumbling block in the development of the park. He anticipated few problems involving the dislocation of residents and the development of private enterprise. When questioned further about farmers in the area, Udall pointed out that the plan was to allow farmers to remain in the area, and he had no trouble with that.[150] Most people in the land between the rivers concluded that they could remain on their land. In retrospect, however, it is clear from the answers Udall gave at the meeting that he made no direct promises to that effect. His remarks were vague, and careful listeners realized that they provided no clear answers to their questions.

On September 15, 1961, the Advisory Board of the National Park Service recommended the establishment of a national recreational project to be known as the Between The Rivers National Recreational Area (thus retaining the historical name for the region). Its recommendation was to include approximately 140,000 acres of land in the land between the rivers region. The next step was to draft and submit the proper legislation at the next session of Congress, scheduled for January 1962. Representatives Ross Bass and Frank Stubblefield met with some citizens of the river area. The meeting was characterized by an obvious lack of communication. Residents wanted to know the exact boundaries proposed for the park, and what provisions had been made to allow them to remain on their land. They were told that the towns of Grand Rivers, Golden Pond, Model, and Dover were to be excluded from the park, and roads serving these towns would be exempted as well. For several months, people in the land between the rivers were led to believe that plans for the park had been established. But in May 1962, the news media in Tennessee and Kentucky reported that the bill to establish the park might not get through Congress during the regular session. This report caused much consternation among people in favor of the project, and they discussed the great loss to the economy if the National Park Service did not develop the project.[151]

True to predictions, the legislation necessary to create the Between The Rivers National Recreation Area did not get through Congress. But on January 3, 1963, Representative Ross Bass announced that the Tennessee Valley Authority would take over and develop the park. TVA did not have to wait for Congress to pass legislation to establish the park. Under existing law, TVA could establish the park, begin developing lands under its control, and then ask Congress for funding to complete the project. On January 3, spokesmen for TVA said they had not been informed of the proposal, but were eager to develop the park if given the responsibility. Paul Evans, Director of Information for TVA, said the agency was waiting for authorization to take control of the park proposal, and even though that authorization had not yet been received, TVA had already planned to submit a request to Congress for the funds needed to complete the project.[152]

Some people reacted to the change in plans with delight, but others had many questions they wanted answered. Frank Stubblefield was one of the first to ask if TVA would compromise on the park boundaries. He was concerned that TVA had not agreed to allow private development in the area, and had not met with citizens to determine who could remain and who would be forced to leave. He asked, in the event that TVA decided to remove everyone from the proposed park, what procedures the agency would follow in relocating the people.[153] Within a few days, people in the land between the rivers were demanding answers to their questions.

The chairman of TVA's Board of Directors, A. J. Wagner, announced on January 9, 1963, that the agency would be glad to develop the proposed park, but he would not comment on any TVA plans for it. He did say that plans for the park had not been settled. A group of residents, representing the five thousand citizens of the land between the rivers, sent a message to Kentucky congressmen asking them to halt all plans for the purchase of any land for a national recreational area. The people questioned the right of the government to force citizens off their land in order to create a recreational area. They were aware that TVA had taken charge of the park's development, and noted that TVA had the reputation of putting projects before people.[154]. Finally, residents were frustrated because they could get no answers to their questions.

Wagner spoke to the Kiwanis Club of Clarksville, Tennessee on April 3, 1963. He outlined the positive effects TVA had produced in the Tennessee Valley, and said that the proposed park was an excellent opportunity to demonstrate a new and unique program. The area would be a "conservation classroom" and provide an ideal recreational and educational facility for millions of Americans in a part of the country where "few acres have been set aside for outdoor recreation."[155] For the first time, TVA officials began to talk about the learning experiences LBL would offer. TVA's decision to stress the educational potential of LBL was a wise one. The earlier emphasis on recreation entailed problems of legal authority; citizens denied TVA's authority to take land for use as a "playground".

On June 14, 1963, President Kennedy told several people, including Representative Frank Stubblefield and Senator John Sherman Cooper, both of Kentucky, that TVA had been directed to take control of the Between The Lakes project. TVA would create a national recreational area as a demonstration in resource development. When asked about specific plans for the area, TVA's response was that planning at that time was general and tentative, and specific plans could not be finalized until Congress had appropriated funds for the project.[156]

On June 19, 1963, the U. S. Bureau of the Budget added four million dollars to its recommendations for funds for the Tennessee Valley Authority. TVA announced that it would use the money to begin buying land in the new Land Between The Lakes recreational area. At this time the historical name for the region was lost, and the new name, Land Between The Lakes became official. TVA announced that when Congress appropriated the money, four basic steps would be taken to organize the Land Between The Lakes: 1.) the land would be mapped; 2.) property ownership would be established; 3.) a policy of land acquisition would be determined; and 4.) some development would be started on Lake Barkley before all the LBL land had been acquired. TVA estimated six months would be needed to get organized, but even before then they intended to have some of the boat dock facilities ready for use.[157]

Citizens in the land between the rivers tried to convince TVA officials to allow them to remain in certain sections of the area. In July they wrote a letter to TVA, requesting that citizens not be forced to sell their land. They wanted TVA to purchase land only from those owners wishing to sell. TVA was reminded that the government already had in its possession ample land for the development of an outstanding recreational area. Since TVA did not need all the land, residents wanted private property owners to remain in the area, with TVA zoning the land to control the types of facilities constructed in the future. TVA's claim that the land in the region was devoid of economic value and unfit for farming was challenged by the people, who asserted that land along the shoreline was ideally suited for private development and, in many cases, farming. The letter informed TVA that little of the land was owned by absentee landlords, and in most cases had been in the owner's family for generations. Citizens were anxious about how TVA intended to develop the area, and how that development would affect the counties involved.[158]

On July 13, 1963, TVA announced that even though detailed plans for the development of the Land Between The Lakes project had not been completed, the agency had tentatively agreed to forbid any type of lodging, restaurant, or resort facilities in the area. TVA was interested in the development of a variety of campgrounds, picnic areas, and other outdoor facilities in both the interior, and along the shoreline of the park. A five-year plan for the area was under development, with an estimated implementation cost of thirty-two to thirty-five million dollars.[159]

Recreation, according to TVA's definition, would include only those activities that could be pursued by tourists who wanted to visit a wilderness area. If the people wanted to find lodging, food, drink, or supplies, they would have to go outside the 170,000 acre facility. They could then return to the camping areas, but the wilderness environment would be protected.[160]

Aubrey J. Wagner, chairman of the TVA Board, announced that the agency had worked with several universities in surveying industries to determine what those industries looked for in the local governments of prospective sites. TVA was trying to induce industries to move into the regions surrounding LBL, and concluded from the survey that the counties involved needed to "perform well the regular functions of government."[161] The directors of TVA were quick to point out that the Land Between the Lakes project was significant because it symbolized the strides made by people in the Tennessee Valley region in "grasping the boundless potential to be realized from the very real recreation business."[162] What the residents of Stewart, Lyon, and Trigg counties wanted, however, was an explanation of how LBL would help them provide better government, since much of their property tax base would be lost when the federal government took the land. County officials argued that it was only a promise that industry would move into the area and bring in more revenue, and estimates of how much money tourists would bring into the region were pure speculation by TVA.

Michael Avedisian, a Paducah attorney representing a group of citizens in LBL, appeared before the Senate Appropriations Subcommittee and asked that TVA be barred from acquiring about 4,000 acres of land along the canal connecting the two lakes. He said TVA would still have some 170,000 acres in the development, and the canal-front acreage, which included farms, businesses, and subdivisions was not needed in the recreational park.[163]

THE TROUBLED BIRTH OF LBL

On January 3, 1964, TVA announced that acquisition of property for the LBL Recreational Area would begin in early spring. An estimated 250 locally hired workers would begin building harbors and other waterfront facilities. These projects were to be completed before the adjacent Lake Barkley was impounded. It was estimated that at least five years would be needed to complete the initial phase of the project, at a cost of thirty-three million dollars.[164]

On January 16, 1964, TVA announced that it would be ready to begin buying land for the LBL National Recreational Area on March 1, 1964. All land between Kentucky Lake and the yet-to-be-filled Barkley Reservoir, from near Grand Rivers, Kentucky, to the southern boundary (generally along U. S. Highway 79) would be purchased. The area would include approximately 103,000 acres which were privately owned, and 67,000 acres already owned by the federal government. January 1, 1968 was the target date by which all land in the area was to have been acquired. Landowners were promised that TVA would help in their relocation.[165]

Landowners in the area were informed that they would usually be allowed to remove any structures on their properties. Structures not removed by the seller or used by TVA would be offered for sale at public auction or by sealed bids, and then removed.

Information about the exact positions of the southern and northern boundaries of LBL was released on January 17, 1964. The southern boundary would run from the Scott Fitzhugh Bridge on Kentucky Lake, eastward along the north side of U. S. Highway 79 to Bear Creek, some four miles west of Dover. There the boundary would leave the highway, and extend generally northeast along the southern slope of the ridges south of Bear Creek, to reach Lake Barkley at about mile 86 on the Cumberland River. The northern boundary would follow the canal linking the Tennessee and Cumberland rivers. The old towns of Golden Pond and Model, and the growing, newer settlement of Twin Lakes, would be purchased by TVA. Highway 68 would be kept free of commercial development as a wilderness road through the Land Between The Lakes.[166]

Thus the people in the land between the rivers had their worst fears realized. The land they fought so hard to keep was now lost, and many would not receive what they considered a fair price for it.

TVA assigned four officials in the Division of Reservoir Properties as supervisors for the Land Between The Lakes area: R. M. Howes, Division Director; W. R. Holden, Assistant Director; Harold Van Morgan, Director of Recreation Staff; and W. Sherril Milliken, Resource Development Officer. They were to begin work immediately in the Land Between The Lakes region. Milliken was also to serve as liaison officer between TVA and the people and organizations of the area.[167]

In 1964, people in LBL were mystified by all the talk about the thousands of tourists who would rush into the wilderness area. One farmer grimaced and said, "They'll have to put a bounty on rattlesnakes first."[168] People surely would not camp with snakes crawling around. Others, who had visited state parks in the region and never seen them full of people, were pessimistic about the number of acres in the park. One resident asked: "Why would people drive from St. Louis to be chased off by snakes and bugs?"[169] Probably the most common complaint was that TVA had failed to adequately inform people about its plans for the region.

People in the land between the rivers were angry and resentful because they had been led to believe that the National Park Service would be the agency responsible for the park's development. The National Park Service had agreed to let the people remain on their land if they wished, and now another federal agency, from which they had extracted no agreements, had been given responsiblity. The people felt betrayed, and saw the switch in agencies as a devious device to allow the taking of their land without consulting the people or their representatives in Congress. Surely, they felt, the U. S. Congress would not allow any government agency to force citizens to sell their land to serve only recreational purposes. Moreover, if the bill to establish the park had been sent through proper channels, TVA would never have been involved in the park program. In their view, TVA had stepped in where it did not belong and denied the people any voice in determining the type of park that was to be created.[170]

One fundamental question voiced by LBL residents was whether or not TVA had the authority to get involved in the recreation business. They thought TVA's concerns should be limited to electric power, fertilizer production, and flood control, and should not extend to the development of a public playground. TVA officials knew that people in the LBL region were distraught, and they expected trouble when they set about determining property lines. But when TVA representatives came into each community, they were amazed at how polite--in some instances even friendly--the people seemed. What officials may not have realized was that these people were forced by their culture and traditions to be courteous. The people knew that TVA employees had not made the decision to remove them from their land, and consequently these "hired workers" were not to be blamed for the people's great loss.[171] TVA officials though, did not seem to realize how angry the people were, and that they perceived TVA to be the enemy. The agency was about to face a difficult period in its public relations.

In January, 1964, President Lyndon Johnson asked for more funding for the LBL project. It was then learned that TVA intended to acquire two church camps south of the canal, and a black settlement usually referred to as "New Chicago". When local newspapers reported that more money had been appropriated so that TVA could buy the additional land, the Trigg County Chamber of Commerce called a special meeting, and prepared to fight the TVA program. Members attending the meeting on January 20, 1964 accused TVA of breaking a promise made earlier when they had agreed to consult with the people before making final decisions. Bob White, Publicity Chairman for the Chamber of Commerce of Cadiz, said at the meeting that the people needed to arrange a meeting of the directors of TVA and the county officials of Trigg and Stewart counties, in hopes that they could "forge a statement of joint objectives." [172]

Citizens of Stewart, Lyon, and Trigg counties met on January 29, 1964, to discuss strategy and methods of protest to be used to stop TVA from acquiring all the land in the Land Between The Lakes. The protest meeting was held at the Golden Pond School. School and tax officials from the three counties presented estimates of the effect that the loss of population in the counties would have on schools and county governments. Schools would suffer not only a loss of students and teachers, but also of revenue from the state and federal governments. Tax assessors outlined the loss of revenue from the lands that would be taken by TVA. The group listened as Michael Avedisian told them of his earlier attempt to argue, before the Senate Subcommittee, the case for his clients who lived near the canal. He suggested that TVA might not have legal authority to take their property, knowing that property had enhancement value in the near future. During the discussion, it was generally acknowledged that in the past TVA had been an asset to the region, and most landowners would not be opposed to selling their land if it served the general welfare of the local people. But most also agreed that TVA had sufficient land already to provide a playground for the eastern United States.[173]

J. H. Wiseman, Lyon County Court Clerk, wrote several letters to First District Congressman Frank Stubblefield, pointing out that Lyon County would be forced to close down its county government if TVA took all the land it proposed to take. He said that the Corps of Engineers had told him in 1958 that Barkley Dam was needed for progress. While conceding that possibility, he wanted to know, "Was the construction of camp grounds and camping sites progress?" To Wiseman it seemed absurd for people to have to give up their homes, businesses, schools, churches, and farms, just to provide a place for people to come and be bitten by rattlesnakes and mosquitoes. Wiseman asked Stubblefield to force TVA to prove to Congress that <u>all</u> the land in the area was needed for the park. Perhaps his most compelling statement came near the end of the letter, when he related details concerning the earlier fate of some 8,076 acres of land purchased by TVA for the Kentucky Dam. Wiseman said that TVA had bought the land for as little as five dollars an acre. Later some roads were graveled through it, two subdivisions were established, and 217 acres auctioned off to individuals at prices ranging from $200 to $2,325 per lot. To Wiseman, this was profiteering by a government agency, and there was nothing to prevent a recurrence in the Land Between The Lakes project; land in LBL would become increasingly valuable as years went by, and the government might simply hold the land until prices increased and then sell it.[174]

Although residents continued to hope for some relief, the future they faced was vividly demonstrated in February, 1964, when bulldozers and demolition crews began to remove homes and public buildings in Eddyville, Kentucky. This action was one of the last stages involved in preparations for the impounding of

Lake Barkley. With a sense of great loss, people watched as the buildings were razed and foundation stones of historic sites were torn from the ground. It did not seem possible that Chittenden Lyon's historic LaClede Hotel, a reproduction of an old English Inn, could be destroyed. The hotel had many famous guests, including Andrew Jackson, Henry Clay, Jenny Lind, and Peter Cartwright. Just as traumatic was the destruction of the newspaper building. Eddyville was one of the first towns in Kentucky to have a newspaper when Matthew Lyon and his son James purchased a printing press from Benjamin Franklin and brought it to Kentucky. The Lyon family had even manufactured their own newsprint from linden trees growing along the Cumberland River. Though the old press was salvaged, the building was destroyed. (Bricks from some of the older buildings in Eddyville were saved and later used as a veneer on the Visitor Center Museum in the Kentucky Woodlands National Wildlife Refuge.)[175]

A dramatic change in the mood of many local people was apparent at a public meeting held at a school in Trigg County on February 3, 1964. There was talk of "open warfare" and "violence of any kind" to protect their property. The statements were packed with emotions, and the word "communistic" was used to describe TVA's actions. People accused TVA of resorting to "political takeover", and vowed to take their case to the U. S. Supreme Court rather than allow confiscation of their land. They were also angry that TVA and some newspapers had "made fun of us" in describing the "stingy lands" in LBL. They also resented the media's portrayal of them as poor and unable to make a living on the land. Many agreed to deny access to their property to all unauthorized TVA employees.[176]

Rather insensitively, TVA announced on February 4, 1964, that appraisers would proceed to inspect land and buildings in Land Between The Lakes. Within a few days after inspection, the landowner would be informed by letter of the appraised value of the property. Landowners were urged to accompany the appraiser during property inspection. If the TVA offer was unsatisfactory, the landowner could refuse to accept it. In the case of refusals, however, TVA would petition for a condemnation of the property. January 1, 1968 was announced as the date by which TVA planned to have taken possession of all property in LBL. The tone of the announcement made it appear that TVA officials were unaware or unconcerned about the growing resentment and hostility among residents.[177]

Congressman Frank Stubblefield realized that many of his constituents were angry with him for not speaking out against the amount of land that TVA intended to take. Pressure to do this became so compelling that on February 7, 1964 he sent a strong protest to Aubrey J. Wagner. In it he wrote that TVA had led him to believe that Golden Pond, Twin Lakes, and a four-mile-wide corridor along Highway 289 running north from Highway 68 would not be purchased by TVA. He said he was "shocked" when he learned that these areas were to be taken by TVA.[178] Stubblefield sent a copy of his letter to Judge Francis Utley, urging him to encourage the citizens of Trigg, Lyon, and Stewart counties to continue their protests. The citizens took Congressman Stubblefield's advice and organized another meeting. The meeting was held at Golden Pond on February 16, and the people planned a tri-county protest. The major concern expressed at this meeting was that TVA had deliberately "deceived the residents who lived between the rivers." They had been tricked into believing that the recreational area would be limited to the 67,000 acres the government already owned. The protesters sought ways to delay the TVA plan to appraise the land, thus allowing residents more time to explore legal avenues they could use to stop TVA.[179]

TVA proceeded with its plans, in apparent disregard of the residents' concerns. The first workers were hired and work began on February 19, 1964. Thirty men began planting 600,000 pine seedlings on a six-hundred-acre tract in the Kentucky Woodlands National Wildlife Refuge. The tri-county group of protesters continued to hold meetings, and write letters to congressmen and senators. Judge Utley went on WPSD-TV to discuss the concerns of citizens in Lyon, Trigg, and Stewart counties.[180]

It was not until February 20 that TVA appeared to recognize the strong resentment that people in LBL felt toward the agency. On that date TVA announced that the three counties affected by the LBL project would not suffer financial loss because of the project; any tax revenue lost by the counties would be offset by tax-replacement arrangements. The people were told that TVA had already completed a detailed analysis of the county tax rolls, studied the assessed valuation of property to be purchased, and determined that TVA purchases represented only about eight percent of the county revenue base in Trigg County, ten percent in Lyon County, and twelve percent in Stewart County. However, according to TVA, the taxes on those properties provided only about two to three percent of the total revenue for those counties.[181]

It was announced on February 21, 1964, that President Johnson had been asked by Kentucky senators John Sherman Cooper and Thurston Morton to stop TVA from buying any more land in LBL until residents of the area had time to protest. Both senators agreed that TVA was taking more land than was needed for a recreational project. While the people waited to see what President Johnson might do about the request, Judge Utley, speaking for the tri-county organization, informed TVA that the people were not ready to accept its promises. "The road to Hades is paved with good intentions" said Judge Utley. TVA was not known for keeping its promises, and the county governments were near bankruptcy. Utley noted that in 1963 TVA had paid Lyon County $384.00, in lieu of taxes for approximately eleven thousand acres of fertile Tennessee River bottom land purchased for the Kentucky Dam reservoir.[182]

In response to a TVA statement that the counties would save money when they no longer had to provide services to the people in the land between the rivers, Judge Utley retorted that the statement was an insult "to the intelligence of a moron. Why not justify it by destroying the three entire counties and thereby save one hundred percent of operating costs?" He contested TVA's claim that the land "was thinly populated." Utley maintained that the land held by private individuals was rather densely populated, and that TVA's claim was based on calculations which included approximately 100,000 acres of government land where people were not allowed to live.[183]

In March, 1964, TVA began for the first time, to inform the public about LBL projects via news releases and presentations. TVA spokesmen, visiting civic organizations outside the LBL area, discussed proposals for the project, and provided news releases about their speeches to newspapers and TV stations. Each such speech or news release began with a statement saying that the agency intended to spend at least thirty-five million dollars in the area over the next five years. The LBL region had been chosen, TVA claimed, because the area "could no longer support the people", and in fact "The land had not really supported the people since the Indians left."

In news releases TVA shrewdly emphasized the positive, thereby garnering support for the project outside the region. It announced, for example, that workers were already planting pine trees so that the area would have some winter color. Hunters would be able to use the area for both large and small game hunting. Land Between The Lakes would be an unusual park, emphasizing recreation rather than preservation. Plans included five thousand campsites to accommodate twenty thousand campers per night. More campsites would be added as plans were developed. A model farm was proposed for demonstrating farming activities of the past. Aquatic biology laboratories would be established, and buffalo eventually brought to the park.[184]

The paternalistic tone which colored TVA's publicity about its plans for LBL infuriated and humiliated many people living in the region. Women carrying picket signs appeared in Twin Lakes at a meeting TVA had called for discussing land purchase procedures. The signs read, "TVA GO HOME", "WE WEEP FOR OUR HOMES", "LEAVE US OUR LAND AND TEND TO YOUR OWN DAM BUSINESS", and "WE WANT TO BE FREE Of TVA." After about an hour, the picketers left. Though it had taken several months, TVA officials were finally forced to acknowledge the extent of the residents' opposition.[185]

Aubrey Wagner, TVA's director, delivered a speech in Memphis in March in which he indicated that recreation was one of

TVA's goals. He said, "Recreation has become a very real business in the Tennessee Valley Authority's region in western Kentucky and Tennessee." More than $150,000,000 in public and private monies had already been invested in recreational equipment and facilities developed along TVA reservoirs, and hundreds of millions of tourist dollars were attracted to the area every year. TVA was committed to developing a "new recreational tool" which would bring even greater benefits to the area and to the nation. For the first time since the controversy had begun months earlier, Wagner explained why TVA felt it had to acquire all the land in the Land Between The Lakes. He explained that TVA had chosen the "natural boundaries" for the area. Within these "natural boundaries", TVA could create "a unique area set apart for complete development of the woodland environment," and effectively protect the "back-to-nature atmosphere." If any land were left in the hands of its present owners, "the inevitable souvenir shops and commercialism would destroy the character" of the land.[186]

From the spring of 1964 to the spring of 1965, TVA was busy requesting funding in order to continue development of the LBL area. The term "recreational" seemed to arouse some interest among members of the 88th Congress. On July 2, 1964, the U. S. Senate had read into its proceedings an item dealing with TVA and its plan to acquire additional land. The item stated that TVA had a history of being a crown prince in dealing with private citizens, but that lately the crown prince had turned into a tyrant. The tyrant was planning to build a park, and in the process destroy three towns, each with a history dating back to the earliest settlement of Tennessee and Kentucky. Over the protest of the citizens of these towns and the adjoining rural areas, TVA was taking the land, homes, and churches to built...a playground .[187]

On April 27, 1964, TVA announced that Dr. Milton Garbrielson of New York University, a nationally recognized authority in the field of outdoor recreation, had been hired as a consultant. Dr. Gabrielson declared the LBL Project to be "potentially the most significant single development of outdoor recreation" to occur in this century.[188] Dr. Gabrielson held the title of Director of Recreation and Camping Education at New York University, and it appeared that he would assist in the planning of campsites in the LBL project. When the budget appropriations for TVA ran into difficulty in the U. S. Senate in 1964, however, Dr. Gabrielson changed his approach and began to talk about LBL as a place where formal and informal opportunities would be provided for education. TVA planned to develop a "vast outdoor classroom" to teach conservation and related subjects.[189]

On August 7, 1964, the Senate deliberated over Title IV, TVA's request for almost forty-eight million dollars (the request did not include three million dollars which had been cut by the House of Representatives). It was pointed out that some five million dollars had been included in the appropriation request by TVA, and that that money was to go to the Land Between The Lakes project. The original request for the project had been six million dollars. By this time two senators questioned TVA's involvment in an extensive recreational project. Senators Vance Hartke of Indiana and Allen Ellender of Louisiana suggested that TVA might not have authority to develop LBL for recreational purposes. Senator Ellender, Chairman of the Senate Appropriations Public Works Subcommittee, questioned the legality of TVA appropriating land for recreational purposes. Ellender wanted to know why, when TVA officials submitted their budget request in 1964, they entitled the request "The Land Between The Lakes Demonstration Program", while the original title of The Land Between The Lakes Recreational Area was still being used in most of their messages. He said that he felt there was a "substantial" question whether the development was authorized. If the development was to be, "a simple study, an experiment or demonstration necessary and suitable to the making of plans" useful to Congress and the several states under Section 22 of the Tennessee Valley Authority Act of 1933, then TVA would be authorized to request funding. Senator Ellender then asked whether or not TVA was developing the project to provide recreation. If, in fact, that was the end result of the development, then in his opinion TVA did not have authority to continue the development. He said that he believed "their own testimony convicts them on this score."[190]

Senator Ellender stated that the project should have been under the control of the National Park Service, not the Tennessee Valley Authority. He was concerned because in the past TVA had acquired land by condemnation, sold the land to private investors, and made profits on the sales. It was not the intent of Congress, stated Senator Ellender "to acquiesce in the condemnation of private lands, for subsequent disposal to private interests, according to the whims of a bureaucrat." TVA was charged with trying to enter "into a new sphere." Ellender believed TVA had authority to provide for studies in reforestation, the best use of fertilizer, and things of that nature, but it did not have the authority to "embark on a new program that involves the purchase of land for the purpose of developing a national recreational area."[191]

After lengthy debate, Section 22 of the Tennessee Valley Authority Act of 1933 was read into the record. An outline of the historical background of TVA's involvement in the Land Between The Lakes Project was discussed, and several letters from citizens in the area were read into the record. These letters contained complaints about how TVA officials had handled the land surveys before a purchase offer was made. The people claimed to have been threatened, and said that surveyors had sneaked onto their lands without permission of the owners. Also included in the letters was a list of the real property owned by the United States in Kentucky and Tennessee as of June 30, 1963.

The list showed that the federal government owned 4.2 percent of the land in Kentucky and 5.8 percent of the land in Tennessee. TVA owned 441,296.4 acres of land in Tennessee and Kentucky. Tennessee ranked third in the United States in the value of federally owned real property within its borders, and Kentucky ranked twelfth. Ultimately, the appropriation bill was passed, but TVA had gotten a clear message that programs designed for the Land Between The Lakes needed to be reevaluated.[192]

Concerns expressed by some senators about TVA's actions in LBL alerted many people to the precarious position that TVA would face if other opponents of the whole concept of the Tennessee Valley Authority were to join in the debate. Newspapers seemed concerned that the agency's policies had been questioned, and many editorials supported the acquisition of all the LBL land. They warned that if people did not stand up and fight for the LBL project, they were going to lose it, along with the millions of dollars that increasing tourism and new industry would have brought into the region. The mood of the people outside LBL had apparently shifted, and opponents of development were accused of standing in the way of progress and prosperity for the whole region.[193]

Most newspaper articles and editorials were now clearly in favor of the TVA program. According to the articles, people being forced off their land would get a fair price for their property, and be assisted in finding a better place to live. The attitude seemed to be that the future of TVA was more important than the future of a few residents of the land between the rivers. People living in the land between the rivers were hurt and angered by what they considered a complete disregard of their legal rights in the matter. The news media seemed unconcerned that individuals were protesting that their rights were being violated by TVA. To the people in the land between the rivers it seemed that their friends living outside the area had turned against them.[194]

The larger newspapers in Kentucky and Tennessee called upon the senators from both states to support the Land Between The Lakes project, and accused them of "sitting there tranquilized" while the enemies of TVA tried to "destroy" the agency. The senators, warned to wake up and support park development or be held accountable by the citizens, responded almost immediately. They sent messages back to Kentucky and Tennessee stating that they had talked with Senator Ellender, and were sure that he now understood that the people of Tennessee and Kentucky supported the Land Between The Lakes project.[195]

Officials in Kentucky and Tennessee seemed to have finally accepted Land Between The Lakes as a reality, and they began to concern themselves with the question of how to use the area to their advantage. Kentucky newspapers gloated that their state had started early to develop highways which would funnel tourists into the area. Tennessee, they said, had been out-maneuvered because it had not developed an adequate highway program to take full advantage of the Land Between The Lakes. Judge Ira Atkins of Stewart County was quoted as saying that because Tennessee had not planned roads into Stewart County to allow easy access to LBL from the south, that both Tennessee and his county would lose much of the tourist trade to Kentucky.[196]

In the spring of 1965, Tennessee was heavily involved in a proposal to straighten and widen Highway 79, which formed much of the southern boundary of LBL. Stewart and Henry county officials wanted Tennessee to replace the Scott Fitzhugh Bridge over the Tennessee River and the Sidney Lewis Bridge over the Cumberland River at Dover. They explained that Highway 79 served the only southern entrance to LBL, and the state must be concerned that people would enter LBL via Kentucky if Tennessee did not provide adequate roadways. In spite of their entreaties, the Tennessee State Legislature waited almost two decades before appropriating money to improve those sections of the road.[197]

Spokesmen for TVA announced in 1965 that as soon as funding was available, they hoped to develop an aquatic science center, a nature craft center, a fish management demonstration center, a natural science museum, camp craft demonstrations, reforestation and soil conservation demonstrations, hiking trails, trails for disabled persons, a weather station, and other facilities. Dr. Gabrielson suggested it might be possible to include a national leadership training center for outdoor education. Conservation teachers, planners, and administrators would be able to come to a park well equipped with facilities for learning. Approximately two hundred camping centers for small groups, as well as facilities for larger organizations such as the Scouts and YMCA, would be available. TVA needed this new approach to counteract earlier criticism it had received. If TVA did not have the legal right to get into the primary business of recreation, it would make recreation a secondary goal for LBL. People would still come for the camping and water sports, but they would have the opportunity to learn many things about nature and their environment while in the area.[198]

TVA spokesmen said they agreed with the 1962 report of the Outdoor Recreation Resources Review Commission that, "the chief reason for providing outdoor recreation is the broad social and individual benefits it produces. Recreation demonstrations also bring about desirable economic effects." TVA had finally touched the right chord when it brought the long-range goals of recreation in with the economic benefits it could provide for the people.[199]

The Recreational Development Project was now within the guidelines of Section 22 of the TVA Act which said that TVA had authority to further the proper use, conservation, and development of natural resources, and to provide for the general welfare of citizens in the area. All that was needed was for the President to request funding and Congress to approve the money.[200]

TVA began to demonstrate its intent to turn LBL into a learning laboratory. The agency was determined to provide a model for the most effective means of developing a recreation area. Plans were drawn for and construction begun on a Conservation Education Center, described as "an adult activities center" which provided housing, meeting, and study facilities for students and teachers in conservation education. Dr. Henry S. Mosby, an expert on forestry and wildlife, and Dr. Leslie L. Glasgow, a noted author on wildlife and Director of the Louisiana Wildlife and Fisheries Commission, were hired as consultants to develop an extensive wildlife program.[201]

With access to some of the country's top authorities on recreation, and with abundant financial resources, TVA was able to develop some unique educational facilties. One example was an overlook built atop a silo which had been left on a farm. From it people could see deer, wild turkeys, waterfowl, and other animals. Schools throughout the region were invited to bring classes to the Youth Activities Station, and many elementary school children were brought there. Work was started on an educational farm. An arts and crafts building was constructed. Highway 453, known as "The Trace", was rebuilt, and a number of access roads were constructed to allow visitors to travel to the more remote areas of the park. Plans were developed to allow hunters to kill deer, squirrels, doves, rabbits, turkeys, and quail. A coon shake-out was allowed in 1967.[202]

TVA had won the fight. Citizens still living in LBL began to realize they would have to move by 1968. The "last stand" by LBL residents came on December 14, 1967, when Federal Judge Henry L. Brooks, in a lawsuit over twenty-eight acres of land owned by Blondall Lilly Flood and Robert F. Flood, ruled that TVA did have the right to acquire the land under the right of eminent domain. The lawsuit had charged that TVA's acquisition of the land was unnecessary, arbitrary, capricious, and in bad faith. TVA successfully argued that condemnation was proper under the commerce clause, the general welfare clause of the Constitution, and the TVA Act of 1933.[203]

TVA reported that in 1967 approximately 134,000 people visited LBL. Expectations were that in years to follow even more people would use the facilities. The predictions were correct. Residents of LBL who had expected to halt the acquisition of land had failed, and most now realized it was only a matter of time until they would be forced to leave. In the final stages of land acquisition, TVA handled negotiations with the people more diplomatically. It attempted to find new homes for the displaced people, and granted some extensions of time to allow people to make arrangements to move. Gradually, in late 1968, the last families moved from the area.

The land was finally deserted--except for one man who refused to leave his home. Cleo Griffin, born near Model in 1923, refused to leave his home even though TVA officials warned him that he would be removed, by force if necessary. His house was scheduled for immediate demolition, but Griffin was a man with a tough past and not a little grit. Cleo Griffin, who had attended Martin College before World War II, left school to serve in the army. He was sent to Italy and fought in the battle of the Anzio Beachhead. When he returned home, he enrolled at Murray State University. But the psychological effects of his battlefield experiences had taken their toll. He was unable to cope with the demands placed on him, and left school and went home to Model. There he spent most of his time in seclusion. He had been transformed from a young man with a bright academic future to a person who shunned strangers and crowds. TVA officials were distressed when their threats to use force made no impression on him. The family, especially his sister Mrs. Christine Whitford, worried about what might happen. "In the middle of the night TVA officials came to my home and told me to remove my brother from the house right then," said Mrs. Whitford. "My husband told them that he was not going to force Cleo out of the house. The Veteran's Administrations had heard of what they were trying to do to Cleo and stopped them."[204] Since then, Cleo has been left alone to live on his homeplace.

Of the five thousand residents of the land between the rivers, only one was finally able to defeat the attempts to remove him from his home. Today he lives alone in the wilderness called a park. Others who lived in the land between the rivers moved away, and found new homes throughout the country. But many have not forgotten their old homes. Each year a reunion is held by those who feel it necessary to come back to the land that was settled by their ancestors. And each year the number at reunions grows smaller. As the former residents of LBL die, their children and grandchildren do not feel the same impulses to keep in touch with friends and former neighbors. The old ways are slowly being forgotten by those who experienced the good times and the bad times in the land between the rivers. In not too many years none of the former residents of the land between the rivers will be alive to tell the stories of adventure and struggle that were the fabric of the culture in the land between the rivers.

NOTES

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[41]Court Records, 1839-1844.

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[51]Court Records, 1855-1857.

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[53]Ibid.

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[60]Census Records, 1840.

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[62]Ibid.

[63]Court Records, 1857.

[64]Court Records, 1860.

[65]Court Records, May 18, 1861. A total of 120 men were chosen.

[66]Ibid.

[67]Ibid., July Session.

[68]Ibid.

[69]Court Records, January Session, 1862.; Letters by J. C. Cook, Confederate Collection, Manuscript Account No. 801, Tennessee State Library and Archives, Nashville, Tennessee.

[70]Thomas A. Wigginton and The Civil War Centennial Commission, Tennessee in the Civil War (Nashville: Civil War Centennial Commission, 1964), 203-245.

[71]Court Records, 1862.

[72]Robert U. Johnson and Clarence C. Buel, eds., Battles and Leaders of the Civil War (New York: Century Press, 1887), 269-271.

[73]Broomfield L. Ridley, Battles and Sketches of the Army of the Tennessee Mexico, Missouri: Missouri Press, 1906), 6.

[74]Court Records, 1862.; J. C. Cook Letters.

[75]General Service Schools, Fort Henry and Fort Donelson Campaigns February 1862: Source Book (Kansas: The General Services Schools Press, 1912), 202-210. Hereafter referred to as the Source Book.

[76]Ibid.

[77]Ibid., 248-249.

[78]Ibid.

[79]Ibid., 250-252.

[80]Fred C. Ainsworth, Leslie Perry, Joseph W. Kirkley, The War of the Rebellion: A Compilation of the Official Records of the Union and Confederate Armies, vol. 1-7 (Washington, D.C.: Government Printing Office, 1898), 145. Hereafter referred to as O. R. Series.

[81]Ibid.

[82]Source Book, 109-110.

[83]Ibid.

[84]Ibid., 136.

[85]Ibid., 137.

[86]Ulysses S. Grant, Personal Memoirs, vol. 2 (New York: Webst 1894), 192.

[87]Source Book, 355, 521.

[88]Ibid., 268-273.

[89]Ibid.

[90]John Allen Wyeth, That Devil Forrest: Life of General Nathan Bedford Forrest (New York: Harper and Brothers Publishers, 1959), 32-40.; O. R. Series I., vol. 7, 175.

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[93]O. R. Series I, vol. 7, 239, 253.

[94]Ibid.

[95]Journal owned by Mrs. Goldie Barrow of Dover, Tennessee.

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[97]O. R. Series, II, vol 3, 267, 626.; Stewart County Times, October 28, 1927.

[98]O. R. Series, III, vol. 3, 272.

[99]Source Book, 451.

[100]O. R. Series I, vol 10, Part II, 680-681.

[101]Ibid.

[102]Court Records, 1865.

[103]Ibid.

[104]Court Records in Stewart, Trigg and Lyon Counties.

[105]Letters of Sara A. Kennedy, Civil War Collection, Box 10, Tennessee State Library and Archives, Nashville, Tn.; Letters by Charles C. Nott, J. Milton Henry Collection, Tennessee State Library and Archives, Nashville, Tn.

[106]County Records, 1865.; U. S. Census, 1900.

[107]County Records, 1900-1920.
[108]Stewart County Times, 1912-1922.
[109]Court Records, 1900-1932.
[110]Interview with Roy P. Wallace, Big Rock, Tn.
[111]Stewart County Times, article on whiskey and crime August, 1945.
[112]Ibid.
[113]Ibid.
[114]Roy P. Wallace and Rees Wallace visited relatives at Golden Pond, Kentucky from 1930 to 1940.
[115]The Nashville Tennessean. July 24, 1959. Article on the effects of TVA.
[116]Ibid.
[117]Ibid.
[118]Ibid.
[119]Sun Democrat. Paducah, Ky., February 5, 1960. An article on the slow development of industry in the Tennessee Valley.
[120]The Record, Cadiz, Ky., January 15, 1955, June 8, 1957.
[121]The Commercial Appeal, Memphis, Tn., January 22, 1964.
[122]Courier-Journal, Louisville, Ky., February 6, 1961.
[123]The Nashville Tennessean, February 3, 1961.
[124] Tennessee Valley Authority Technical Library, Knoxville, Tennessee. Copy of letter in files.
[125]Ibid.
[126]The Nashville Tennessean, June 22, 1961.
[127]Ibid.
[128]Courier-Journal, Louisville, Ky., June 25, 1961.; Leaf Chronicle, June 29, 1961.
[129]News Sentinel, Knoxville, Tn., July 7, 1961.
[130]Ibid.
[131]Times, Chattanoga, Tn. July 9, 1961.
[132]Sun-Democrat, Paducah, Ky., August 16, 1961.
[133]Press Scimitar, Memphis, Tn., August 13, 1961.
[134]Ibid.
[135]The Nashville Tennessean, August, 29, 1961.
[136]Sun-Democrat, Paducah, Ky., August 13, 1961.
[137]Commercial Appeal, Memphis, Tn., August 25, 1961.
[138]News-Sentinel, Knoxville, Tn., August, 1961.
[139]Ibid.
[140]Ibid.
[141]Leaf Chronicle, Clarksville, Tn., Sept. 1, 1961.
[142]Times, Kingsport, Tn., August 29, 1961.
[143]Ibid.
[144]Ibid.
[145]Ibid.
[146]Nashville Banner, Nashville, Tn., August 28, 1961.
[147]Ibid., August 29, 30, 31, 1961.
[148]Nashville Tennessean, August 29, 1961.
[149]Ibid.
[150]Ibid.
[151]Nashville Tennessean, May 10, 1962.
[152]Nashville Tennessean, January 3, 1963.
[153]Ibid.

154 Ibid. January 9, 1963.
155 Leaf Chronicle, Clarksville, Tn., April 4, 1963.
156 Sun Democrat, Paducah, Ky., June 15, 1963.
157 Sun, Jackson, Tn., June 20, 1963.
158 Times, Chattanooga, Tn., July 8, 1963.
159 Nashville Tennessean, July 13, 1963.
160 Ibid.
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162 Ibid., August 2, 1963.
163 Record, Cadiz, Ky., January 3, 1964.
164 Ibid., January 17, 1964.
165 Sun Democrat, Paducah, Ky., January 16, 1964.
166 Ibid.
167 Ibid.
168 Sun Democrat, Paducah, Ky., January 14, 1964.
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The Kentucky Prairie Barrens of Northwestern Middle Tennessee: An Historical and Floristic Perspective

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ABSTRACT

Extensions of the Big Barrens of Kentucky occur in parts of at least three northwestern Middle Tennessee counties. At the time of settlement, or in the late 1700s, the barrens were vegetated by grasslands interspersed with oak forests and swamps. Transeau considered these grasslands to be part of the Prairie Peninsula but many now believe that presettlement vegetation was not climax and was more likely fire-maintained. Most of the barrens are now under agricultural stress or have been otherwise so drastically altered that little remains of the original vegetation. Comparisons between the flora of northwestern Middle Tennessee barren remnants and that reported for the Kentucky Big Barrens show a high correlation (91 percent). Also, almost half of 200 species characteristic of the true prairie are known from these barren remnants.

INTRODUCTION

The poorly-drained, rolling to level lands of northern Montgomery, Robertson, and Stewart counties, Tennessee are part of an extensive area found mostly in Kentucky and referred to there as the Big Barrens or occasionally as the Kentucky Meadows. Settlers gave the name "barrens" to these and similar areas because they did not know the French word "prairie" and chose "barrens" over "meadows" or "glades" (Sauer 1927). However, most authors (e.g., McInteer 1942, 1946) assumed that "barrens" was used because of the lack of continuous forest and the belief that the soil was poor or barren. Also, due to a lack of surface streams, settlers believed that the barrens were extremely hot and dry and thus chose peripheral sites closer to timber and water for their farms and towns (Dicken 1935). Eventually it was realized that the barrens were agriculturally productive and those settlers arriving later often developed the best farms (Killebrew et al. 1874).

The vegetational significance of the barrens and other forest openings in eastern North America was pointed out by DeSelm (1986) and includes such factors as high endemism, disjunctions, endangered species, and species at or near the limit of their range. Obviously, such vegetation and landform types need to be preserved and maintained as examples of our natural heritage and biological diversity. However, this unique aspect of the Tennessee biota (i.e., that of the Big Barrens extension) has received little attention from state botanists. Unfortunately, most of the barrens have now been destroyed or altered due to cultivation, fire control, invasion by weedy (often introduced) species, development, or other factors, to the extent that few representatives of the original vegetation remain. Even so, it is important that present and, insofar as is possible, past conditions of this landform and its vegetation be documented.

The purpose of this paper is to (1) summarize conditions at the time of settlement, based on published accounts, (2) describe current conditions, and (3) compare the known flora of existing barren remnants with published lists for the Big Barrens of Kentucky and with indicator species of true prairie.

LITERATURE SUMMARY

The presence of barrens in various parts of Tennessee has been known since the first surveyors arrived (DeSelm 1975). As early as 1718, Guillaume de l'Isle, in his Carte de la Louisiane et du Cours du Mississippi, showed barrens north of the Cumberland River (Arnow 1960). After Andre Michaux, in 1802, noted floristic affinities between barrens and midwestern prairies (Shull 1921, McInteer 1942), the term "barrens" often became synonymous with "prairie" (Mahler 1970).

Several early Tennessee writers (e.g., Safford 1869, Killebrew 1897, Gattinger 1901) commented on barrens in various parts of the state and in 1935, when Transeau mapped the eastward extensions of midwestern grasslands (the well-known Prairie Peninsula), segments along the Tennessee-Kentucky border were included. The map of Dicken, also published in 1935, likewise showed prairie segments in that area.

Shanks (1958) outlined the floristic regions of the state and discussed three areas of barrens:

(1) Kentucky Prairie Barrens in northern Middle Tennessee, or essentially the area outlined by Transeau and Dicken. This area was considered to be floristically similar to prairies of the midwest, with few species of Coastal Plain affinity.

(2) Barrens of the southwestern Highland Rim. Open forests with many prairie species but without the extensive continuous stands found in the Kentucky Prairie Barrens.

(3) Barrens of the southeastern Highland Rim. Areas of often swampy flatlands containing many prairie species but also well-known for plants with Coastal Plain affinities.

Of these three areas, the southeastern Highland Rim barrens have received most attention. Gattinger (1901) described the flora of oak barrens around Tullahoma, and the nearby May Prairie was discussed by Keever (1971), DeSelm (1975), Quarterman (1975), DeSelm and Clebsch (1977), and Quarterman and Powell (1978). Results of prescribed burnings, and the literature on this area were summarized by DeSelm et al. (1973).

Barrens in other parts of the state have received some attention. DeSelm et al. (1969) described barrens and barren-like vegetation in the Ridge and Valley Province, and Quarterman and Powell (1978) discussed two areas in the Central Basin that showed both cedar glade and barren characteristics. Little is known about barrens west of the Tennessee River although Transeau (1935), Dicken (1935), and Kuchler (1964) showed extensions from the western Kentucky Purchase Area into northern West Tennessee. Braun (1950) noted that these barrens were similar to the Kentucky Prairie Barrens to the east. Risser et al. (1981) considered the Black Belt Prairie of Alabama and Mississippi to extend for a short distance into southern West Tennessee. Southwestern Highland Rim barrens have received little study but DeSelm (1961) reported on presettlement conditions there.

Since the synopsis of Shanks (1958), the most extensive study of Tennessee barrens is the ongoing work of DeSelm (1981), which was initiated in 1954. Raunkiaerian life form distributions and geographic relations have been presented for the flora of 77 sites, mostly from the Ridge and Valley Province, and nine other sites were reported under study (DeSelm 1981).

While little information is available on the northwestern Middle Tennessee barrens, much has been written on contiguous areas in Kentucky. Bourne (1820) noted that the Kentucky barrens have topographic and vegetational features in common with midwestern prairies. Garman (1925) indicated that the barrens flora had been largely replaced by weeds but included a list of characteristic species. Sauer (1927), Dicken (1935), and McInteer (1942, 1946) provided much information on boundaries, physiography, geology, presettlement conditions, and postsettlement changes. More recently Bryant (1977) and Quarterman and Powell (1978) gave information on extant sites, and Baskin and Baskin (1977, 1978) described small cedar glades in the barrens. Much of the historical information was summarized by Baskin and Baskin (1981), who also described current conditions, gave the results of several site studies, and presented their theories on relationships to the Prairie Peninsula.

THE NORTHWESTERN HIGHLAND RIM BARRENS OF TENNESSEE

Location and Characterization

The northwestern Highland Rim barrens of Tennessee

(Kentucky Prairie Barrens of Shanks) are the southernmost part of the Big Barrens of Kentucky, a crescent-shaped area extending from the Ohio River about 56 km west of Louisville, southward into Tennessee, and westward almost to the Cumberland River. The Tennessee extension is within the Highland Rim Section of the Interior Low Plateaus of Fenneman (1938) and the Mississippian Plateau of Braun (1950). Barrens are found mostly in northern Montgomery and Robertson counties and northeastern Stewart County (figure 1) and are generally confined to the Pennyroyal Plain Subsection although there are outliers in the Western Highland Rim Subsection south and west of the Cumberland River.

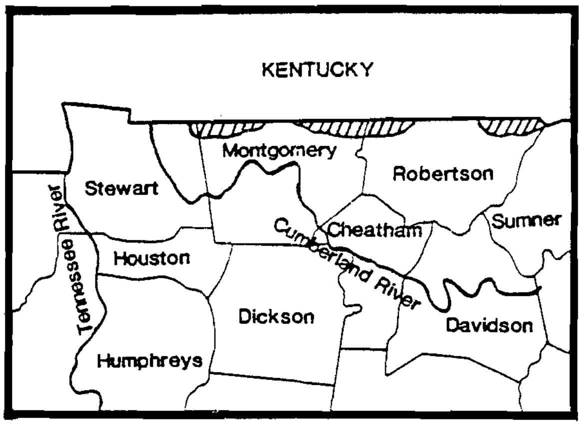

Figure 1. Historical location (shown by shading) of Northwestern Highland Rim Barrens in Tennessee [from Dicken (1935) and Transeau (1935)]

Braun (1950) noted that these barrens are closely correlated with areas of karst topography underlain by cavernous Mississippian limestone. The Ste. Genevieve, St. Louis, and Warsaw limestones comprise the bedrock of the Pennyroyal Plain, with most of the karst areas underlain by the Ste. Genevieve (Quarterman and Powell 1978). The surface is characterized by sinking streams, sinkholes, and sinkhole plains with broad expanses of nearly level to slightly rolling lands at elevations of 150-200 m above sea level. Much of the drainage is underground and many of the soils have fragipans with resultant poor drainage and scattered marshy areas, upland flats, or swamps. Locally referred to as "pondy woods" if forested or "crawfishy lands" if open, many such areas have recently been drained and converted to agricultural lands.

The adjacent Western Highland Rim Subsection, which supports barren outliers, is a maturely dissected upland plateau with steep slopes, ridges, and stream valleys, numerous caves, and springs. There are some karst features but few sinkhole plains.

Permanent surface streams are more numerous, there are fewer fragipan soils, and the Ste. Genevieve limestones are mostly lacking. The Cumberland River provides the major drainage, with numerous dendritic-pattern streams feeding into it.

Soils of both subsections are heterogeneous and several associations and series are represented. Most are Red-Yellow Podsols and limestone derived (Quarterman and Powell 1978). Many are covered with a loess mantle ranging up to 1 m in thickness and overlying a clay alluvium. Limestones normally occur at depths of more than 3 m on the Pennyroyal Plain but outcrops and bluffs are common in the Western Highland Rim Subsection (Lampley et al. 1975).

The climate is temperate and characterized by long, moderately hot summers and short, usually mild winters. Mean annual precipitation is about 122 cm and well distributed throughout the year. The growing season averages 206 days and extends from early April to late October. The ground freezes to a depth of 5 to 15 cm several times during most winters and commonly remains frozen for two to twelve days. However, local conditions vary considerably because of elevation and topographic variations (Smalley 1980).

Vegetationally the area is within the Deciduous Forest Formation, Western Mesophytic Forest Region of Braun (1950). This is a broad transition region with local climate, topography, and edaphic factors of importance in determining the mosaic of vegetational types. Generally considered to be oak-hickory (Eyre 1980), studies by Duncan and Ellis (1969), Jensen et al. (1973), and Chester et al. (1976) showed that while the present secondary forests are mostly oak-hickory, more mesophytic species such as Acer saccharum, Fagus grandifolia, and Liriodendron tulipifera become important on mesic slopes and in ravines, while bottomlands and streambanks are dominated by expected species such as Acer negundo, A. saccharinum, Platanus occidentalis, Populus deltoides, and Ulmus spp.

Quarterman and Powell (1978) noted that uplands of the Pennyroyal Plain support forest types similar to those of the Western Rim, i.e., oak-hickory on drier sites and with a high beech component on more mesic sites. While upland flats and swamps have a high proportion of such mesophytic oaks as Quercus bicolor, Q. falcata var. pagodaefolia, Q. phellos, and Q. shumardii, selective timber harvesting has resulted in dominance mostly by such less desirable timber species as Acer rubrum, Liquidambar styraciflua, and Nyssa sylvatica.

All forests of both subsections are secondary and few old-growth stands occur. Even upland swamps have received considerable disturbance from timber harvesting, pasturing, or draining (Scott et al. 1980). The dominant vegetation today is that resulting from agricultural practices and includes managed pastures, soybeans, small grains, and tobacco.

METHODS

Literature on presettlement conditions of northwestern Middle Tennessee barrens was obtained from the libraries and archives of Austin Peay State University, The University of Tennessee, Vanderbilt University, and the State of Tennessee Archives. The Interlibrary Loan Department of the Woodward Library, APSU, obtained some older material from other libraries and archives.

The vascular flora of Montgomery, Robertson, and Stewart counties has been intensively studied by Royal Shanks (early 1940s), Alfred Clebsch (1940-1960), and the author (since 1962). Barrens, and barren-like openings in rocky oak woods and on bluffs often received special attention (vouchers are at APSU and TENN.) A composite list of species taken from these sites was developed to provide insight into the floristic composition of northwestern Tennessee barren remnants, and for comparisons with the Big Barrens of Kentucky and true prairies.

To verify the floristic association between northwestern Tennessee barrens and those in south-central Kentucky, comparisons were made between the Tennessee list and that of Baskin and Baskin (1981), which gave 64 species characteristic of five prairie-cedar glade sites in four Kentucky counties. The Baskin and Baskin review of the Big Barrens is the most recent and complete summary available. Likewise, in order to ascertain floristic affinities between northern Tennessee barrens and true (tall-grass) prairies, comparisons were made with the floristic lists and categories of Weaver and Fitzpatrick (1934). This source (i.e., Weaver and Fitzpatrick) was chosen because of its extensiveness (based on data from 135 tracts in six states) and general acceptance as some of the best data on prairie composition (Transeau 1935; Weaver 1954, 1968; Risser et al. 1981; Baskin and Baskin 1981).

RESULTS AND DISCUSSION

Presettlement Conditions

The barrens landscape before or at the time of settlement is discussed in two types of literature: (1) in references dealing with the entire area or specifically with the Big Barrens of Kentucky and (2) in scattered sources dealing with the Tennessee extension directly.

Braun (1950) emphasized the tall grass aspect of the original vegetation and described the general lack of trees, while Kuchler (1964) showed the pristine vegetation to be mostly oak-hickory forests with scattered areas representing a mosaic of oak-hickory forests and bluestem prairie.

Concerning the Big Barrens of Kentucky, Garman (1925) noted that the first botanists found "waving grasses so tall as to conceal a man on horseback" with abundant sedges and rushes in wet places, a great variety of herbaceous species, and a few woody plants on drier grounds. Shull (1921) and Dicken (1935), both quoting from notes made by Michaux during his 1802 travels, mention grasses two or three feet high, small willows, and a few sumacs. Dicken further noted that the characteristic vegetation consisted of bluestem, many flowering plants, and hazel bushes. There were isolated scrub oak and hickory stands but no large trees. On knobs the timber was heavier and similar to that of surrounding forests. McInteer (1942, 1946) noted that various composites, sedges, woody vines, and scattered but small trees were found with the most common plant, tall bluestem. He also emphasized that the prairie vegetation was not continuous but rather was interspersed with marshy spots and timber, and that the first settlers found an "open prairie with hardly a stick of timber of sufficient size to make a rail as far as the eye could see."

The barrens of northwestern Middle Tennessee, which were probably the largest natural grasslands within the state at the time of settlement (Underwood et al. 1973), were referred to in some early literature. The Goodspeed History Series (1886) described the vegetation as "scrubby and coarse, though a rank grass which grows in open woods supplies large herds of stock." Two excellent descriptions of Stewart and Montgomery counties shortly after settlement are available. Killebrew et al. (1874) discussed northeastern Stewart County and divided barrens found there into two types: (1) Barren Plains - or areas which merged into bottomlands along mostly non-permanent creeks and which were considered choice farmland. These barrens had a "gently rolling surface, small and indifferent timber, mostly blackjack and hickory, with an undergrowth of hazel and gum." (2) The Barrens - or areas adjacent to the Barren Plains but more upland. It was noted that the two were quite similar in appearance and "will probably in the course of nature become of the same character." Changes which had occurred over the 30 years prior to writing, or from about 1840 to 1870, were also discussed. Since the first settlers arrived in Stewart County in 1795 (Foster 1923), the Killebrew et al. (1874) account is probably the best early description available for that area and time:

> It was the custom with the early settlers to burn off these lands every spring, in order that the barren grass, a strong, coarse, but nutritious herbage, might spring up and supply summer grazing for the cattle. During spring and summer, the chimes of a hundred bells might have been heard as the cattle browsed over the natural meadow. There were but few trees, and those of an inferior kind

> for timber, being scrubby black jack, which owing to the thickness of the bark, is able to resist the prairie fires.

It was also observed that by 1874 most of the barren grass and scrubby oak had disappeared and been replaced by farms and forests of red oak, post oak, hickories, and a rank understory of gum, hazel, hickory, and red oak.

The best descriptions of Montgomery County barrens are those of Ross (undated), who in 1812 moved to a 120 ha farm 13 to 19 km northwest of Clarksville (the farm was bounded on the north by the Kentucky line and was in the center of Montgomery County barrens). This county was settled in about 1780 (Foster 1923) but few lived in the barrens at that time. Ross described the area during winter as "one barren, cheerless waste as far as the eye could reach." Further descriptions by Ross indicate conditions in 1812 and also provide insight into the importance of wildfire:

> During this winter I first saw the tremendous fires caused by the burning of the dry grass. In many places, this grass was very thick and tall; and when perfectly dry, should it get on fire, the wind being high, the spectacle became truly sublime, especially at night. The flames...would sometimes burn the leaves on trees twenty or thirty feet in height. No one who ever witnessed one of these great fires would ever afterward be at a loss to account for the scarcity of timber in the Barrens, as trees of all kinds, when small, were destroyed by them. Should a little twig or bush put up from the ground one season, it was sure to be burned the next. The Indians, in early times, used to set this grass on fire, when hunting, and killed great quantities of game as it fled before the flames.

Conditions of the barrens in spring and summer were aptly described by Ross, who often rode horseback across the barrens to Hopkinsville, Kentucky, a distance of about 29 km:

> But if, in winter, the barrens looked cheerless and dreary, it was far otherwise in spring and summer. It would be difficult to imagine anything more beautiful. Far as the eye could reach, they seemed one vast deep-green meadow, adorned with countless numbers of bright flowers springing up in all directions...only a few clumps of trees and now and then a solitary post oak were to be seen...Here I first saw the prairie bird, or barren-hen, as we called it, which I afterwards met with in such vast numbers on the great prairies of Illinois. Here the wild strawberries grew in such profusion as to stain the horses hoofs a deep red color.

Floristic Comparisons

In their study of prairie-cedar glade sites in the Big Barrens region of Kentucky, Baskin and Baskin (1981) found 64 species which had been reported from at least three different sites in the Prairie Peninsula to the north and west of Kentucky (both native and introduced weedy species were excluded). While their conclusion was that the Big Barrens should not be considered part of the Prairie Peninsula, the strong floristic affinity was noted. Ninety-one percent (58 of 64) of the species from the Big Barrens also occur in barren remnants (including open oak woods and rocky slopes and bluffs) of northern Montgomery, Robertson, and Stewart counties, Tennessee (appendix 1). This high correlation was expected and supports the suggestion by Braun (1950) and Shanks (1958) of floristic similarities between barrens of the two states. The six species on the Baskin and Baskin (1981) list not known from northwestern Middle Tennessee barrens are *Aster sericeus*, *Cypripedium candidum*, *Echinacea angustifolia*, *Linum sulcatum*, *Petalostemum candidum*, and *P. pupureum*.

Comparisons between the barrens flora of the three Tennessee counties and species characteristic of the true prairie also reveal affinities. From the Weaver and Fitzpatrick (1934) list of 200 major indicator species (197 when duplicates from different taxa groups are removed), 98 species, or 49 percent, are known from the study area (table 1 and appendices 2, 3, and 4). In addition to the 142 major forbs (appendices 3 and 4), Weaver and Fitzpatrick (1934) note that at least 200 others commonly occur. Species from that 200 which are known from the study area include *Allium cernuum*, *Ambrosia bidentata*, *Apocynum cannabinum*, *Ascelepias hirtella*, *Aster oblongifolius*, *Chrysopsis camporum*, *Coreopsis tripteris*, *Desmanthus illinoensis*, *Helenium amarum*, *Liatris spicata*, *Parthenium integrifolium*, *Physostegia virginiana*, *Polygala senega*, *Scutellaria parvula*, *Silphium terebinthinaceum*, *S. trifoliatum*, *Solidago nemoralis*, *Spiranthes cernua*, *Vernonia missurica*, and *Viola pedata*.

As expected, there is a much stronger relationship between the Prairie Peninsula and true prairie than between the barrens and true prairie. For example, Transeau (1935) compared the Prairie Peninsula of Ohio with the major taxonomic categories of true prairie given by Weaver and Fitzpatrick (1934). These data, along with numbers from the Tennessee study area, are given in table 2. Also, the same relative proportions exist when prairie-center uplands and lowlands are compared with the Prairie Peninsula and the Tennessee study area; there is a stronger affinity between both the Ohio data and the study area to prairie-center lowlands than to uplands (table 2). However, many grasses and forbs considered primary prairie species by Weaver and Fitzpatrick (1934) are absent, and not all species are restricted to barrens.

Table 1. Numerical comparison of prairie-center taxa groups and numbers in each (from Weaver and Fitzpatrick 1934), with the flora of northwestern Middle Tennessee barren remnants

Taxa groups from the prairie-center, and number of species in each area	Number of these species found in NWMT barrens	Percent
Major Grasses (11)	6	54.5
Minor Lowland Graminoids (22)	12	54.5
Minor Upland Graminoids (25)	9	36.0
Total Graminoids (58)	27	46.6
Major Lowland Forbs (67)	47	70.0
Major Upland Forbs (75)	24	32.0
Total Forbs (142)	71	50.0
Total Graminoids and Forbs (200)	98	49.0

Table 2. Percentage comparison of major taxa groups from the prairie-center (data from Weaver and Fitzpatrick 1934), the Ohio Prairie Peninsula (data from Transeau 1935), and barren remnants of northwestern Middle Tennessee

Major taxa groups from the prairie-center	Percent found in Ohio prairies	Percent found in the NWMT barrens
11 Major Grasses	100	54.5
22 Minor Lowland Graminoids	73	54.5
25 Minor Upland Graminoids	58	36.0
67 Major Lowland Forbs	84	70.0
75 Major Upland Forbs	40	32.0

Origins and Relationships

Questions concerning the barrens vegetation have long been discussed in Kentucky botanical literature. Since these discussions apply equally to the Tennessee extension, they will be summarized here.

Atwater (1819) suggested that the barrens vegetation was due to waterlogged soils preventing tree growth. Earlier, Michaux

(1805) suggested a fire origin when he observed that the few residents burned the barrens yearly, continuing a policy "formerly practised by the natives, who came in this part of the country to hunt." Wells (1819) proposed a definite fire origin, which Bourne (1825) expanded, and further noted that:

> . . .the present appearance was caused by fires. . . generally kindled by the Indians. They have features in common with the prairies, but are essentially different in many respects.

Bourne (1825) also observed that once the barrens were settled:

> . . .the Indians recede, fires are seldom seen, a young growth of trees, healthy and vigorous soon springs up, far superior to the stinted growth which the frequent fires have scorched, and the barren assumes the appearance of a timbered country. That the barrens are frequently burned, and that when burnings cease, a young vigorous growth of trees soon springs up, are facts which can be attested by the most respectable people in the country.

Shaler (1876), Shull (1921), and Sauer (1927) also proposed a fire origin while Garman (1925) concluded that fire only maintained a treeless condition which developed during glacial or postglacial times and that the "... prairie flora that first appeared was assembled by conditions of moisture and temperature unfavorable at first to the settlement of forests."

Dicken (1935) summarized previous theories under three headings: (1) natural origins such as glacial, natural fires, and trampling by buffalo; (2) cultural origins, or fires set by Indians; (3) a combination of the first two. McInteer (1942, 1946) also suggested a combination of factors, including soil conditions, climate, underlying rock, and fire. More recently, Baskin and Baskin (1981) considered fire to be of primary importance.

While questions related to vegetational origins are not resolved, the fact remains that the first settlers found extensive tracts of grassland with many plants (and animals) similar to those of the true prairie. Kuchler (1964) mapped the potential vegetation of the area as a mosaic of bluestem prairie and oak-hickory forests and Transeau (1935) had earlier included the area as the southern limit of the Prairie Peninsula (the wedge-shaped projection of prairie vegetation extending from the midwestern grasslands into the deciduous forests). Both King (1981) and Risser et al. (1981) do not consider the Prairie Peninsula to extend into Tennessee and Kentucky, and Baskin and Baskin (1981) presented convincing evidence that the Big Barrens of Kentucky should not be considered as a part of the peninsula. Among other ideas, they pointed out that all indications are for a deciduous forest climax and that there is no evidence that grassland was ever climax or even subclimax (edaphic). The quick return to deciduous forest following cessation of burning has long been known and supports this premise. As early as 1921, Shull observed that:

> None of these areas is barren (treeless) now, excepting as it is farmed. The custom of burning over large areas ceased long ago, and trees, mainly oaks, begin to come in. There is at present no conspicuous difference between the barren districts and the surrounding country as to the number of trees. . . . The transformation which has occurred in these regions has gone so far that the barrens are only a memory.

An example of quick barren succession may be observed in Land Between The Lakes, a Tennessee Valley Authority facility just west of the Cumberland River in Tennessee and Kentucky. Prior to TVA purchase in 1963, most of the area was in small farms, and the generally upland lands had been over-tilled, were of rather poor, often cherty soil, steep-sloped, and frequently eroded. Burning was commonplace to control "broomsedge" (mostly Adropogon virginicus) in pastures. After reverting to public ownership, some fields were invaded by prairie species such as Andropogon gerardi, Sorghastrum nutans, various other graminoids, and species of Asteraceae, Fabaceae, and Lamiaceae. However, woody seedlings quickly appeared and succession, in the absence of fire, appears to be leading to forest communities similar to those surrounding the fields. In a few cases, regular burning and/or clipping is conducted by TVA in an attempt to maintain the prairie aspect. This publicly-owned area, where conditions can be controlled and monitored, provides a unique opportunity for long-term study of western Kentucky and Tennessee barrens and grasslands.

SUMMARY

An extension of the Big Barrens of Kentucky occurs in parts of northern Montgomery, Robertson, and Stewart counties, Tennessee. These areas, the Kentucky Prairie Barrens of Shanks, probably included the largest natural grasslands in the state at the time of settlement. The origin and pre-settlement maintenance of barrens vegetation has long been considered, and most believe that fire played an important role.

Transeau included the area within the Prairie Peninsula and many authors have followed this proposal. Current concensus is that the barrens should not be considered part of the Prairie Peninsula since the grasslands rapidly became deciduous forests when regular burning ceased or when they were farmed and abandoned. This is shown today where fields and disturbed woodlands, which are often invaded by prairie species, quickly succeed to hardwood forests if not maintained by burning or clipping.

There is some floristic affinity, if artifactitious, between the flora of barren remnants in the three-county area and both the Prairie Peninsula and true prairie. Comparisons indicate that almost half of 200 characteristic true-prairie species occur in these remnants. Many other species with prairie affinities, but not part of the 200 dominants, are also present. However, species with prairie affinities are not limited to former barrens of the region and the value of using these plants to indicate floristic relations between barrens and the Prairie Peninsula or true prairie is questionable.

Most of the barrens are now under cultivation, or are within the Fort Campbell Military Reservation and hence regularly disturbed, or have been otherwise altered or destroyed by human activities. Prairie species are now limited to marginal farming areas, to old fields in early successional stages, to disturbed woodlands, or to a few barrens-grasslands in Land Between The Lakes.

ACKNOWLEDGEMENTS

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Appendix 1. Species representative of prairie-cedar glade sites in the Big Barrens region of Kentucky (Baskin and Baskin 1981) that also occur in barren remnants of northwestern Middle Tennessee

Allium cernuum
Andropogon gerardi
Andropogon scoparius
Antennaria plantaginifolia
Apocynum cannabinum
Asclepias tuberosa
Asclepias verticillata
Asclepias viridiflora
Aster azureus
Aster oblongifolius
Aster novae-angliae
Aster sagittifolius
Cassia fasciculata
Cicuta maculata
Cirsium discolor
Coreopsis tripteris
Delphinium virescens
Echinacea pallida
Elymus virginicus
Eryngium yuccifolium
Eupatorium altissimum
Euphorbia corollata
Fragaria virginiana
Gerardia tenuifolia
Helenium autumnale
Helianthus hirsutus
Helianthus mollis
Heliopsis helianthoides
Hypoxis hirsuta
Krigia biflora
Kuhnia eupatorioides
Lespedeza capitata
Liatris aspera
Liatris spicata
Liatris squarrosa
Lithospermum canescens
Lobelia spicata
Monarda fistulosa
Oxalis violacea
Parthenium integrifolium
Penstemon hirsutus
Phlox pilosa
Physalis heterophylla
Physostegia virginiana
Polygala senega
Pycnanthemum flexuosum
Ratibida pinnata
Rosa carolina
Rudbeckia hirta
Scutellaria parvula
Senecio plattensis
Silphium terebinthinaceum
Silphium trifoliatum
Sisyrinchium albidum
Solidago nemoralis
Sorghastrum nutans
Spiranthes cernua
Viola pedata

Appendix 2. Prairie-center graminoids known from barren remnants of northwestern Middle Tennessee

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Major Prairie Grasses:
- Andropogon gerardi
- Andropogon scoparius
- Panicum virgatum
- Poa pratensis
- Sorghastrum nutans
- Spartina pectinata

Minor Lowland Graminoids:
- Agrostis alba
- Carex vulpinoidea
- Cinna arundinacea
- Eleocharis acicularis
- Elymus virginicus
- Glyceria striata
- Leersia virginicus
- Leersia oryzoides
- Poa pratensis
- Phalaris arundinacea
- Sphenopholis obtusata
- Tripsacum dactyloides

Minor Upland Graminoids:
- Agrostis hyemalis
- Carex festucacea
- Carex pensylvanica
- Eragrostis pectinacea
- Festuca octoflora
- Juncus tenuis
- Muhlenbergia mexicana
- Poa pratensis
- Sporobolus asper

Appendix 3. Major lowland prairie-center forbs known from barren remnants of northwestern Middle Tennessee

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Allium canadense
Amphicarpa bracteata
Antennaria plantaginifolia
Asclepias incarnata
Asclepias verticillata
Astragalus canadensis
Cassia fasciculata
Cicuta maculata
Equisetum arvense
Erigeron annuus
Erigeron philadelphicus
Fragaria virginiana
Galium tinctorium
Gaura spp.
Helenium autumnale
Helianthus maximiliani
Helianthus tuberosus
Heliopsis helianthoides
Hypoxis hirsuta
Lilium canadense
Lithospermum arvense
Lobelia spicata
Lycopus americanus
Lysimachia ciliata
Lythrum alatum
Mirabilis nyctaginea
Monarda fistulosa
Oenothera biennis
Oxalis stricta
Oxalis violacea
Phlox pilosa
Physalis heterophylla
Physalis virginiana
Polygonum coccineum
Potentilla norvegica
Pycnanthemum virginianum
Ratibida pinnata
Rudbeckia hirta
Senecio aureus
Silphium integrifolium
Silphium laciniatum
Silphium perfoliatum
Solidago canadensis
Teucrium canadense
Veronicastrum virginicum
Viola papilionacea
Zizia aurea

Appendix 4. Major upland prairie-center forbs known from barren remnants of northwestern Middle Tennessee

Allium canadense	*Lespedeza capitata*
Asclepias tuberosa	*Liatris squarrosa*
Asclepias viridiflora	*Lithospermum canescens*
Aster azureus	*Pedicularis canadensis*
Aster sagittifolius	*Polygala sanguinea*
Baptisia leucantha	*Ruellia caroliniensis*
Comandra umbellata	*Salix humilis* (woody)
Delphinium virescens	*Salvia azurea*
Echinacea pallida	*Senecio plattensis*
Erigeron strigosus	*Sisyrinchium angustifolium*
Euphorbia corollata	*Solidago graminifolia*
Hedeoma hispida	*Specularia perfoliata*

CONTRIBUTED PAPERS

SESSION I - BOTANY

Saturday 12 March 1988

Moderated by:

E. Wayne Chester
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Forest Communities of the Kentucky Portion of Land Between The Lakes: A Preliminary Assessment

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KEY WORDS: forest communities, site index, soil, succession, topography

ABSTRACT

Research on the composition and structure of undisturbed, mature forest communities at Land Between The Lakes (LBL) was begun in 1986, under the auspices of The Center for Field Biology of Land Between The Lakes, Austin Peay State University, Clarksville, Tennessee. In the Kentucky or northern portion of LBL, two generally distinct xerophytic communities can be recognized. The first occurs on coarse- to fine-textured soil of south slopes, ridges, and north slopes, and is dominated by *Quercus prinus*. *Quercus stellata* is the major dominant of the second community which is found on medium- to fine-textured soil of southwest slopes, and ridges. *Carya glabra*, *Q. falcata*, *Q. marilandica*, and *Q. coccinea* are components of both communities. Xeric-mesic and mesic sites found throughout the landscape generally support communities of *Q. alba* but *Q. velutina* is the major species in some stands. *Acer saccharum* and other species of mesic sites were found to be a minor component of the forest, although it appears that they are becoming increasingly important and will replace many oak communities at elevations below approximately 140 m.

INTRODUCTION

The forests of Land Between The Lakes (LBL) in western Kentucky and Tennessee are a major resource of the central hardwood region. Most of the land between Kentucky and Barkley lakes was in private ownership prior to purchase by Tennessee Valley Authority (TVA) in 1964 (Henry 1975). While a portion of the land area was farmed, and a larger proportion probably grazed and selectively cut by private owners, many small forest communities appear to have escaped disturbance or have recovered sufficiently to appear relatively undisturbed. Tree age (75 to 120 years) indicates that the forests are nearing maturity although few can be considered old-growth.

An investigation of the composition, structure, growth, succession, and site relationships of LBL forests was initiated in 1986 under the auspices of Austin Peay State University's Center for Field Biology of LBL. This report summarizes the data obtained during the first sampling season (1987) in the Kentucky (northern) portion.

The data presented here represent the initial development of baseline information that will lead to a more comprehensive understanding of LBL forest communities and their environmental relationships. After baseline information has been collected and analyzed, the effects of fire and various silvicultural techniques and the distribution and response of wildlife populations can be evaluated in a more meaningful context.

Previous research on LBL forests and soils primarily identified tree, shrub, herb, and animal species, and soil types. A series of field guides describe the spring wildflowers (Ellis and Chester 1971), summer and fall wildflowers (Ellis and Chester 1973), lichens and ferns (Phillips 1974), trees and shrubs (Ellis and Chester 1980), and amphibians and reptiles (Snyder 1972). The Soil Conservation Service described the soil of Stewart County, Tennessee, (U. S. Dept. Agric. 1953) and Lyon and Trigg counties, Kentucky, (U. S. Dept. Agric. 1981).

Forest sites at LBL have been broadly classified and evaluated for potential productivity, management problems, and species suitability (Smalley 1980). Dr. D. Hassel of Murray State University (Department of Biology), Murray, Kentucky, was investigating the forest communities of approximately 29 proposed ecology study and preserve areas at the time of his death in 1988. The Hardwood Industry Cooperative at North Carolina State University recently established a limited series of plots as part of a study on silvicultural response. Researchers from the Department of Forestry at Southern Illinois University, Carbondale, are studying a 550 ha area burned in 1984.

THE STUDY AREA

Land Between The Lakes is a 92,000 ha area within the Highland Rim Plateau of the Interior Low Plateau physiographic province (Smalley 1980) where that province interfaces with the Coastal Plain. Although the Highland Rim is underlain chiefly by slowly soluble cherty limestone, topography and the underlying rock formations, as well as surface deposits, create considerable variation in soil characteristics. Most of the acreage in Trigg and Lyon counties is in the Meramec and Osage Series of the Mississippian System.

The Coastal Plain material is Cretaceous gravel (dominantly white pebbles) of the Tuscaloosa formation; it overlies bedrock adjacent to Kentucky Lake on the west (U. S. Dept. Agric. 1953, 1981). Quaternary age material includes deposits of loess, small areas of alluvium, and brown gravel. Loess overlies much of the uplands and high stream terraces; it may be up to 1.3 m thick and is nearly stone free. Generally, the land is highly dissected and the topography steep and hilly. Elevation ranges from 110 to 180 m.

Common soil types include: Baxter, Crider, Hammack, and Pembroke (Paleudalfs); Brandon and Saffell (Hapludults); Lax and Nicholson (Fragiudults); Nolin (Eutrochrept); and Newark (Fluvaquent). Baxter was formed in limestone residuum while Hammack, Crider, and Pembroke formed in loess over limestone residuum. Brandon, Nicholson and Lax formed in loess over Coastal Plain deposits; Nicholson and Lax have a fragipan. Saffell formed in Coastal Plain deposits. Newark and Nolin are found in recent alluvium (U. S. Dept. Agric. 1981).

Average annual precipitation is approximately 1173 mm; nearly half occurs during the growing season. Average winter temperature is 3°C; average summer temperature is 24°C. Prevailing wind is out of the southwest (U. S. Dept. Agric. 1981).

METHODS

Stand Selection

The land area of LBL has been subdivided by TVA resource managers into 65 "work areas" of somewhat equal size. Work areas in which a timber harvest could occur within the next five years were excluded from consideration. Potential units within each work area were identified from data on stand conditions (species, age, density, timber harvests, etc.) obtained from records maintained by the LBL Division of Land Stewardship.

Criteria for selection of small forest communities (stands) included lack of disturbance, condition, age, and homogeneity. Stands containing evidence of cutting, fire, wind, disease, or insect damage within the lifetime of the overstory trees were excluded. Stems of overstory species were required to be a relatively homogeneous mixture throughout the stand and to be at least 80 years old. Stands were selected to sample the range of natural forest community types in the Kentucky portion of LBL: *Quercus stellata*-*Q. marilandica*, *Q. prinus*, *Q. velutina*-*Q. coccinea*, *Q. alba*-*Q. velutina*, *Fagus grandifolia*-*Acer saccharum*, and several miscellaneous bottomland types.

Within each selected stand, an area of uniform site conditions (soil, aspect, slope steepness, etc.) at least 1 ha in size was delineated; this size was the smallest area that would enclose the sample plots and a surrounding buffer strip.

Sixty-two upland stands were sampled during the summer of 1987. These stands were located in the northern portion of LBL (north of Highway 68) in Work Areas 1, 7, 9, 12, 13, 14, 17, 19, 20, 21, 23, 24, and 31. A number of stands were located in Ecological Study Areas 5 and 7, and special management areas known as Hematite Lake and Dividing Ridge.

Field Procedure

Within each study stand, two points were randomly located at a minimum distance of 30 m from each other and 18 m from the stand boundary. Each point was permanently marked with a conduit pipe, and used as the center point of a 0.06 ha circular quadrat (radius = 13.82 m). On these plots, all stems larger than 9.0 cm dbh (1.37 m above ground level) were recorded by species and diameter to the nearest 0.1 cm. On several sites, it was necessary to use three 0.04 ha circular or rectangular plots for trees in order to adequately sample stands located on long, narrow slopes or alluvial terraces.

Within each stand, five to seven healthy trees in the dominant or codominant crown classes (*sensu* Society of American Foresters 1958) were measured for height as well as diameter. An increment core was removed from each tree and placed in a soda straw for transport to the laboratory.

Laboratory procedure

Diameters for all stems on the two plots were converted to basal area (m^2); basal area values were summed by species. An importance value (IV) was obtained by dividing species basal area by basal area for all species (relative basal area). Sample basal area was converted to a per hectare basis by multiplying by 8.33.

Increment cores were glued into holders, sanded, and aged using a binocular microscope. Age and height data for the major stand dominants (*Quercus prinus*, *Q. stellata*, and *Q. alba*) were plotted on site index curves developed by Carmean (1971) and an average site index was calculated for each stand.

Community types were delineated on the basis of the dominant species (*Quercus prinus*, *Q. stellata*, *Q. alba*, and *Acer saccharum*) and site characteristics. Average diameter, height, density, basal area, and site index were calculated for each community type.

RESULTS

The Quercus prinus community

Two phases of this community were identified based on a comparison of overstory and understory species composition. One phase included compositionally-stable communities where *Quercus prinus* was likely to remain the canopy dominant. The second phase included a compositionally-unstable (successional) community where *Q. prinus* probably will be replaced by *Q. alba* when the present overstory trees die or are cut.

Five stands of the stable community were sampled. These were found on dry ridges and slopes having an east to southwest aspect. The soil on these sites was derived from weathered limestone (broken chert residuum) or from Coastal Plain gravel deposits. *Quercus prinus* had an average IV of 76, while other associated xerophytic species, *Q. velutina*, *Q. marilandica*, *Q. coccinea*, *Q. falcata*, and *Carya glabra*, had IVs ranging from 1 to 7 (table 1). *Oxydendrum arboreum* reached its highest importance value (IV = 5) in, and generally was restricted to, this community. Few tree species (11) were recorded. Age of the stands ranged from 80 to 110 years.

Only one successional stand was sampled. Here, the IV of *Quercus prinus* was 73 but *Q. alba* also was an important component (IV = 21). This stand was located on a high north slope where the soil was a relatively fine-textured silt loam.

The severity of site conditions in compositionally-stable stands compared to the more mesic conditions in the successional stand is reflected more in basal area and site index than in diameter differences. Quadratic mean diameter for the stable stands (25.0 cm) was moderately lower than that for the successional stand (29.5); basal areas were 22.1 and 28.4 m^2/ha and site indices for *Quercus prinus* were 38 and 63 for the stable and successional stands, respectively (figure 1). In stands dominated by *Q. stellata* and *Q. alba*, *Q. prinus* occasionally appeared as a secondary species. Its site index in the *Q. stellata* community was 48.5, while in *Q. alba* stands its site indices were between 61 and 63.

The Quercus stellata-xerophytic community

Communities dominated by *Quercus stellata* and other xerophytic species of *Quercus* and *Carya* were restricted to silt loam soils of south to southwest slopes and ridgetops. Three of the 14 study stands occurred on ridgetops. Eight stands were dominated by *Q. stellata*, 4 by *Q. falcata*, and 2 by *Q. marilandica*. For all stands, *Q. stellata* was the single major dominant with an average IV of 45; *Q. falcata* and *Q. marilandica* had average IVs of 14 and 10, respectively (table 1). The total number of species recorded was 16, and average basal area was

Table 1. Average importance values (relative basal area) for species in four forest community types at Land Between The Lakes. The *Quercus prinus* and *Q. alba* types are divided into compositionally-stable and compositionally-unstable (successional) variants.

Community Type

Species	*Quercus prinus* Stable	*Quercus prinus* Unstable	*Quercus stellata*	*Quercus alba* Stable	*Quercus alba* Unstable	*Acer saccharum*
Quercus prinus	75.6	73.0	4.2	4.3		
Quercus stellata	3.6		45.3	6.6	2.4	
Quercus velutina	6.7		2.6	12.8	6.3	
Quercus marilandica	2.7		10.4		0.2	
Quercus coccinea	1.8		5.7	2.1	2.0	
Quercus falcata	1.8		14.5	8.3	2.0	
Oxydendrum arborum	5.0			0.1	0.1	
Nyssa sylvatica	0.9	0.7	0.3	0.9	2.1	
Carya tomentosa	0.5		1.6	0.3	0.3	
Diospyros virginiana		0.7				
Carya ovalis			0.2	0.8	3.4	
Carya pallida					0.3	
Ulmus alata		0.4	0.5	0.2	1.6	
Quercus alba	0.5	20.6	8.9	59.8	53.5	2.8
Carya glabra	0.9	3.9	5.2	2.2	4.2	2.8
Carya ovata			0.5	0.7	1.0	3.5
Fraxinus americana		0.7		0.3	1.8	2.1
Prunus serotina			0.1	0.1	0.2	0.1
Acer saccharum			0.1		5.6	33.9
Liquidambar styraciflua			0.1	0.1	2.3	7.3
Quercus bicolor				0.3		
Acer rubrum				0.1	0.6	

Table 1. (Continued)

Species	Quercus prinus		Quercus stellata	Quercus alba		Acer saccharum
	Stable	Unstable		Stable	Unstable	
Sassafras albidum				0.2	0.2	0.3
Fagus grandifolia					0.2	17.7
Quercus rubra					5.6	19.5
Ulmus rubra					0.1	2.1
Liriodendron tulipifera					3.6	1.7
Juglans nigra					0.2	0.7
Quercus muehlenbergii					0.2	2.1
Fraxinus pennsylvanica					0.1	
Carya cordiformis						0.3
Ulmus americana					0.1	
Carya occidentalis					0.1	
Platanus occidentalis					0.1	
Quercus pagodaefolia						2.4
Quercus shumardii						0.7
Celtis laevigata						0.1
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
No. Stands	5	1	14	13	22	3
No. Species	11	7	16	19	30	18
Quadratic Mean DBH, cm	25.0	29.5	24.7	32.5	32.7	35.3
Density, Stems/ha	458	425	402	304	338	283
Basal Area, m^2/ha	22.1	28.4	19.2	24.9	28.1	28.9

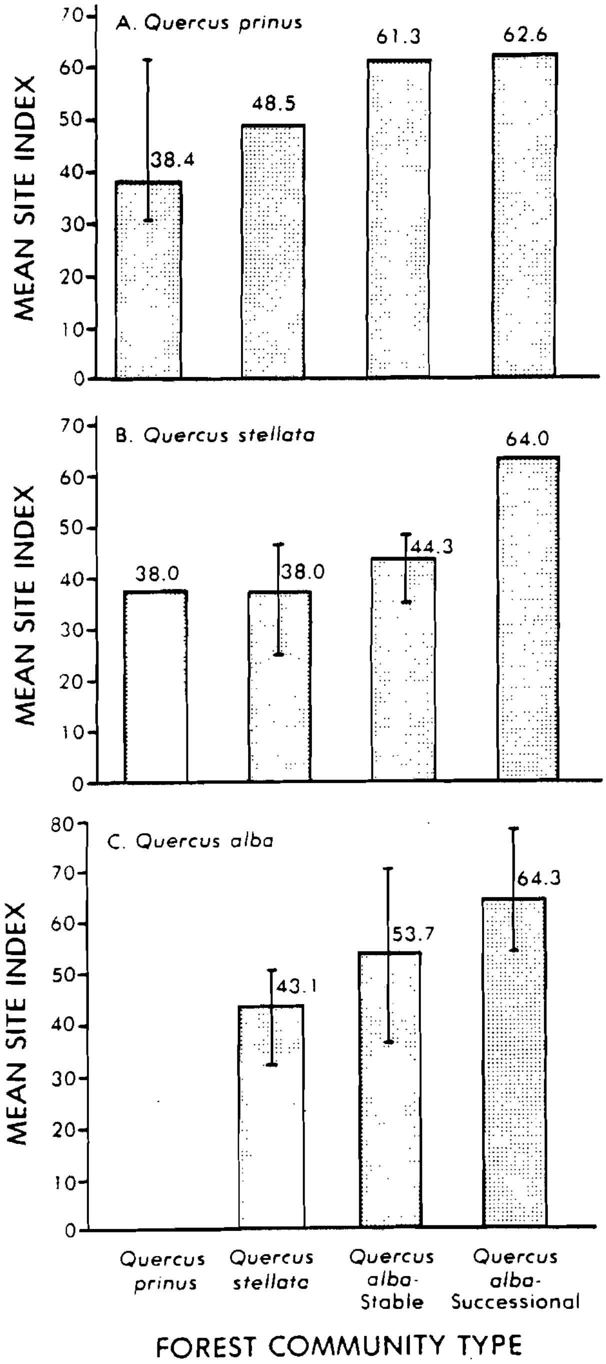

Figure 1. Site indices for Quercus prinus, Quercus stellata, and Quercus alba in four community types at Land Between The Lakes. Vertical lines through the bars indicate the range in site index. Bars without lines have too few samples to determine a range.

19.2 m^2/ha. Quadratic mean diameter of the sample stands was 24.7 cm and ages ranged from 60 to 130 years.

Quercus stellata appeared as a secondary species in stands dominated by Q. prinus and Q. alba. In Q. prinus stands, the Q. stellata site index was 38, a value comparable to that found in Q. stellata-dominated stands (figure 1). In Q. alba stands, average site index of Q. stellata ranged from 44 on dry south, east, and west slopes to 64 on the north slopes and stream terraces.

The Quercus alba community

Two phases of the Quercus alba community were identified. In the compositionally-stable Q. alba community, 13 stands were sampled. These were located in middle to high slope positions and on ridgetops; nine stands had west to south to east aspects. Stands on north to northeast slopes were located near the tops of the slopes. Quercus alba had an average IV of 60; the second most important species was Q. velutina with an IV of 13 (table 1). Total number of species was 19, and average stand basal area was 24.9 m^2/ha. Average site index for Q. alba was 53 with a range of 38 to 70 (figure 1).

Compositionally-unstable stands were located in a middle to low slope position with aspect ranging from northwest to north to southeast. Several stands were on stream terraces. Thirty species were found in these stands, 10 more than the number in compositionally-stable stands. Average stand basal area was 28.1 m^2/ha and equal to that of the Acer saccharum community. Quercus alba had an IV of 53, while Q. rubra, Q. velutina, and A. saccharum each had an IV of 6. The successional status of these stands is reflected by the appearance of A. saccharum in 20 of the 22 stands; in the compositionally-stable community, it was absent from all stands. Average site index of Q. alba was 64 with a range of 53 to 78. These site indices indicate improved growing conditions compared to those of compositionally-stable stands.

The Acer saccharum-mesophytic community

Only three acceptable communities were sampled, two on north to northeast slopes and one on a stream terrace. Soils ranged from thin silt loam over limestone bedrock to deep alluvium. All sites were at elevations of less than 120 m.

Community composition varied considerably and each stand was dominated by a different species: Acer saccharum, Fagus grandifolia, or Quercus rubra. For all stands combined, A. saccharum, F. grandifolia, and Q. rubra had average IVs of 34, 18, and 19, respectively. No other species had an IV > 7. Average basal area was 28.9 m^2/ha and 18 species were recorded in the sample. Although Quercus alba was not found in these stands, site index for this species probably was comparable to that of successional Q. alba stands (S.I. = 64) which were found on similar sites.

DISCUSSION

A relatively consistent and interpretable model for tree growth, stand composition and dynamics, and landscape patterns is emerging from the data taken from the Kentucky portion of LBL. Soil characteristics, aspect, slope position, and elevation appear to influence the distribution, composition, and growth of forest communities within the landscape. Superimposed on these patterns are the disruptive effects of disturbance. Disturbance from fire, farming, timber cutting, and the iron industry has substantially influenced forest community patterns so that they may be less recognizable today than they were 200 or 300 years ago.

Compositionally-stable stands of Quercus prinus are found on soils high in rock and chert located on exposed ridges and southwest slopes. While such stands are not highly productive, the species appears to occupy and grow on sites that otherwise would not support even moderate growth of other tree species. Few other species will invade these xeric soils; thus Q. prinus will dominate indefinitely. Although 11 forest species are part of the community, few are able to grow as rapidly or to the size of Q. prinus. The basal area (22.1 m^2/ha) is moderate, and site index (an index of the rate of height growth) is relatively low (48.5).

It appears that Quercus prinus will not dominate stands on better soil or somewhat cooler slopes when the sites are occupied by communities of other tree species; however, past disturbance has cleared a variety of sites so that Q. prinus can be found dominating a limited number of stands or as a component of stands dominated by other species. Once established where site conditions are more favorable (i.e., greater soil moisture), it grows as fast as or faster than Q. alba (figure 1). Quercus prinus probably will not remain a component in these stands without additional disturbance to reduce competition.

The Quercus stellata-xerophytic community occupies medium-textured (silt loam) soils on southwest slopes; the soils here usually have a shallow fragipan. While Q. stellata is the major species, Q. falcata and Q. marilandica also are important but Q. prinus is not a major component. The sightly better soil condition is reflected in a larger number of tree species (16), several of which may dominate a stand. Basal area (19.2 m^2/ha) is lower than that of the Q. prinus stands, suggesting that Q. prinus will produce a higher biomass level, although the site indices for Q. stellata and Q. prinus are equal (S. I. = 38) on their respective sites.

As with Quercus prinus, both Q. stellata and Q. falcata will invade cooler, moist sites if disturbance removes the existing forest cover generally composed of Q. alba. These species are too shade intolerant to compete with Q. alba, which has intermediate shade tolerance. Once established on better soil of south slopes, Q. stellata growth is slightly increased (S. I. = 44), while on a cooler north slope or stream terrace, growth is nearly equal to that for Q. alba (S. I. = 64).

Probably, severe fires and other periodic disturbances of the past few centuries have permitted Quercus alba to occupy nearly all upland slopes where soil conditions are suitable for its existence. On east, south, west, and northwest slopes, Q. alba is a strong competitor and will continue to dominate. Increased species richness (19), a basal area of 24.9 m^2/ha, and a site index of 53 for Q. alba indicate a higher-productivity site when compared to those on which Q. prinus and Q. stellata dominate.

The most productive sites in LBL north of Highway 68 are on north or northeast aspects, in low slope positions and on stream terraces. Most of these sites are presently occupied by stands of Quercus alba which have a basal area of 28.1 m^2/ha and an average site index of 65 with a maximum of 78. Species richness is high (30) but many of these species are more shade tolerant than Q. alba and once they form a dense canopy, the less shade tolerant Q. alba seedling will be excluded. The density of the shade tolerant species is low in many stands, but with time the most productive Q. alba stands in LBL will convert to mesophytic hardwoods similar to those now dominated by Acer saccharum or Fagus grandifolia. Presently, the understory stems of A. saccharum and other mesophytes are not of sufficient age to produce seed. A major change in the rate of succession will occur when these stems reach reproductive age in a large number of sites.

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Diameter, Height, and Age Relationships for Selected Quercus at Land Between The Lakes

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ABSTRACT

Age and height data were taken from four to seven trees in each of 64 Quercus stands in the Kentucky (northern) portion of Land Between The Lakes. Data were plotted on site index curves developed by Carmean, and an average site index was calculated for each species in each stand where it occurred. Variations in a species site index (an estimate of tree growth and site potential) were examined across the range of community dynamics (successional vs. compositionally stable communities) and site conditions described by Fralish and Crooks.

Stands were dominated by Quercus stellata, Q. prinus, and Q. alba; site conditions ranged from gravelly south slopes to medium- and fine-textured soils of north slopes and alluvial terraces. As a species, Q. alba was found across the entire range of site conditions. Average site index increased from 43 in Q. stellata stands (southwest slopes), to 54 in stable Q. alba stands on west, south, and southeast slopes, to 65 in successional Q. alba stands on north slopes, and stream terraces. Quercus stellata site index increased from 38 in Q. stellata stands to 44 in stable Q. alba stands. The site index of Q. prinus increased from a low of 32 in Q. prinus stands (south gravelly slopes), to a range of 40 to 50 in mixed stands (east gravelly slopes and ridges), to over 60 in Q. alba stands (silty north slopes and stream terraces).

The tree growth-stand stability pattern for each species is similar and the following relationship exists: within the range of its respective environmental tolerances, a species will be most competitive and form a compositionally stable community on sites where it has a slow growth rate (low site index), while on sites where it has a fast growth rate (high site index), it forms a temporary community that will be replaced by one composed of more shade tolerant and, frequently, slower growing species. Simply stated, the most productive Q. alba and Q. prinus communities eventually will be replaced by Acer saccharum and other shade tolerant mesophytes.

An Analysis of the Plant Community of Mudflats of TVA Mainstream Reservoirs

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KEY WORDS: annuals, distribution, mudflat community, perennials, reservoirs, Tennessee Valley

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Fifty-one species of vascular plants were identified during the quadrat sampling of the mudflat community along six Tennessee Valley Authority (TVA) mainstream reservoirs. Annual species dominated the community that contained 11 species of Cyperus and 17 species in the Cyperaceae. Species having frequency of 50 percent or greater were Rotala ramosior, Lindernia dubia, Fimbristylis autumnalis, Eleocharis obtusa, Eragrostis hypnoides, Hemicarpha micrantha, and Ammannia coccinea. Although less than 16 percent of the species identified were considered introductions, species such as Fimbristylis miliacea and Cyperus difformis are rapidly-expanding weeds that often occurred in pure stands and excluded more desirable native species. Regression analysis showed the time of exposure to be a significant factor in biomass production on the mudflat community. Extension of summer pool levels until later in the growing season will not only reduce biomass, but species diversity on mudflats as well.

Herbarium records show the distribution of Cyperus albomarginatus, Cyperus difformis, Fimbristylis miliacea, Fimbristylis vahlii, Hemicarpha micrantha, Leptochloa panicoides, Oldenlandia boscii, and Oldenlandia uniflora in the Tennessee Valley to be primarily limited to mudflats along TVA reservoirs. Although apparently very rare or absent from

reservoir margins in the decade or so following impoundment, most of these species were widespread by the mid-to-late-1970's. They are expected to continue their spread in the Tennessee River system as well as in similar habitats along other river systems with impounded waters.

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INTRODUCTION

The Tennessee Valley Authority (TVA) is responsible for the operation of 46 dams and reservoirs within the Tennessee River system (TVA 1982). On most of the major reservoirs, water levels are lowered beginning in early to late summer to a winter pool level that is attained by the last of December. The magnitude of the drawdown varies from reservoir to reservoir with the amount of dewatered shoreline being dependent on reservoir morphometry and the magnitude of the drawdown. In areas with suitable substrate, the drawdown zone is colonized by plant species that are adapted to intermittent inundation and saturated soils and by species that are capable of completing their life cycle in the compressed growing season between the drawdown and frost.

Along the shoreline of a "typical" mainstream reservoir an emergent community of herbaceous perennials occurs to a depth of about 0.5 m below the summer pool (figure 1). As water levels recede and the soil is exposed, another plant community develops. It is commonly referred to as the mudflat community and consists primarily of pioneer species known as "belly plants" due to their small stature. The mudflat community extends from the deepwater edge of the emergent community, or in some instances, from the elevation of summer pool level, to an elevation approximately 1 m below the summer pool level.

In recent years, several papers (Bates et al. 1978, Browne and Athey 1978, Dennis et al. 1980, Webb and Dennis 1981, Patrick et al. 1983) have been published that contain lists of species or floristic notes on plants along TVA reservoirs. While these complement the early work of Hall et al. (1946) and Isely (1946), none represent a detailed analysis of the mudflat community. In the late summer and fall of 1980, a study was initiated to collect quantitative data to describe the mudflat community along TVA mainstream reservoirs and to study their development in relation to water level fluctuation. This information was needed for various TVA natural resource programs such as wildlife, aquatic plant management, mosquito control, fisheries, and in particular, programs evaluating the impact of changing long-established water level fluctuation schemes.

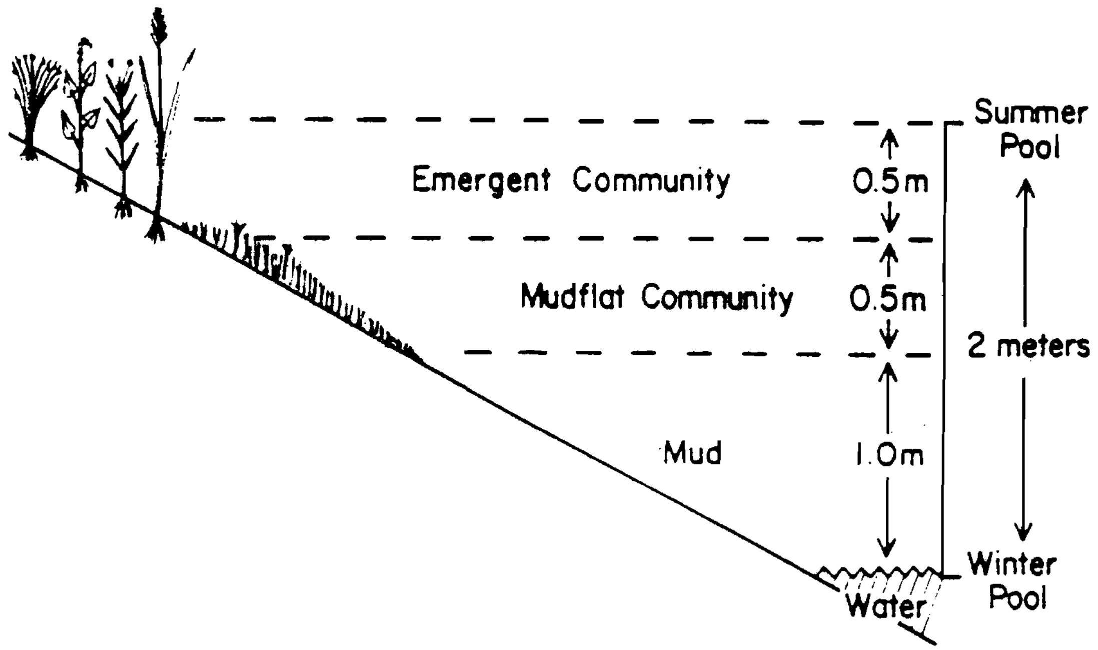

Figure 1. Generalized diagram of vegetation along a TVA mainstream reservoir with an approximate 2 m drawdown

MATERIALS AND METHODS

The mudflat community on TVA mainstream and several tributary reservoirs was surveyed for floristic composition from 1978 to 1987. In addition to collections made by the authors to document distributions along TVA reservoirs, the herbarium collections at Austin Peay State University (APSC), Murray State University (MUR), the University of Tennessee (TENN), and Vanderbilt University (VDB) were examined for selected species. Distributional data also were obtained from the private collection of Raymond Athey of Paducah, Kentucky. Nomenclature for the species primarily follows Radford et al. (1968).

Quadrat sampling was conducted at 16 sampling locations along six TVA mainstream reservoirs (figure 2) during the late summer and autumn of 1980. A belt transect perpendicular to shoreline contours was established at each site. The upper end of each transect was permanently marked with a steel post and the quadrats taken along a fixed azimuth. The upslope boundary of the mudflat community was the deepwater edge of the shoreline emergent community. The mudflat community at each location was sampled by first defining zones based primarily on vegetation height, then by identifying and collecting all vascular plant species within a 0.1 m^2 quadrat at 25 percent, 50 percent, and

75 percent of the total distance across each zone. The various species from each quadrat were separated in the field, labeled, placed in a plastic bag, and returned to the laboratory where they were oven dried at 105°C to obtain a dry weight biomass estimate.

The frequency of each species was calculated according to standard methods and was based on a total of 135 quadrats. The elevation of each quadrat sample was determined using an engineering level and an established benchmark in the vicinity of the sampling site. The number of days that a specific elevation had been dewatered was calculated from water level elevations reported in daily TVA river bulletins. A linear regression was used to determine the relationship between time of exposure (independent variable) and biomass (dependent variable). Sites along the tailwaters of reservoirs were not analyzed by linear regression because highly variable water level fluctuations associated with hydroelectric generation did not allow an accurate determination of days of exposure.

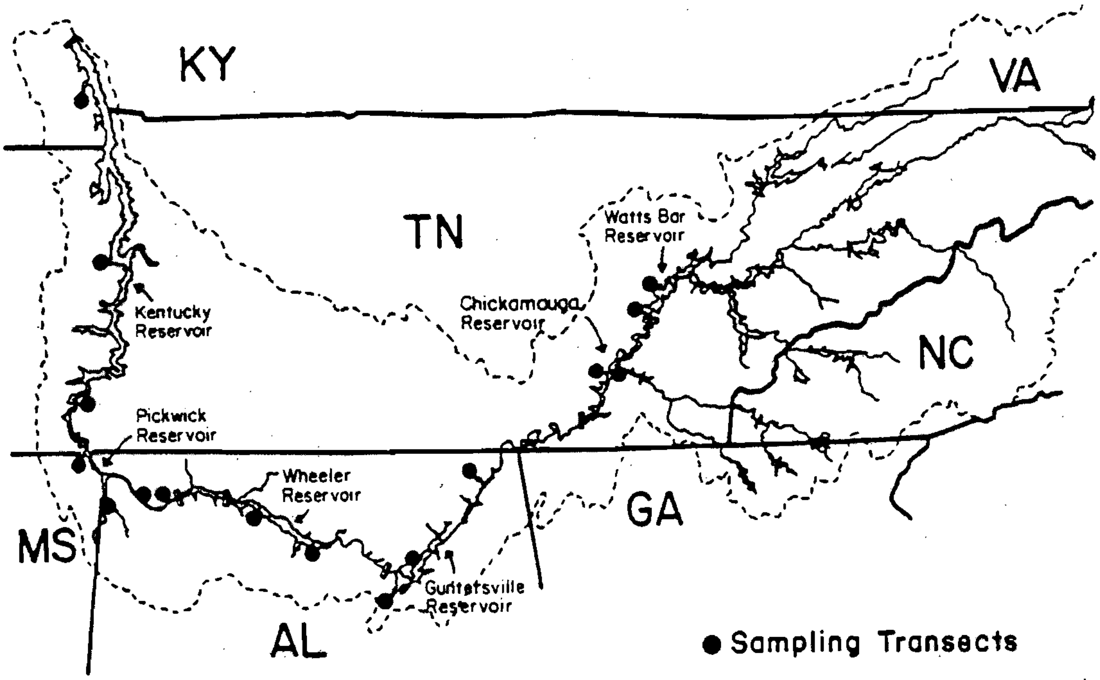

Figure 2. Location of 16 sampling transects along six TVA mainstream reservoirs

RESULTS AND DISCUSSION

Quadrat Sampling

The 51 species identified during quadrat sampling are listed in table 1. They represent 16 families and 32 genera (table 2). Seventeen species in the Cyperaceae and 8 in the Poaceae comprised about one-half of the identified species. Within the Cyperaceae, 11 species were in the genus *Cyperus*, 3 in *Fimbristylis*, 2 in *Eleocharis*, and 1 in *Hemicarpha*. A single species from *Digitaria*, *Eragrostis*, *Leersia*, *Leptochloa*, and *Zizaniopsis* and 2 species of *Panicum* were identified in the Poaceae. Other genera with more than one species were *Oldenlandia* (2 species, Rubiaceae), *Justicia* (2 species, Acanthaceae), *Ludwigia* (3 species, Onagraceae), and *Juncus* (2 species, Juncaceae).

Table 1. Species identified during quadrat sampling along six TVA mainstream reservoirs including data on frequency, biomass, life form, status, and distribution

Species	Frequency* (%)	Biomass+	Life$ Form	Status@	Reservoir&
Rotala ramosior	83	26.2	A	N	C,G,K,P,W
Lindernia dubia#	79	5.7	A	N	C,G,K,P,W
Fimbristylis autumnalis	73	17.9	A	N	C,G,K,P,W
Eleocharis obtusa	72	27.8	A	N	C,G,K,P,W
Eragrostis hypnoides	70	15.0	A	N	C,G,K,P,W
Hemicarpha micrantha	52	4.3	A	N	C,G,K,P,W
Ammannia coccinea	50	8.3	A	N	C,G,K,P,W
Eleocharis acicularis	43	78.3	P	N	C,G,K,P,W,WB
Cyperus aristatus	36	1.0	A	N	G,K,P,W
*Cyperus odoratus***	30	15.3	A	N	C,G,K,W
Fimbristylis miliacea	27	66.0	A	I	C,G,K,P
Fimbristylis vahlii	23	9.2	A	N	K,P,W
Cyperus esculentus	18	25.2	A	N	G,K,P
Leptochloa panicoides	17	26.1	A	I	G,K,P
Oldenlandia boscii	16	1.9	P	N	K,P,W
Cyperus difformis	14	41.4	A	I	C,G
Cyperus erythrorhizos	10	5.2	A	N	G,K,P,W
Aster simplex	8	11.7	P	N	C,K,P
Cyperus albomarginatus	8	5.5	A	N	C,K,P
Ludwigia palustris	8	22.1	P	N	C,G
Bacopa rotundifolia	7	5.1	P	N	K,P
Justicia americana	7	96.1	P	N	C,G,P
Leersia oryzoides	7	78.3	P	N	C,G

Table 1. (Continued)

Species	Frequency* (%)	Biomass+	Life$ Form	Status@	Reservoir&
Oldenlandia uniflora	7	<0.1	A	N	K,P,W
Panicum dichotomiflorum	7	5.5	A	N	G,K,P
Sagittaria calycina	5	0.6	A	N	G,K
Unknown	5	<0.1	-	-	C,K,W
Alternanthera pliloxeroides	4	154.7	P	I	P
Amaranthus tuberculatus	4	0.3	A	N	W
Cyperus iria	4	4.7	A	I	P
Eclipta alba	4	1.5	A	N	K,P,W
Ludwigia decurrens	4	12.0	A	N	G,K
Xanthium strumarium	4	34.9	A	I	K
Eryngium prostratum	3	0.3	P	N	P,W
Justicia ovata	3	67.2	P	N	P
Paspalum fluitans	3	4.8	A	N	K,P
Cyperus flavescens	2	2.3	A	N	G
Hypericum mutilum	2	<0.1	A	N	K,P
Juncus repens	2	0.7	P	N	P
Juncus sp.	2	0.3	-	-	C,G,W
Leucospora multifida	2	0.4	A	N	G
Aneilema keisak	1	11.3	A	I	C
Cyperus polystachyos	1	0.6	A	N	P
Cyperus rivularis	1	0.4	A	N	G
Cyperus tenuifolius	1	0.7	A	N	K,P
Digitaria ischaemum	1	5.1	A	I	K
Eupatorium capillifolium	1	33.3	A	N	G
Juncus acuminatus	1	63.1	P	N	G
Ludwigia glandulosa	1	10.7	P	N	G
Panicum agrostoides	1	119.3	P	N	P
Panicum sp.	1	0.4	-	-	G
Paspalum sp.	1	5.3	-	-	G
Polygonum sp.	1	2.9	-	-	G
Phyllanthus caroliniensis	1	<0.1	A	N	W
Rorippa islandica	1	0.6	A	N	K
Zizaniopsis miliacea	1	42.6	P	N	G

*Frequency of occurrence in 135 quadrats
+Dry weight in grams/m ^{2}
$Annual (A) or Perennial (P)
@Native (N) or Introduced (I)
&Chickamuga (C), Guntersville (G), Kentucky (K), Pickwick (P), Wheeler (W), or Watts Bar (WB)
#Including Lindernia anagallidea
**Including Cyperus ferruginescens

Of the species identified, 35 are annuals and 16 are perennials (table 1). The dominance of the annuals in the mudflat community is even more striking when perennial species more characteristic of the emergent community such as Alternanthera philoxeroides, Aster simplex, Juncus acuminatus, Justicia americana, Justicia ovata, Leersia oryzoides, Ludwigia glandulosa, Ludwigia palustris, Panicum agrostoides, and Zizaniopsis miliacea, are excluded. These species are generally found from top summer pool of the reservoir to about 0.5 m below. Their inclusion in the sampling transects is a result of the irreqular boundary between the emergent and mudflat community and small variations in elevations that favor species characteristic of the emergent community.

Table 2. Family, number of species per family, genera, and number of species in each genus in sampling quadrats on six TVA mainstream reservoirs

Family	Number of Species	Genera (Number of Species)
Acanthaceae	2	Justicia (2)
Alismataceae	1	Sagittaria (1)
Amaranthaceae	2	Alternanthera (1), Amaranthus (1)
Apiaceae	1	Eryngium (1)
Asteraceae	4	Aster (1), Eclipta (1), Eupatorium (1) Xanthium (1)
Brassicaceae	1	Rorippa (1)
Commelinaceae	1	Aneilema (1)
Cyperaceae	17	Cyperus (11), Eleocharis (2), Fimbristylis (3), Hemicarpha (1)
Euphorbiaceae	1	Phyllanthus (1)
Hypericaceae	1	Hypericum (1)
Juncaceae	2	Juncus (2)
Lythraceae	2	Ammannia (1), Rotala (1)
Onagraceae	3	Ludwigia (3)
Poaceae	8	Digitaria (1), Eragrostis (1), Leersia (1), Leptochloa (1), Panicum(2), Paspalum (1), Zizaniopsis (1)
Rubiaceae	2	Oldenlandia (2)
Scrophulariaceae	3	Bacopa (1), Lindernia (1), Leucospora (1)
	51	

Of the six remaining perennials (Eleocharis acicularis, Cyperus esculentus, Oldenlandia boscii, Bacopa rotundifolia, Eryngium prostratum, and Juncus repens), only E. acicularis, O. boscii, and C. esculentus had a frequency greater than 10 percent (table 1). Eleocharis acicularis, the perennial with the highest frequency (43 percent), is widespread throughout the mainstream reservoirs of the TVA system. This diminutive spikerush only occasionally sets fruit, and spreads primarily by slender stolons. Growth occurs while E. acicularis is submerged and later when exposed by receding water levels of the late summer and early autumn. This and related species of Eleocharis are currently under study as a naturalistic control for submersed weedy species, because of its competitiveness and purported allelopathic properties (Yeo and Fisher 1970, Frank and Dechoretz 1980). Cyperus esculentus, with a frequency of 18 percent, is a difficult-to-control weed in agricultural row crops. A cultivar known as chufa forms numerous tubers and is often planted in wetlands as a food for waterfowl.

Fourteen annual species had a frequency of occurrence greater than 10 percent (table 1). Although sedges in Cyperus and Fimbristylis dominated the group, the species with the greatest frequency were Rotala ramosior in the Lythraceae (83 percent) and Lindernia dubia in the Scrophulariaceae (79 percent). Two grasses, Eragrostis hypnoides and Leptochloa panicoides, Ammannia coccinea in the Lythraceae, and the sedges Eleocharis obtusa and Hemicarpha micrantha comprised the remainder of the annual species exceeding 10 percent. Although cocklebur (Xanthium strumarium) occurred in only 4 percent of the quadrats, it has been observed in dense and often pure stands on several reservoirs in the TVA system. It is often a weed that replaces more desirable waterfowl food plants in wildlife management areas where it can be partially controlled by various schemes of water level manipulation (Fredrickson 1982).

The mudflat community is comprised primarily of species listed by Fernald (1950), Radford et al. (1968), and Godfrey and Wooten (1979, 1981) as native in the eastern United States. Of the 51 species in table 1, only the following 8 are regarded as introductions: Fimbristylis miliacea, Leptochloa panicoides, Cyperus difformis, Cyperus iria, Xanthium strumarium, Digitaria ischaemum, Alternanthera philoxeroides, and Aneilema keisak. The last 2 species generally are a part of the emergent rather than the mudflat community. All are generally considered weeds in agricultural or aquatic systems.

Perennial species characteristic of the emergent community, such as Leersia oryzoides, Justicia americana, Justicia ovata, and Panicum agrostoides, and Eleocharis acicularis of the mudflat community, had the highest biomass (table 1). Several annuals (Rotala ramosior, Eleocharis obtusa, Fimbristylis miliacea, Cyperus esculentus, Leptochloa panicoides, Cyperus difformis) of the mudflat community had biomass exceeding 25 g/m^2, indicating a relatively high density when present within the sampling quadrats. Of particular note was the relatively high biomass of the introduced weeds, C. difformis and F. miliacea; their mean biomass values were, respectively, 41.4 and 66.0 g/m^2. These weeds often form pure stands on mudflats and displace native species considered to be desirable waterfowl food plants. These species ultimately may become the dominants of the mudflat community throughout the reservoir system.

Linear regression analysis with biomass (dependent variable) versus exposure time (independent variable) showed the time of exposure to be significant on Kentucky, Pickwick, Guntersville, and Chickamauga reservoirs and not significant on Watts Bar and Wheeler reservoirs (table 3). While the small number of sampling points used in the regression analysis for Watts Bar (n = 3) and Wheeler reservoirs (n = 6) limits the power of the analysis, the lack of significance on Watts Bar is readily explained. The summer pool level on Watts Bar Reservoir does not begin to recede until 1 October compared to 1 July for Pickwick, Wheeler, Guntersville, and Chickamauga reservoirs, and 15 June for Kentucky Reservoir. As a result of the extended pool on Watts Bar, only Eleocharis acicularis, a perennial capable of underwater growth, was present in the sampling transects. Exposure time is less important for this species than for annuals whose germination and growth is dependent on being dewatered early in the growing season.

Table 3. Linear regression analysis of effects of exposure time on mudflat community biomass on six TVA mainstream reservoirs

Reservoir	Number of Transects	N	Slope	R-Squared	F-Value
Kentucky	2	18	1.01	0.83	79.37*
Pickwick	2	18	0.52	0.68	34.58*
Wheeler	1	6	0.41	0.50	4.03
Guntersville	2	18	0.45	0.60	23.91*
Chickamauga	2	15	0.58	0.48	12.16*
Watts Bar	1	3	-0.69	0.41	0.71

*Highly significant, $p < 0.01$

Exposure time must be considered a primary factor in the development of the mudflat community. Extension of full pool levels in the summer months will function not only to reduce biomass production, but decrease species diversity on mudflats as well. Along most sampling transects there was a decrease in species diversity from the upslope to downslope quadrats. The height and density of most species also decreased along the transect, and species typically several centimeters in height in the upslope portion of the transect might be only a few millimeters in height at the downslope end. Of the species characteristic of the mudflat community, Eleocharis acicularis is the species least likely to be adversely impacted by extended summer pool levels.

Distributional Studies

An examination of collections from regional herbaria and records from Raymond Athey for western Kentucky indicate the distribution of Cyperus albomarginatus, Cyperus difformis, Fimbristylis miliacea, Fimbristylis vahlii, Hemicarpha micrantha, Leptochloa panicoides, Oldenlandia boscii, and Oldenlandia uniflora, in the Tennessee Valley to be primarily confined to mudflats along reservoirs of the Tennessee River system (figures 3 through 10). In a few instances, collections were from alluvial bottoms along the reservoirs or in areas managed for waterfowl. None of these taxa are listed by Isely (1946) and several have been recently reported as state records or noteworthy collections (Kral 1973, Browne and Athey 1978, Dennis et al. 1980, Webb and Dennis 1981). Three of the species (C. difformis, F. miliacea, L. panicoides) are introductions, with the remaining five species being native to eastern United States.

Cyperus difformis and Fimbristylis miliacea are both considered weeds that were likely introduced into the United States with the rice culture (Kral 1971, Lipscomb 1980). The introduction and spread of C. difformis in the United States is discussed in Lipscomb (1980) and Tyndall (1983), with the earliest records for Alabama and Tennessee reported by Kral (1973) and Webb and Dennis (1981). Cyperus difformis is now widespread and abundant along portions of Guntersville and Wheeler reservoirs (figure 4) and is expected to move downriver to other mainstream reservoirs. The collection from Chickamauga Reservoir (Webb and Dennis 1981) is somewhat puzzling as it represents an upstream extension that can most logically be attributed to waterfowl or as an inadvertent introduction in plantings for waterfowl food plots on Hiwassee Island Wildlife Refuge where it was first collected. Fimbristylis miliacea, like C. difformis, appears to be rapidly expanding and currently has a much wider distribution in the Tennessee Valley (figure 5) than reported by Kral (1971). Waterfowl may be an important factor in its expanded distribution as Powers et al. (1978) report germination of F. miliacea seeds taken from the intestines of ducks.

Of the eight species, Cyperus albomarginatus and Hemicarpha micrantha have the widest distributions in the Tennessee Valley (figures 3 and 7). The distribution of Fimbristylis vahlii (figure 6) is interesting in that it is not known from either

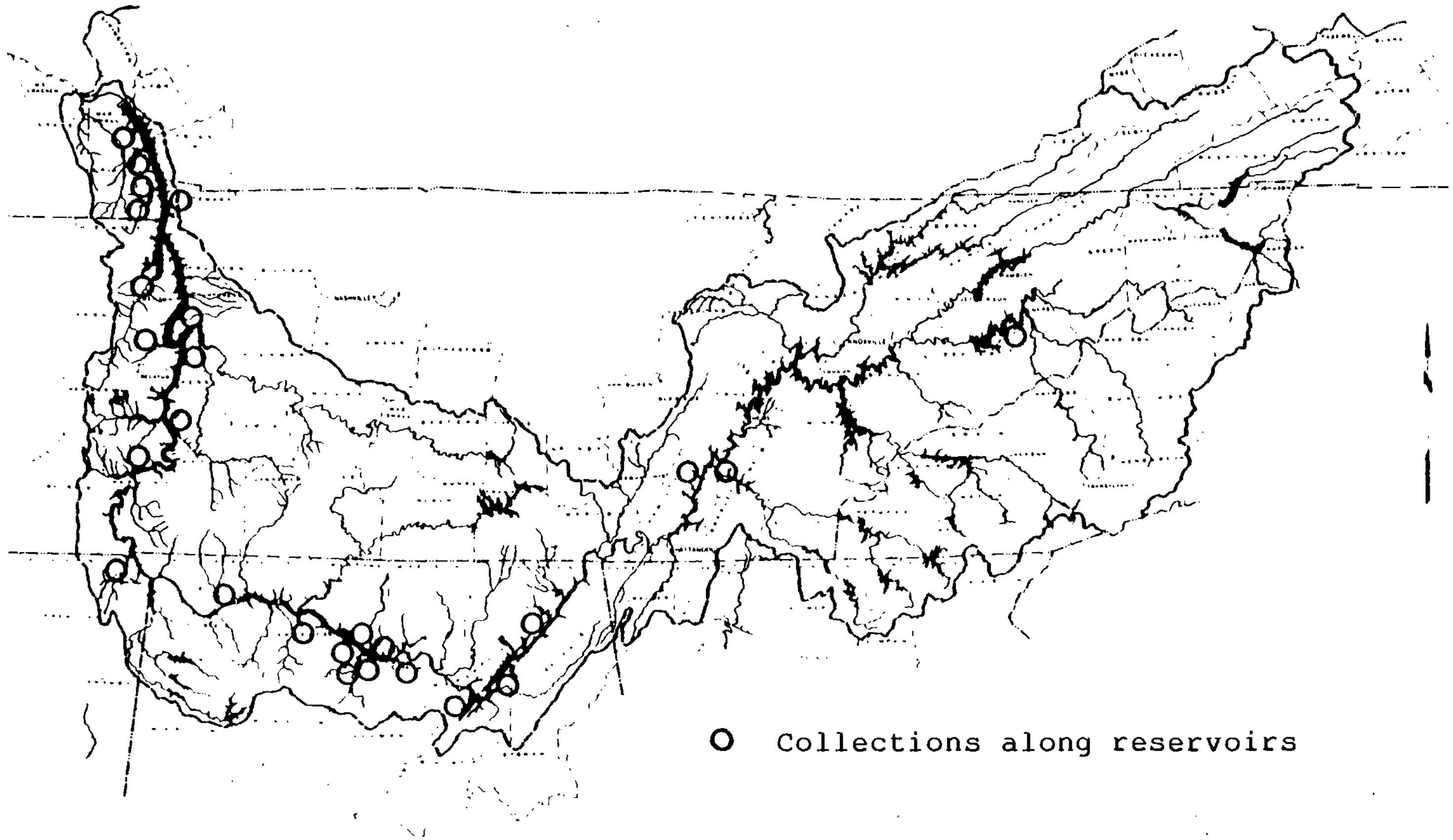

Figure 3. Distribution of _Cyperus albomarginatus_ in the Tennessee Valley

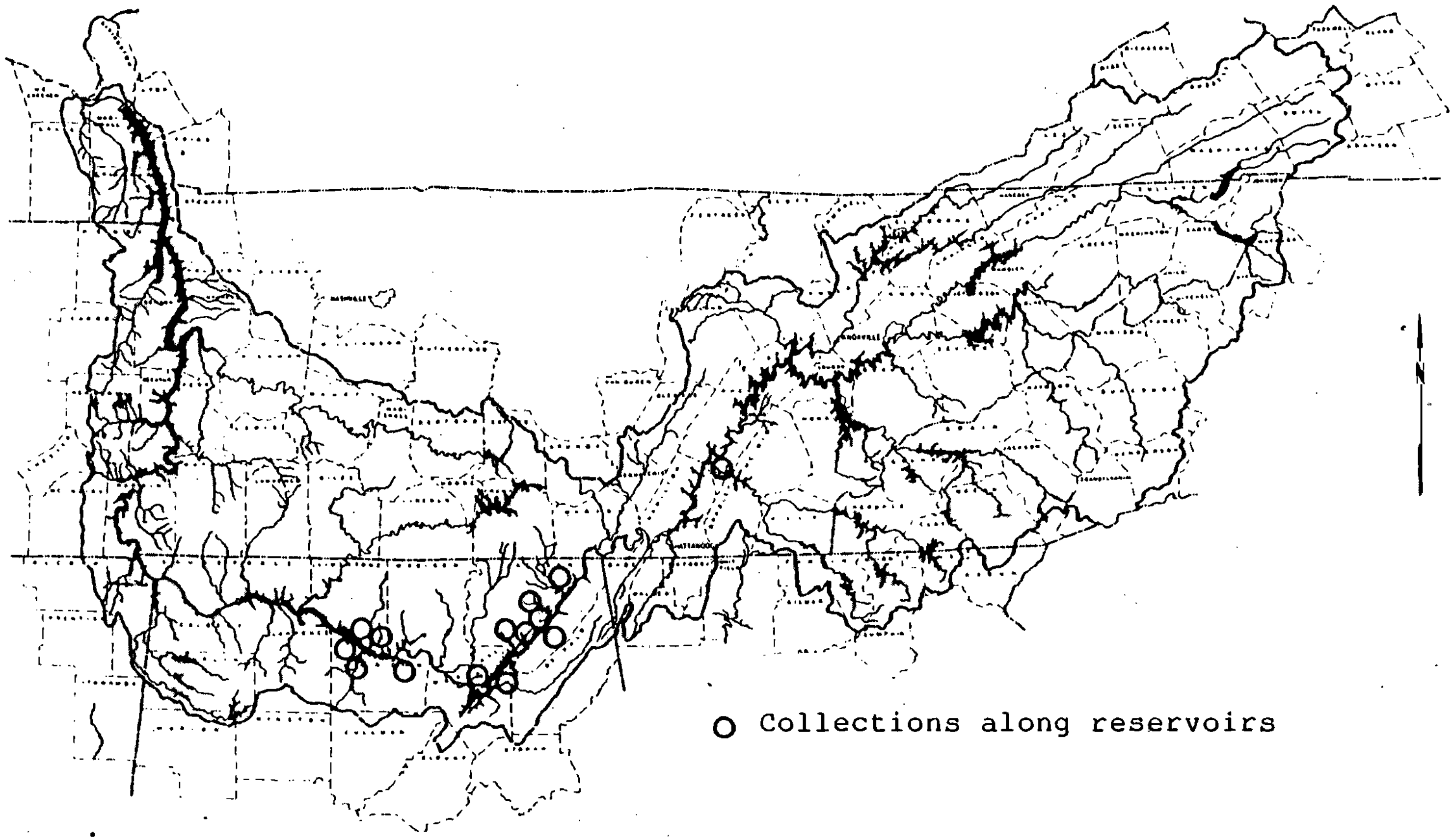

Figure 4. Distribution of <u>Cyperus difformis</u> in the Tennessee Valley

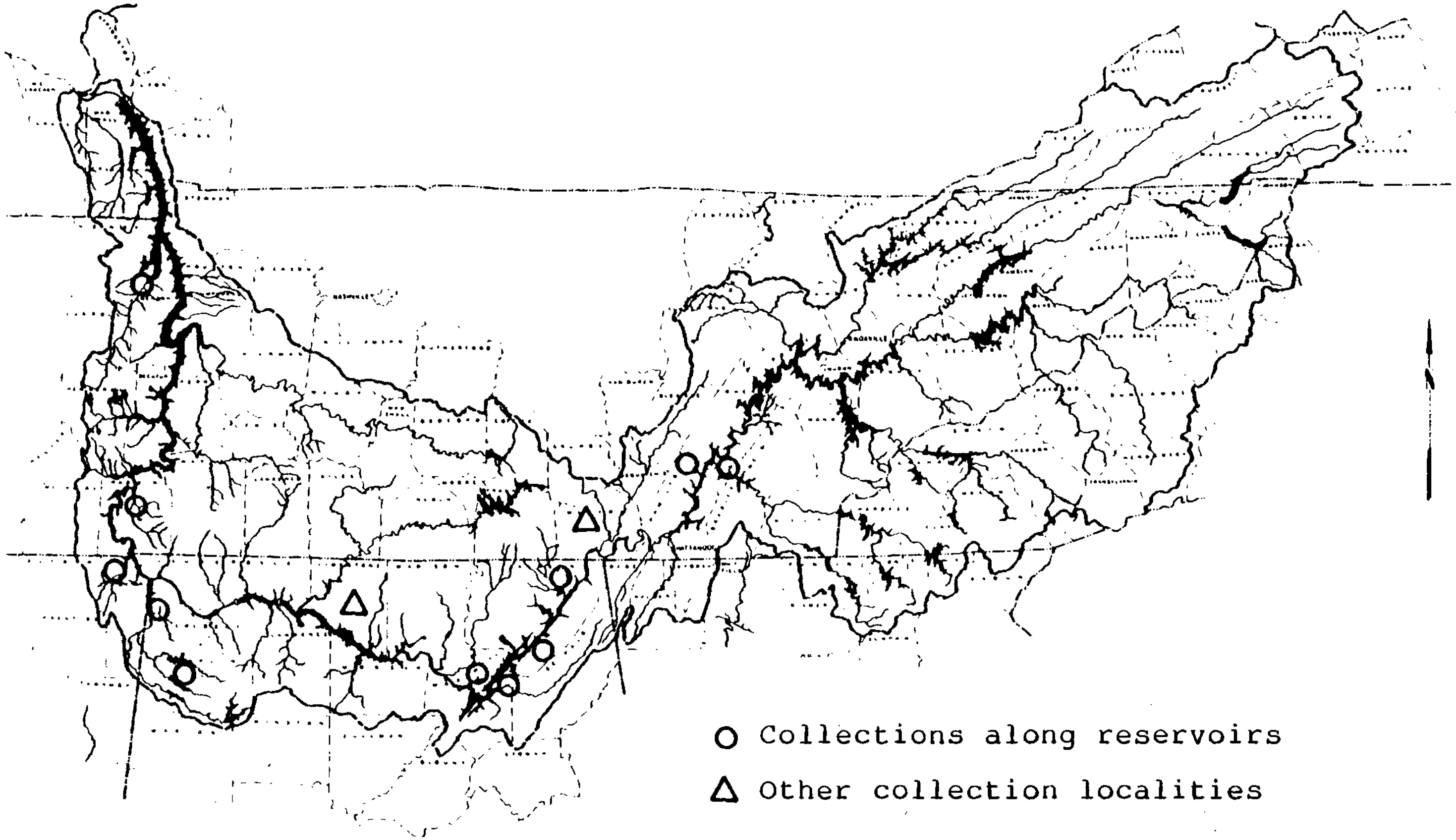

Figure 5. Distribution of Fimbristylis miliacea in the Tennessee Valley

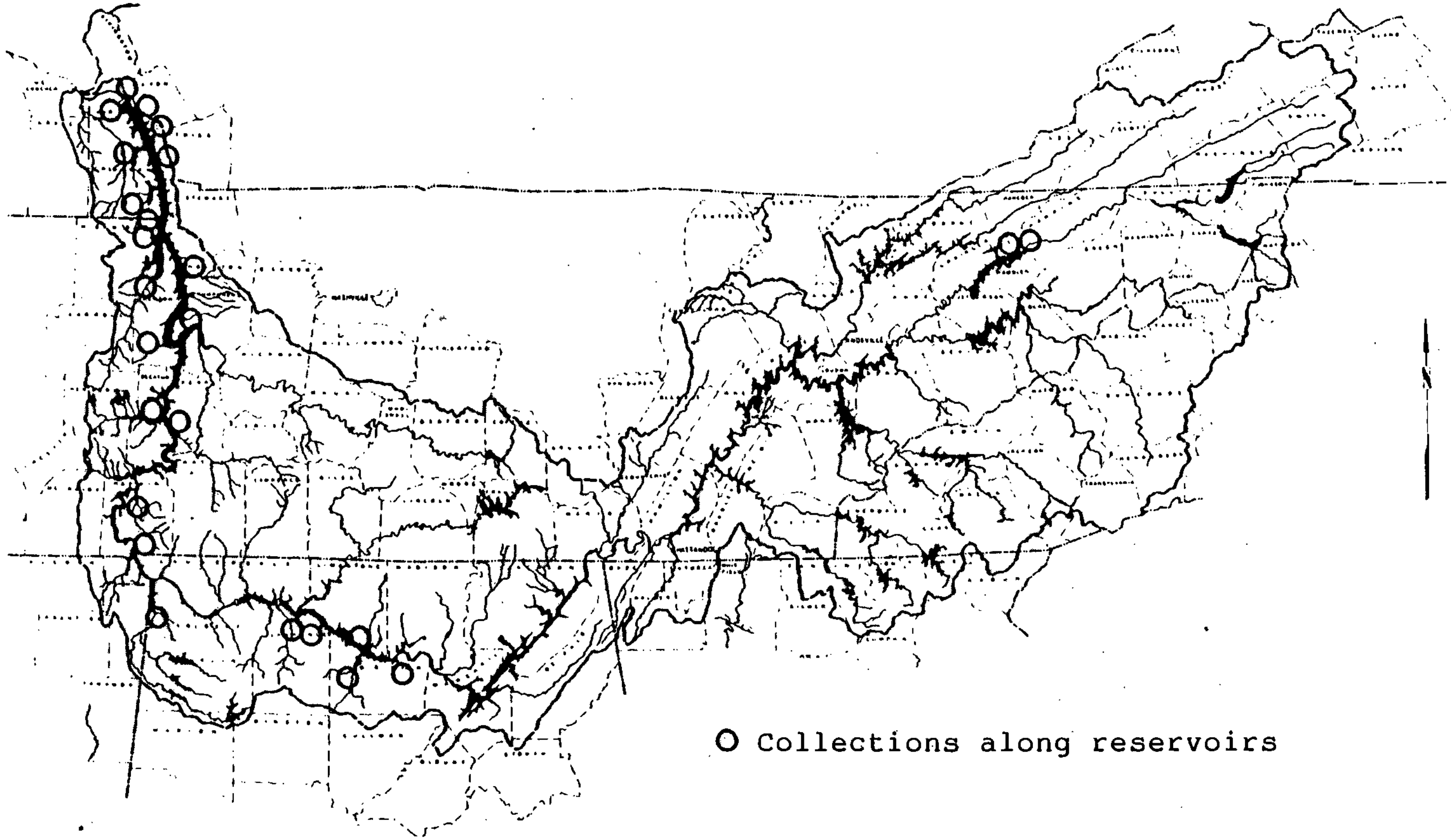

Figure 6. Distribution of Fimbristylis vahlii in the Tennessee Valley

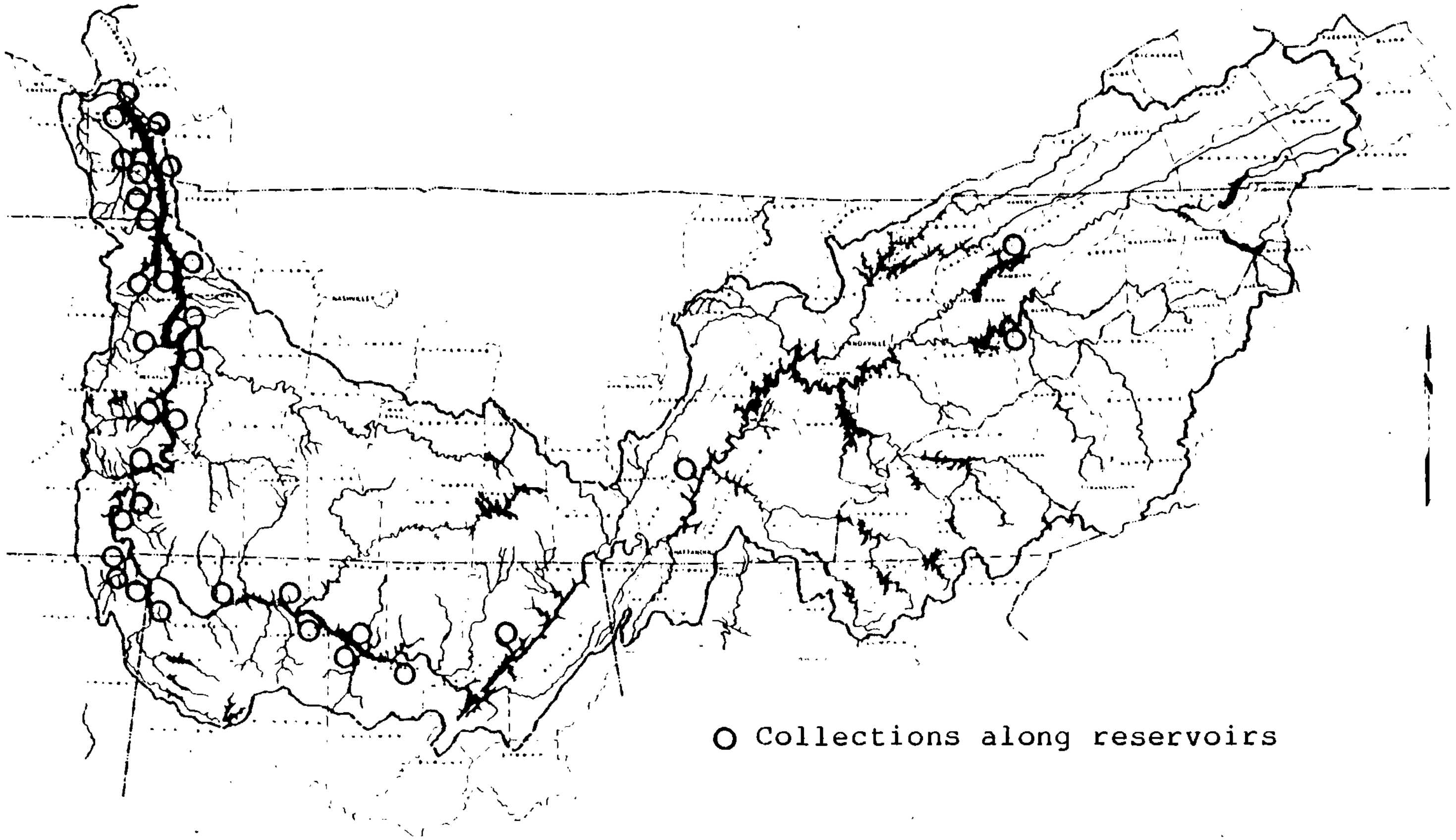

Figure 7. Distribution of Hemicarpha micrantha in the Tennessee Valley

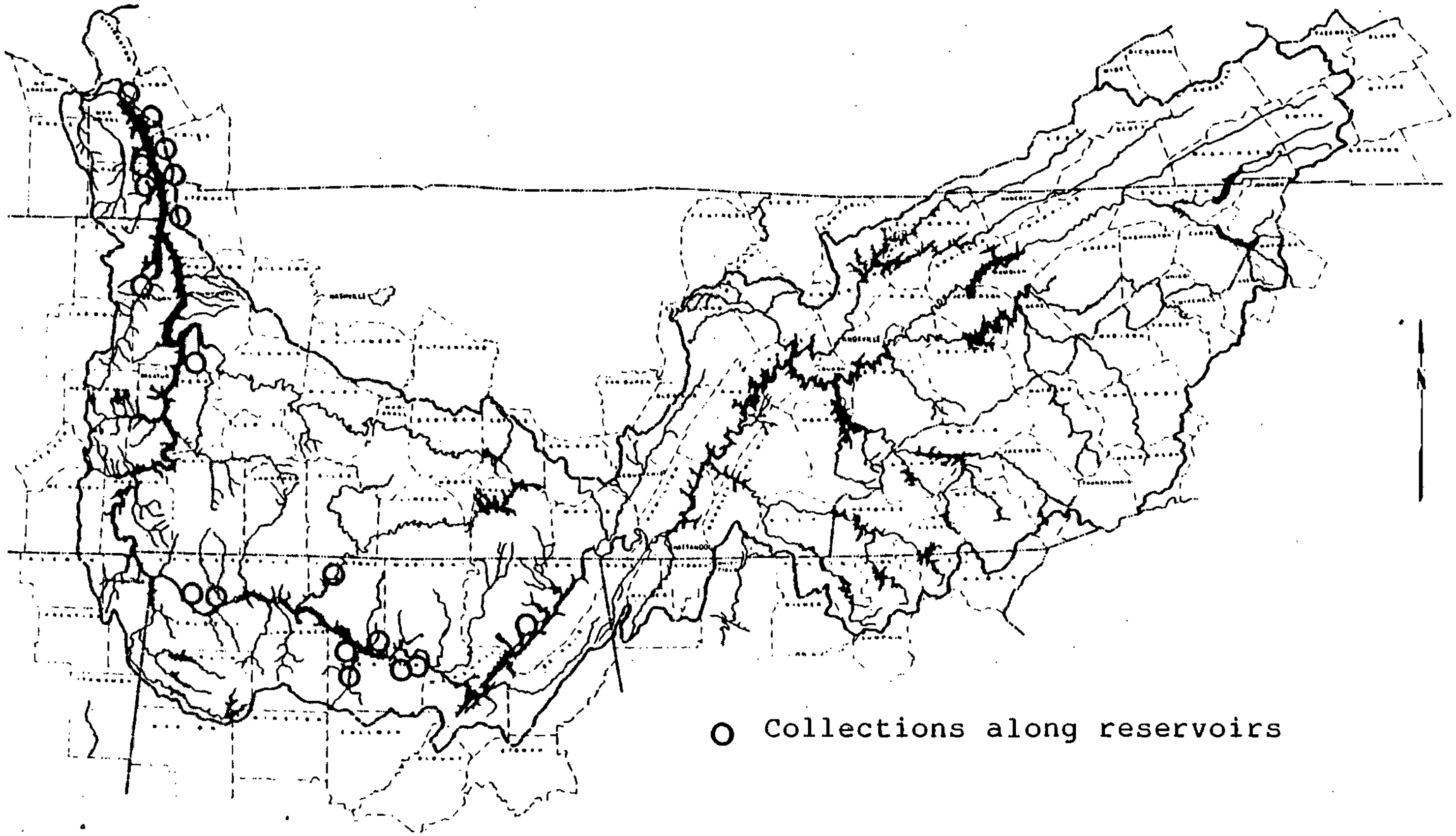

Figure 8. Distribution of <u>Leptochloa panicoides</u> in the Tennessee Valley

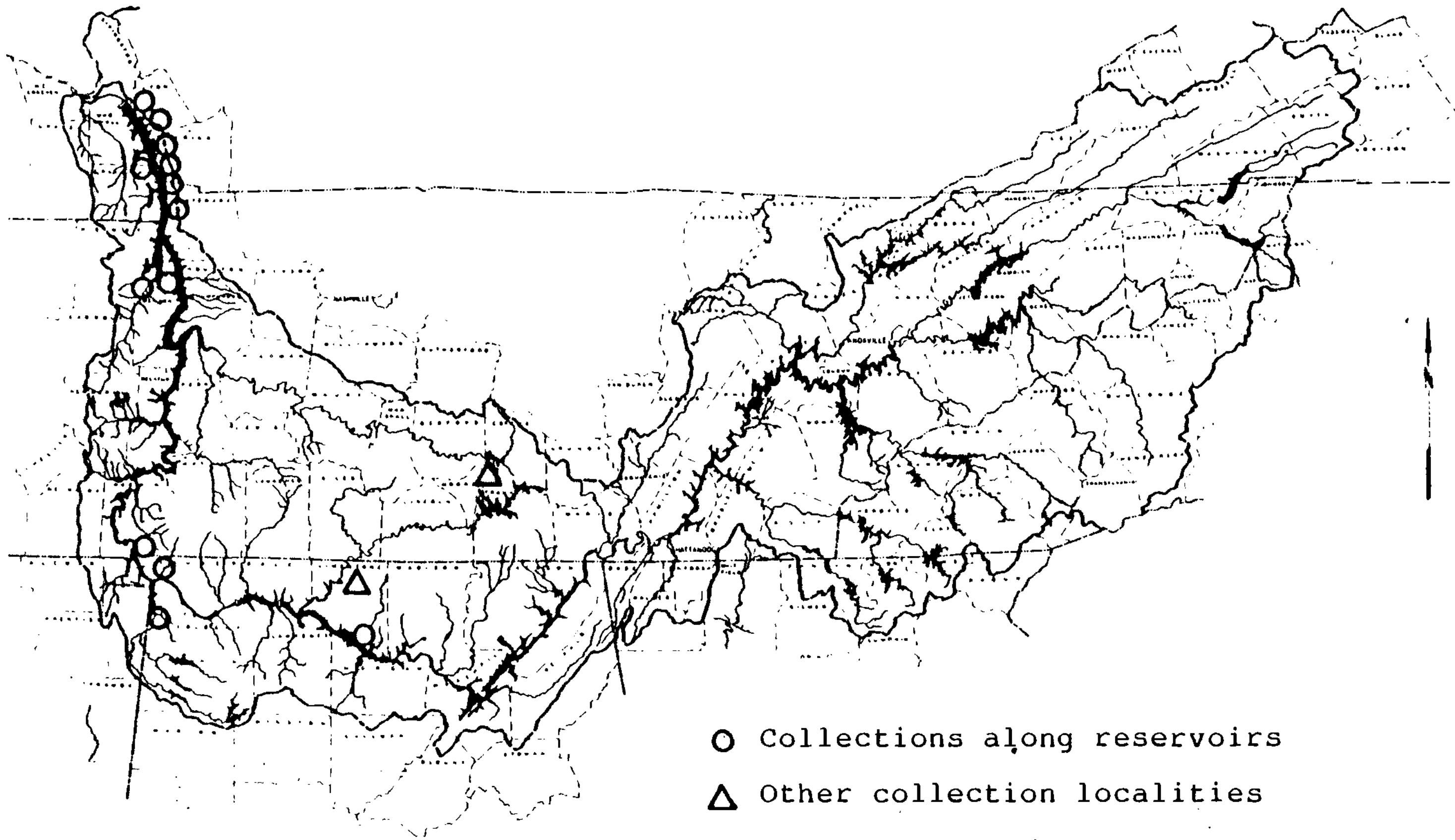

Figure 9. Distribution of <u>Oldenlandia</u> <u>boscii</u> in the Tennessee Valley

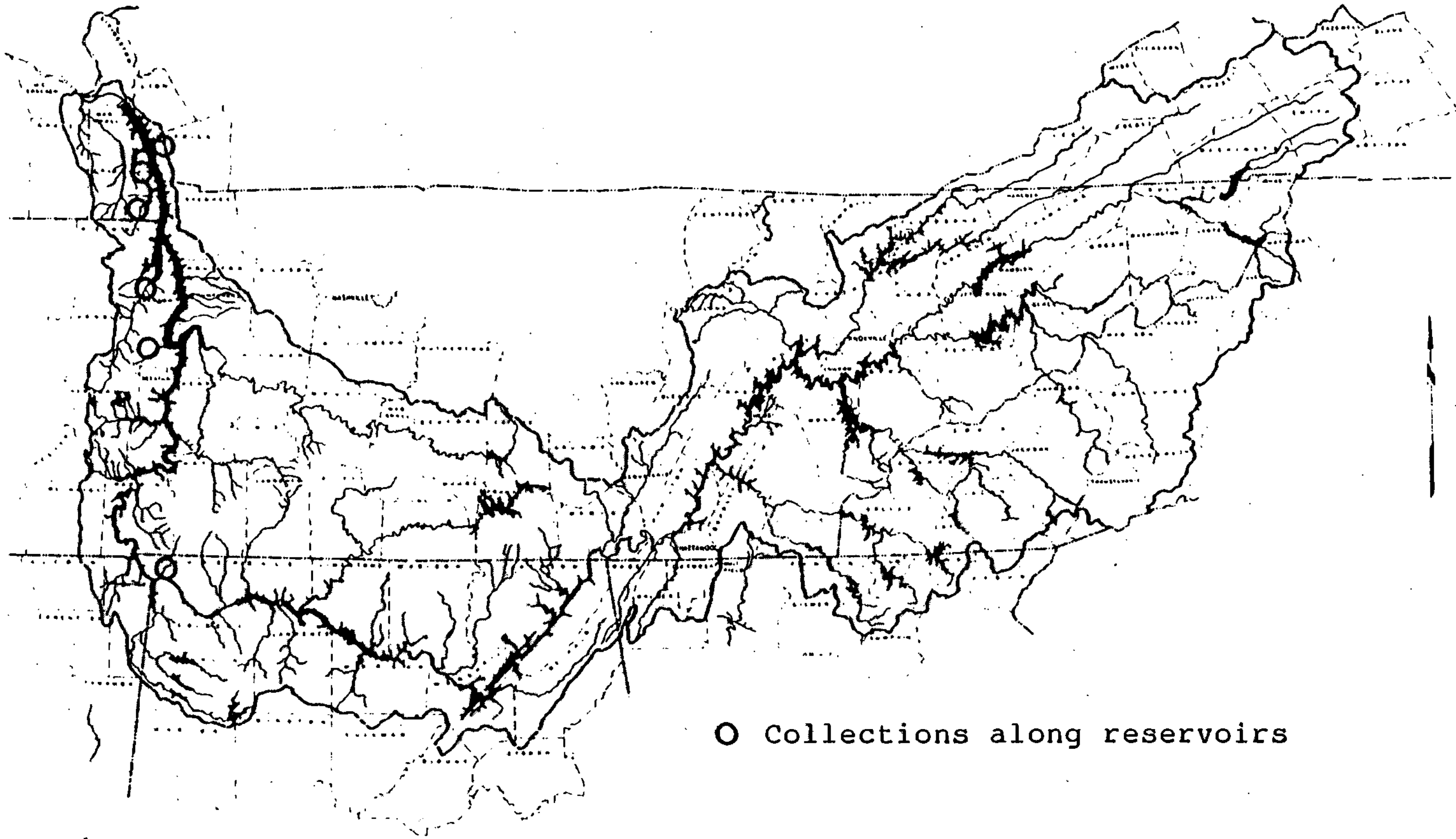

Figure 10. Distribution of Oldenlandia uniflora in the Tennessee Valley

Guntersville or Chickamauga reservoirs but is rather widespread in the western end of the valley and occurs on Cherokee Reservoir in eastern Tennessee. *Oldenlandia uniflora* currently is reported only from the western end of the valley (figure 10) and has the most restricted distribution of the eight species. *Oldenlandia boscii* and *Leptochloa panicoides* have similar distribution patterns (figures 8 and 9), ranging from the central valley region (Guntersville or Wheeler reservoirs) into the western end of the valley. A paucity of collections from along Kentucky Reservoir likely indicates that *Fimbristylis miliacea* is just beginning its spread in the northwestern end of the Valley (figure 5), a segment of the reservoir system that has been intensively collected.

A comparison of the earliest collection dates for the eight species largely confined to mudflats of TVA reservoirs is shown in table 4. Four mainstream reservoirs (Wilson, Nickajack, Watts Bar, Ft. Loudoun) are not included in table 4 because the water level fluctuation scheme on these reservoirs does not allow the development of a diverse mudflat community. While collections dating in the 1940's were located for *Fimbristylis miliacea* and *Oldenlandia boscii*, the earliest collections examined for the other five species were in the 1970's. With the exception of *Oldenlandia uniflora*, first collected in 1978, 1970 was the earliest collection date for *Cyperus albomarginatus*, *Cyperus difformis*, *Fimbristylis vahlii*, *Hemicarpha micrantha*, and *Leptochloa panicoides*. The last five species were all collected in 1970 by Dr. Robert Kral from Wheeler Reservoir in north central Alabama. Comparison of the earliest collection dates on the other reservoirs (table 4) shows most of the species to have been fairly widely distributed by the late 1970's. These data seem to indicate that the date of earliest introduction and establishment preceded 1970. This also is supported by the distribution maps of Kral (1971) that show a collection of *Fimbristylis vahlii* from western Kentucky and a collection of *Fimbristylis miliacea* from northeastern Mississippi. Those collections were not deposited in the herbaria visited during this study but likely predate the earliest collections along reservoirs listed in table 4 (Robert Kral, personal communication).

Presumably, little attention was given mudflats due to inaccessibility and a lack of interest in the "artificial" flats that were created when the Tennessee River was impounded. Several of these taxa, such as *Cyperus albomarginatus*, *Fimbristylis miliacea*, *Fimbristylis vahlii*, and *Hemicarpha micrantha*, also have been collected from tributary reservoirs in the TVA system such as Douglas and Cherokee reservoirs in east Tennessee and Cedar Creek Reservoir in northwestern Alabama. Several species characteristic of the mudflat community of the Tennessee Valley's mainstream reservoirs are listed for similar habitats along the Cumberland River by Carpenter and Chester (1987).

Table 4. Earliest collection date for eight species found in the mudflat community along TVA reservoirs and the Tennessee Valley

Species	Kentucky	Pickwick	Wheeler	Guntersville	Chickamauga	Other	Tennessee Valley
Cyperus albomarginatus	1974	1980	1970	1978	1980	Douglas, 1982	1970
Cyperus difformis	-	-	1970	1972	1980	-	1970
Fimbristylis miliacea	1978	1978	-	1971	1980	Cedar, 1963	1942
Fimbristylis vahlii	1973	1978	1970	-	-	Cherokee, 1978	1970
Hemicarpha micrantha	1973	1978	1970	1978	1978	Cherokee, 1985 Douglas, 1982	1970
Leptochloa panicoides	1973	1978	1970	1980	-	-	1970
Oldenlandia boscii	1978	1973	-	-	-	-	1940
Oldenlandia uniflora	1978	1980	-	-	-	-	1978

Undoubtedly, these species will continue to expand in distribution within the TVA system, and other uncommon species will be found on the mudflats. Solanum sarrachoides, a new adventive to Tennessee, was recently reported by Chester et al. (1987) from along Kentucky Reservoir.

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The Barrens of the Western Highland Rim of Tennessee

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KEY WORDS: barrens, flora, Middle Tennessee, prairie, vegetation

ABSTRACT

Eighteen samples of barren (prairie-like) vegetation have been examined on the western Highland Rim of Tennessee. Four samples are from loess covered uplands of the central and southwestern part of the study area, and 14 samples on shallow soils over limestone are generally in the western border of the area. Both kinds of areas exhibit summer drought. The openings are known in nineteenth century scientific literature. Of the 425 vascular taxa known, most are regional intraneous and southern taxa. Local intraneous and northern extraneous taxa are more numerous on limestone; western taxa are more numerous on loess sites. Using physical site factors, a type of direct gradient analysis demonstrated that groups of species are distributed differentially across parts of the mesic to xeric gradient. Vegetation on four plot-sampled sites are of the Schizachyrium scoparium-other graminoid and Schizachyrium-forb types.

INTRODUCTION

The barrens of western Highland Rim are part of a system of barrens-prairie vegetation which extends widely in the southeast from the Kentucky Barrens to the Black Belt of Alabama and Mississippi. The term barrens refers to vegetation resembling tallgrass prairie but locally may include grassy, low-density woodland or forest, thickest, savanna, and woodland with a grass understory. The term was used by travelers such as Michaux (1793-1796), Safford (1869), Killebrew and Safford (1874), and Dicken (1935), among others. Whether forest openings seen in the eighteenth century resulted from Amerind land use is not settled--nor is the extent to which present-day examples of this vegetation are represented by old fields. The relationship between some modern fields and barrens has been examined (DeSelm et al. 1969). Barrens studies include that in East Tennessee (DeSelm et al. 1969), an understory burn study in Middle Tennessee (DeSelm et al. 1973), and brief reviews of the problem (DeSelm 1981, 1986).

This paper characterizes open barrens of the western Highland Rim from the standpoint of their flora and vegetation; early historical reports for such openings have been sought in the literature (figure 1).

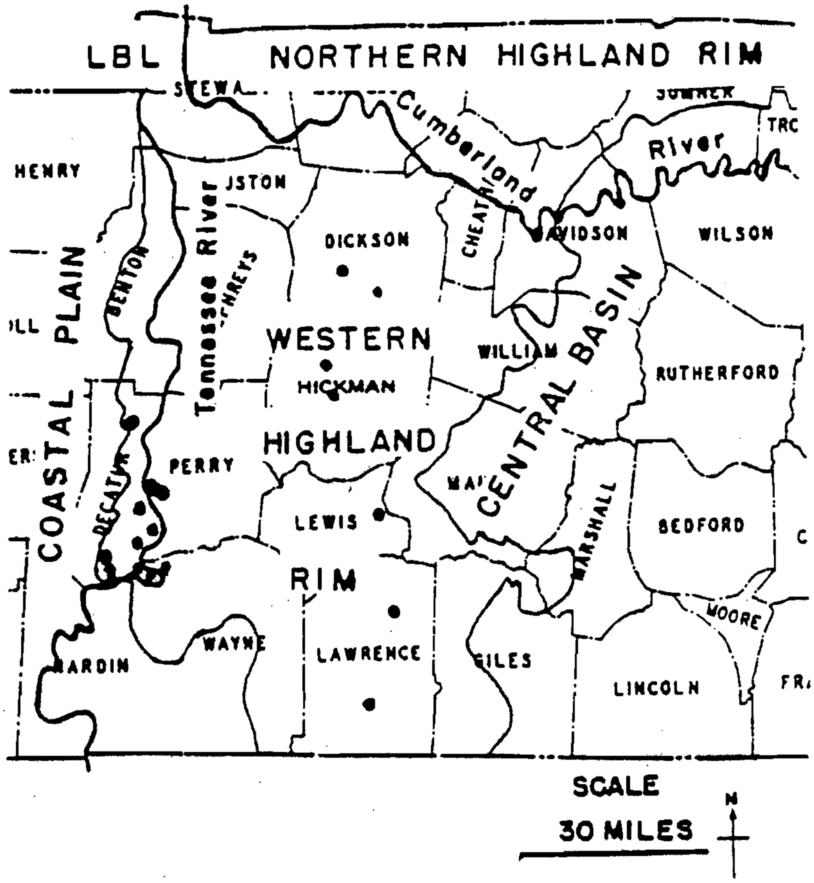

Figure 1. The western Highland Rim showing location of study sites.

THE STUDY AREA

The Highland Rim (figure 1) is part of the Interior Low Plateaus Province (Fenneman 1938); it is part of the Highland Rim physiographic-floristic area of Shanks (1958), who mapped the Kentucky Barrens as extending into Tennessee and the barrens of the southwestern Rim in Tennessee. The area lies within the Western Mesophytic Forest region of Braun (1950).

The western Highland Rim, as defined here, extends from the central Basin on the east and Cumberland River on the northeast, west to the Cretaceous deposits of Hardin and Wayne counties (east of the Tennessee River); the boundary lies a few kilometers west of the Tennessee River in Decatur and Benton counties; from southern Stewart County north, the Tennessee River becomes the western edge.

The climate of this region is humid mesothermal with "little or no" water deficiency in any season (Thornthwaite 1948). Maximum temperatures average 9-11°C (January), 32-33°C (July); minimums average -2-0°C (January) and 18-20°C (July) (Dickson 1960). Precipitation, mostly rain, averages about 142 cm per year in the south to 122 cm in the north. Vaiksnoras and Palmer (1973) calculated that between 1929 and 1969, 28 percent of the growing season months exhibited mild to extreme drought in Middle Tennessee. Safley and Parks (1974) calculated that, at Dickson, seven-day droughts had an 8-34 percent probability of occurrence during the June-October period in shallow, 2.5 cm average water-holding capacity soil. In deeper soils, probabilities are less; for fewer days than seven, probabilities are greater.

Much of the western Rim is underlain by more or less level-bedded, Mississippian limestones of the St. Louis, the Warsaw, and the Fort Payne Formations. These are cherty, calcareous, and dolomitic silicastones with some limestone and shale. Small areas are underlain by Devonian, Silurian, and Ordovician limestones and calcareous shales. Of importance to this study, in addition to the cherty Mississippian limestones above, are the Birdsong Shale and the Lobelville Formation. Cretaceous gravels occur sporadically as caps over the Mississippian strata in the western half of the area. Much of the upland is covered by loess (Hardeman 1966, Wilson 1949, Elder and Springer 1978).

Soils of the area are described by Springer and Elder (1980) and mapped by Elder and Springer (1978). Over the whole area, their character, especially as it relates to forest potential, is reviewed by Smalley (1980). The barrens are few enough, however, that only a few soils are represented. Barrens on flat to gently sloping uplands over loess occur on Guthrie (Lawrence, Sango), Dickson, and Mountview soils. These are silty clay loam or silty clay soils and all but the Mountview have a pan below 20 to 56 cm. Mottles are common. Soils are strongly to extremely acid; fertility is low. The pan results in winter waterlogging and summer droughtiness (Overton et al. 1958, Lampley et al. 1975). The loess is of Pleistocene Wisconsin (Peorian) age (Leighton and Willman 1950). Barrens (and glades) also occur on rocky, shallow soil over limestone near the Tennessee River. The soils are mapped as stonyland (Odom et al. 1955, Townsend et al. 1953) or rock land (Proffitt et al. 1963), generally from limestone or Talbott soil material. The areas are 25 to 75 percent rock outcrops. Between the bedrock is the silty clay loam or silty clay soil a few cm to a few dm deep. Its surface and volume contains chert and limestone rock fragments.

Slope varies to 15 percent, occasionally more. Bedrock may be cavernous and underdrained.

HUMAN HISTORY

Middle Tennessee was the living and/or hunting area of a sequence of Amerind cultures that populated eastern North America beginning late in the Pleistocene. Paleoindian evidence occurs as do Archaic settlements, Woodland burial mounds, and Mississippian culture temple mounds (Lewis and Kneberg 1958, Swanton 1946). Populations found by DeSoto and later Europeans were numerous to the north, east, and south of Middle Tennessee, but few, if any, Amerinds lived there after 1514 when the last Shawnee left under pressure from the Cherokee (Williams 1937). Probably the Yuchee had left the area earlier. Except for possible burning, it is not known that Amerinds had much impact on this landscape except near village sites (Lewis and Kneberg 1958). Intensive exploration, and harvesting of mammals (deer, elk, bison, beaver), began in the 1760s; French Lick (Nashville) was settled in 1780; the treaty of 1805 opened the land for settlement (Putnam 1859).

Forests were disturbed in several ways. Logs were cut and used locally or they were shipped as products (e.g., as staves) from the region. Forests and fields were grazed by swine, cattle, horses, and locally, sheep. The forest understory was burned to facilitate spring growth of forage. In at least several counties where iron ore was mined, wood was used to make pig iron. This resulted in extensive and repeated heavy forest cutting which continued through most of the nineteenth century (Corlew 1956, Spence and Spence 1900, McClain 1966, Garrett 1963, Haywood 1823, Goodspeed 1886).

REGIONAL FOREST OPENINGS

Several kinds of presettlement openings in the forest are known in the western Rim and adjacent region. The Shawnee village remnant and trading post were known in the 1760s; the opening at Clover Bottom (Haywood 1823) was an animal lick or Amerind old field. Amerind camps in nearby Hardin County (Harbert 1947) suggest that settlements and fields on the Rim were possible. Haywood (1823), repeating reports from early travelers, tells of a large open lick on the Duck River. The larger streams of the Rim have strip flood-zone openings similar to those of Shaver and Denison (1928).

Eighteenth century recorded literature on grass-covered loess-site and limestone-site openings on the Western Rim cannot be found. The long hunters (Haywood 1823) ranged over Kentucky and Middle Tennessee but it seems likely that their references to grassy openings are to those in the Kentucky Barrens or barrens of the Northern and Eastern Rim. Hutchins (1792, in Imlay 1797) notes, "The first of those ridges divides the waters of the Cumberland River from those of the Tennessee... but the plains are chiefly without timber and are called barrens." The location is not precise. Nineteenth century references to the barrens are chiefly those of the scientific writers Safford (1869), Killebrew and Safford (1874), Safford (1884), and Gattinger (1887, 1901). Information varies from a bare mention of the existence of barrens to accounts of a flat tableland with shallow, acid soils and scrubby small-tree cover, or, "broad prairie-like areas . . . open woods . . . scrubby timber and barren grass . . .," or "the wild grasses upon the broad areas of flat lands grow with spontaneous luxuriance, " or "a third class of land is flat and open, covered during the summer with a rank wild grass" (Hickman, Lewis, and Wayne counties, respectively). Gattinger (1901), from among hundreds of taxa listed in the Flora of Tennessee, lists only one specifically from the barrens of the Western Rim, Nabalus (Prenanthes) serpentarius, from the barrens of Dickson County.

The limestone sites were recorded as early as 1825, by Croft, on the tops of Tennessee River cliffs (Younger 1977). Safford (1869) recorded "gravelly or marly places mostly naked but presenting here and there patches of bushes or shrubby cedars." These were recorded for Decatur, Perry, Hardin, and Wayne counties. Killebrew and Safford (1874) and Safford (1884) described them briefly again. In the Tennessee Division of Geology series, "Geologic Map and Mineral Resource Summary" of many quadrangles, the glade-forming Birdsong Shale and Brownsport Group are mapped (Wilson 1967, see also Wilson 1975).

METHODS

My reconnaissance to locate open barrens began in Middle Tennessee in 1954. The Pickadilly site was found in 1957. Between 1957 and 1960, several small sites in Dickson, Hickman, Wayne, and Lawrence counties were found and examined--some repeatedly. The Lawrence County area was suggested by R. E. Shanks. In 1978, Dr. W. H. Martin, III, showed me limestone barrens in Decatur County. I have examined several of these through 1987, and have added others from Decatur and Perry counties. In 1985 three limestone sites were shown to me by Vernon Bates and Larry Wilson. An unusual limestone and shale site was seen in 1981 with Day Lohman and Dr. Elsie Quarterman. In 1987, Milo Guthrie called my attention to the Mashburn site west of Dickson. Floristic lists were compiled for each of 18 study sites. Ranges of native taxa were determined from Fernald (1950), Little (1971, 1977), Pennell (1935), and Bridges and Orzell (1986). Nomenclature, for the most part, follows Gleason and Cronquist (1963). Based upon their floristic lists, the floristic similarity between pairs or groups of sites has been calculated using a Jaccard coefficient of community (Mueller-Dombois and Ellenburg 1974).

THE SAMPLE AREAS

The list of study areas follows. Sites one through four occur over the Mississippian limestone (Pickadilly is over a Cretaceous Cap) on Mountview and Dickson soils. Unless otherwise indicated, sites 5-18 are on Talbott soils (Brownsport Group).

1. Ethridge. Along a railroad at the northwest corner of Ethridge, Lawrence County.
2. South of Lawrenceburg. Along a railroad and along route 6 south of Lawrenceburg, Lawrence County.
3. Dickson-Centerville. Along Routes 46 and 48 between Dickson and Centerville, in both Dickson and Hickman counties.
4. Pickadilly. On a gravel road 0.16 km north of U. S. 70. The junction of the gravel road and U. S. 70 is 6.4 km west of the railroad-U. S. 70 crossing at the west edge of Dickson, Dickson County. The Pickadilly site is supplemented by the Mashburn site, which is on U. S. 70, 7.0 km west of the above-mentioned junction.
5. Junction Barren. At the intersection of Route 114 and Bobs Landing Road, 2.2 km east of Bath Springs, Decatur County.
6. Parnassia Site. On Langford Branch on Route 99 in eastern Lewis County. It composes a gravelly screen (seep) dominated by _Parnassia grandiflora_, an open south-facing grass-covered bluff above a stream, a small sedge-covered swale along the creek, and adjacent old fields. The site is 0.7 km east of Fox Lake. The screen is cherty limestone; the bluff is Chattanooga shale.
7. Decatur Number 5. Along the east edge of the road triangle north of Mt. Nebo Church, Decatur County.
8. Swallow Bluff Road. Site is 0.08 km north of the Tennessee River. This road is west of Bath Spring on Route 69, Decatur County. It is on Talbott soils over generally cherty limestones and argillaceous shales.
9. Mt. Carmel Church. A few meters behind the church, Decatur County.
10. Big Barren. On the south side of Webbs Landing Road, Perry County, at the curve 0.5 km west of bench mark PM CP 16 (Perryville Quadrangle).
11. Mt. Lebanon Church. Site extends about 70 m northeast of the church, parallel to the road; Talbott soils, Brownsport Group, Decatur County.
12. Gravel Barren. On a gravel road which extends south from Webbs Landing road from about bench mark PM CP 16 (Perryville Quadrangle), Perry County.
13. Cub Creek. On the east side of Route 69 about 0.3 km south of its crossing of Cub Creek in northern Decatur County. It is on Talbott soils, Ross Formation.

14. Carol Cabin Road Barrens. On that road which is the first south branch from Smith Gravel Pit Road (which bears east from Bobs Landing Road about 2.4 km from its junction with Route 114), Decatur County.
15. Decatur Number 4. On both sides of Route 114 and on an adjacent old roadcut at about BM GN 83, Decatur County.
16. Long Point Barren. On Webbs Landing Road centering at its intersection with the crest of Long Point Ridge, Perry County.
17. Hilltop Barren. North of Route 69 on a gravel road near Swallow Bluff Road, Decatur County.
18. Clifton Cliff. On the southwest-facing cliff top above the Tennessee River about 3.6 km north-northeast of the center of Clifton (above mining activity), Wayne County.

In September, 1986 and 1987, I sampled four of the openings using 20, 0.5 m^2 plots spaced one m apart on a line across the longest axis of each opening. These were: the Mashburn site on loess, Dickson County; Long Point Barren and Big Barren in Perry County; and Carol Cabin Road Barren in Decatur County (these last three are on limestone). Frequency was calculated and percentage cover was estimated for each species in each plot. Relative frequency and relative cover were calculated and summed, giving an Importance Value (IV)--the maximum possible is 200. Frequency and percent cover per plot were also recorded for lichens/bryophytes, rock/gravel, bare soil, and tree litter.

Sites were ranked from mesic to xeric using the direct gradient method (Whittaker 1967). Several site physical characteristics which control available soil moisture (Brady 1974) were rated on a scale of one to five. They were:

aspect; flat (1) to southwest facing (5) (Lloyd and Lemmon 1970).
slope angle; 0-40 percent in units of 8 percent.
soil stoniness (surface inspection); none (zero) to 100 percent gravel in units of 20 percent.
soil depth; (1) soil in crevices to 5 cm depth, (2) soil overall depth to 5 cm, (3) soil to 10 cm, (4) soil to 15 cm, and (5) soil to 20 cm.

Numbers found for each site were totaled making a potential maximum of 20 and a minimum of 4. In the Gradient Analysis (see later) these numbers have been used to array the sites from mesic to xeric to see how presence of selected groups of species compared to the site array, representing available soil moisture.

RESULTS AND DISCUSSION

Flora

A total of 425 vascular taxa occur on 18 barrens. Of the theoretical 7650 species occurrences, 18.1 percent have been found. Of this flora, 79 families are represented, and only 5.9

percent of the taxa are not native. The native taxa include 21 percent Asteraceae, 13.5 percent Poaceae, 6.0 percent Fabaceae, and 4.5 Cyperaceae. Trends are similar to those seen in the whole Tennessee barrens flora (DeSelm, unpublished) and at the Big Clifty Prairie, Grayson County, Kentucky (Bryant 1977). Surprisingly, in a study of vegetation dominated by herbs, 20.3 percent of the native flora is woody.

A few taxa from these barrens are considered in different endangerment categories by federal and state agencies (Tennessee Department of Conservation 1986, Committee for Tennessee Rare Plants 1978). They are:

- Arabis glabra. State, special concern.
- Aster sericeus. State, threatened.
- Leavenworthia exigua var. exigua. Federal category 2; state, threatened.
- Liatris cylindracea. State, threatened.
- Onosmodium molle ssp. occidentale. State, threatened (cf. Baskin et al. 1986).
- Parnassia grandifolia. State, special concern.
- Salvia azurea var. grandiflora. State, special concern.
- Xyris tennesseensis. Federal category 2; state, endangered (cf. Kral 1978).
- Draba cuneifolia. Under consideration, state.

Nine such taxa is a small number compared to the 90 in the Citico Creek Wilderness Study Area (Malter 1977). Probably the total areas examined are similar in size, but Malter used rare plant lists for seven states as his base. The approximately two dozen rare taxa on the cedar glades (compare Tennessee Department of Conservation 1986, with Baskin et al. 1968 and Baskin and Baskin 1975) approximate the few found here; but, the cedar glade areas--mainly those of the Central Basin--are much more extensive than the small study units used here. Probably more rare taxa will be found here as study continues.

On the four loess substrate sites, 211 native taxa are known; on 14 limestone sites 312 natives occur. Ranges of the species of the native plants of these combined lists were compared:

- regional intraneous; on loess 62.6 percent, on limestone 60.2 percent.
- southern; on loess 30.3 percent, on limestone 27.9 percent.
- northern; on loess 3.8 percent, on limestone 7.1 percent.
- local intraneous; on loess 1.9 percent, on limestone 3.2 percent.
- western; on loess 3.8 percent, on limestone 1.6 percent.

It seems probable that the paired percentages for intraneous and southern taxa are similar enough that they should be considered the same. The intraneous and southern percentages compare favorably with that seen in the Ridge and Valley (Oxendine 1971). The northern percentages are only 16 to 30 percent of those in the Ridge and Valley (Oxendine 1971) but approximate that percentage (7.8) for the Tennessee barrens as a whole (DeSelm 1981). Similarly the western taxa approximate that for the barrens as a whole (2.3 percent, DeSelm 1981).

The northern extraneous taxa reach a higher percentage on the limestone soil barrens than those on the more level loess areas. It seems likely that the diverse topography has more microclimatic habitats similar to those farther north that would support the successful growth and reproduction of these taxa (Geiger 1965, Daubenmire 1974). Indeed, northern taxa are not uncommon in the Blue Ridge and Cumberland Plateau where factors associated with elevation meet their needs (maps in Shanks 1958; Little 1971, 1977). It has also been suggested that large river valleys were major southward dispersal routes during the Pleistocene (Delcourt and Delcourt 1975).

The number of taxa with local intraneous distribution is small, but percentages on loess and limestone are quite different--there are more on limestone. Of the 12 taxa (both site types), all are typical barrens plants except _Leavenworthia exigua_ var. _exigua_; four other limestone taxa occur on cedar glades (as interpreted by Baskin et al. 1968, Baskin and Baskin 1975). As in the Central Basin the local intraneous taxa (endemics) occur on limestone (Baskin and Baskin 1986). It is not clear why limestone more than the loess substrate should be an important option for local evolution or habitat preference

A higher percentage of loess than limestone taxa are extraneous western. This suggests the relative absence of limestone sites in Arkansas and Missouri from which these taxa may have come. However, these sites are common in Arkansas (Dale 1986) and Missouri (Nelson 1985).

Elevations of the limestone sites in this study ranged from 122 to 159 m. Straight line distance from each site to the center of Kentucky Lake averages 2.6 km (range 0.2-6.4). A high "old" terrace soil, the Waynesboro, occurs near the River. In the northern part of Hardin County in the Pickwick-Talbott, Waynesboro Association (Proffitt et al. 1963), it was at 165 m on the Hookers Bend U.S.G.S. 1949 7.5 minute quadrangle. A terrace occurs at 165-168 m in Decatur County at Utah School (Odom et al. 1955) on the Perryville U.S.G.S. 1949 7.5 minute quadrangle. This site is 54 m above average pool level--about 58 m above the now submerged flood plain. A terrace about eight m above the flood plain on the Duck River at Cheek Bend (Brakenridge 1984) was 7250 years old, but on the Little Tennessee River in East Tennessee the second terrace (of nine) was 25,000-30,000 years old at 8.5 m above the flood plain (Delcourt and Delcourt 1985). This high Waynesboro terrace may date from the middle third of the Pleistocene (David Litzkey, personal communication) (figure 2). This suggests that for part of the last perhaps many tens of thousands of years, the lower elevation limestone sites were buried under alluvium (or had not yet been excavated by the river) and were unavailable to receive migrating species from the west. More modern terraces are below the limestone sites along the river. Probably both limestone and loess sites were available during the recent Hypsithermal (Delcourt 1979) and received species at that time. Was this the time of arrival of the western taxa? If so, why were they unequally distributed? The question of the age of Tennessee barrens, including all those south of the glacial border in the central Southeast, is far from settled. Transeau (1935) included the Kentucky Barrens among Hypsithermal age prairies. Braun (1928) never resolved the question, and for DeSelm (1981) it is still open.

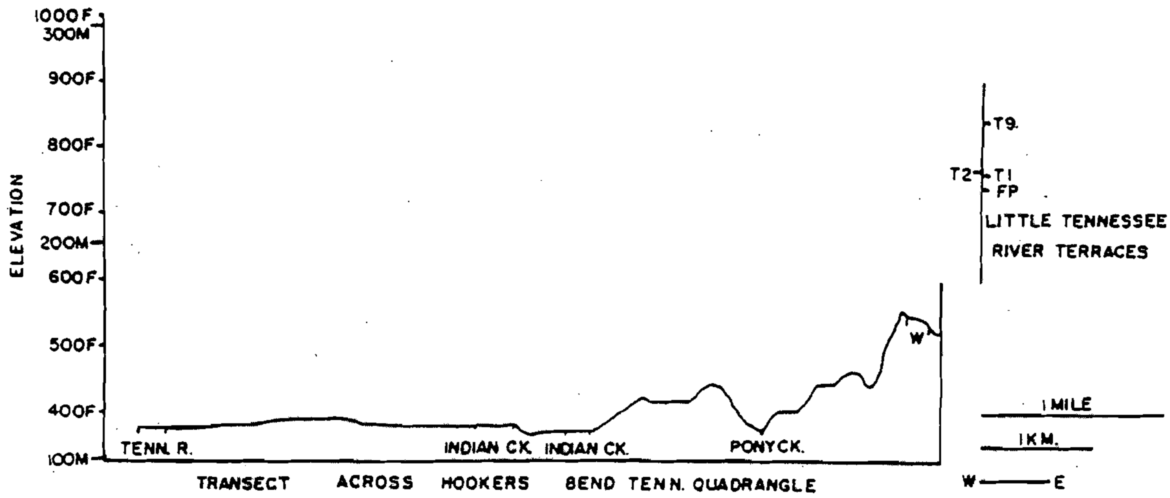

Figure 2. Section across eastern part of the Hookers Bend U. S. G. S. 7.5 minute quadrangle. W, in the figure, indicates positioning of Waynesboro soils. Talbott soils are below the Waynesboro many m above the flood plain. At right is elevation of the Little Tennessee River flood plain and terraces 1, 2, and 9. Terrace 2, only slightly above the flood plain, is 25,000-30,000 year B.P.

Site Variation

Among the 4 loess and 14 limestone sites the mean number of taxa seen is 77, but ranges from 20 to 173. The great variation has several causes. Five sites seen but one or two times have yielded a flora of 35 or fewer taxa. Barrens seen 6-12 times each have species numbers over 100. Size is also important, but irregular shape makes size difficult to determine; sizes vary from 0.08 to 0.61 ha. Quadrupling the area from 0.2 to 0.8 ha increases the flora by 61 percent (56 to 90 taxa). The land use history of the sites is unknown, but probably at least several have been grazed, especially during Tennessee's open-range period (from the time of settlement until the early 1940s). Preferential grazing, causing elimination of palatable taxa, and slope erosion may have occurred. While the first may eliminate species directly (Curtis 1959, Thill 1983), the second may reduce the area with deep soil and conversely increase the area with gravel or bedrock exposure. Loss of deeper soil areas probably resulted in more species being lost than were added by invasion of new species into shallow soil areas. Sites of diverse terrain (a variety of aspects, slope positions, slope angles, and creeks or springs) had more taxa than sites with only one slope form, but greater site terrain diversity may be confounded with sample area size.

Gradient Analysis

The dominance of Schizachyrium and the xeric appearance of most parts of most sites suggested that the group of sites is homogeneous. The coefficient of community of 0.48 between the loess and limestone sites again suggests some uniformity. However, site characteristics were used (see Methods) and compared with the summed presence (one unit per species) of 24 hyrophytic/mesophytic taxa and 22 xerophytic taxa. They are:

Mesophytic

Acer rubrum
A. saccharum
Boltonia diffusa
Eupatorium perfoliatum
Helenium flexuosum
Helianthus angustifolius
Euthamia graminifolia
Carex complanata
C. granularis
C. muhlenbergii
Rhynchospora globularis
Quercus imbricaria
Q. nigra
Q. phellos
Chasmanthium laxum
Panicum virgatum
Spartina pectinata
Liquidambar styraciflua
Juncus biflorus
Rhexia mariana
Platanus occidentalis
Nyssa sylvatica
Galium tinctorium
Populus deltoides

Xerophytic

Allium canadense
Arenaria patula
Aster oblongifolius
Crotonopsis elliptica
Draba verna
Euphorbia dentata
Helianthus occidentalis
Isanthus brachiatus
Kuhnia eupatorioides
Leavenworthia exigua
Linum sulcatum
Nothoscordum bivalve
Panicum flexile
Pinus echinata
P. virginiana
Polypodium polypodioides
Sedum pulchellum
Scutellaria leonardii
Sporobolus asper
S. clandestinus
S. neglectus
S. vaginiflorus

These taxa were chosen from the floristic list without reference to the sites on which they occurred. Results (figure 3) indicate that these taxa collectively follow gradient trends characteristic of prairie species (Curtis 1955). It also illustrates that the xeric end of this series may represent glady barrens or cedar-pine glades and that there is, at the mesic end, a small area which is hydric (with Spartina).

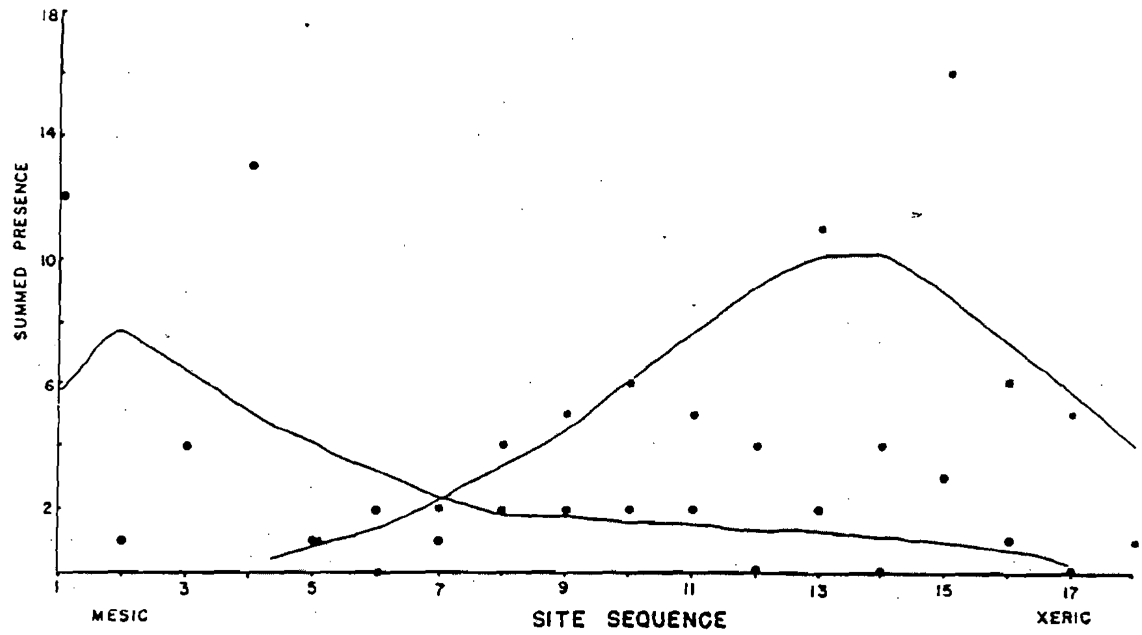

Figure 3. Response of 24 mesophytic (dot) and 22 xerophytic (asterisk) taxa shown as summed presence (using a running average of five for the eye-fitted curves) on site sequence.

Community Variation

The sampling of four sites--Mashburn on loess, and Long Point, Carol Cabin Road, and Big Barren on limestone--revealed somewhat the different character of their vegetation. Cover of lichens and bryophytes was low everywhere but their frequency was highest on the loess site. This was related to a large area of exposed soil and low rock/gravel cover. In contrast, the limestone sites had high rock/gravel cover and low lichens/bryophyte cover (table 1).

Table 1. Importance Value-200 of plants on four barrens. Frequency (F) and mean cover ($\bar{x}C$) is shown for surface types.

	Mash-burn	Long Point	Big Barren	Carol Cabin Rd.
	F-$\bar{x}$C	F-$\bar{x}$C	F-$\bar{x}$C	F-$\bar{x}$C
Lichens/Bryophytes	50-5	15-3	5-1	4-1
Rock/Gravel	10-2	55-22	85-25	49-27
Soil	20-30	25-14	5-3	21-11
Tree Litter	15-11	60-9	65-15	2-7
			I.V. - 200	
Acerates viridiflora		2.6	x*	
Agave virginica	x	2.6	2.2	
Andropogon gerardii				14.2
Apocynum cannabinum			1.5	
Aristida purpurescens	x	2.6		3.1
Asclepias verticillata		x	1.5	
Andropogon gyrans	16.8			
Ascyrum stragalum	1.2	x		
Aster dumosus	6.6		1.5	
A. hemisphericus	1.2	6.2		
A. patens	3.6	4.4	4.3	3.5
A. sericeus				6.8
A. undulatus			3.6	6.8
Berchemia scandens			2.9	2.5
Cassia nictitans	3.0			
Celtis tenuifolia		x	1.6	
Cercis canadensis				2.0
Composite, unknown	1.2	2.6		
Coreopsis major	8.4	x	x	
C. tripteris	1.8	x		0.5
Crataegus sp.				0.5
Croton monanthogynus		x	11.4	
Cyperaceae				2.9
Danthonia spicata	2.9	2.6	x	
Desmodium ciliare	x	2.6	1.5	
Dicot, unknown	6.0	2.6	2.9	4.7
Diospyros virginiana	1.2	x	1.5	
Eupatorium rotundifolium	1.2			
Euphorbia corollata	x	16.9	8.6	1.3
E. preslii	x		2.9	
Fimbristylis puberula				16.1
Galactia volubilis	3.6	22.2	3.6	1.3

Table 1. (Continued)

	Mash-burn	Long Point	Big Barren	Carol Cabin Rd.
	F-$\bar{x}$C	F-$\bar{x}$C	F-$\bar{x}$C	F-$\bar{x}$C
Galium pilosum	1.2		x	
Gaura biennis			3.6	
G. filipes		2.6	x	1.9
Gerardia tenuifolia	x	7.9	2.9	2.6
Helianthus atrorubens	1.2			
H. hirsutus	5.0			1.1
H. mollis	4.9			
Heliotropium tenellum		2.6	x	4.2
Houstonia calycosa		6.2	3.6	2.7
Hypericum dolabriforme			5.0	
H. sphaerocarpon				4.0
Juniperus virginiana	1.2	2.6	1.5	4.1
Kuhnia eupatorioides		4.4	2.9	0.5
Lespedeza procumbens	x	11.2	x	
L. virginica				1.1
Liatris cylindracea				6.0
Linum sulcatum		x	2.9	0.5
Lithospermum canescens		2.6	x	0.5
Lobelia spicata		x	1.5	0.5
Monarda fistulosa				2.2
Opuntia compressa		18.2		
Panicum angustifolium	15.2			
P. flexile			1.5	1.5
P. laxiflorum	3.0	x		
P. oligosanthes	1.2	x		
P. sphaerocarpon	3.0	x		
P. sp.	1.2			0.5
Parthenium integrifolium	16.2	x		1.7
Phlox amoena				1.2
Physostegia virginiana	x	2.6	2.9	8.3
Polygala ambigua	x		1.5	
P. verticillata				0.5
Potentilla simplex	2.4	x	x	
Prunella vulgaris	1.2	x	x	0.5
Pycnanthemum tenuifolium	1.2	2.6	x	
Quercus muhlenbergii		x	2.2	
Q. marilandica	x	x	3.6	
Ratibida pinnata				1.0
Rhus copallina	1.2	x	x	
Rosa carolina	1.2	x	2.2	0.5

Table 1. (Continued)

	Mash-burn	Long Point	Big Barren	Carol Cabin Rd.
	F-$\bar{x}$C	F-$\bar{x}$C	F-$\bar{x}$C	F-$\bar{x}$C
Rubus (dewberry) sp.	1.2			
Rudbeckia hirta	1.2	2.6		
Ruellia humilis		4.4	8.8	2.3
Sabattia brachiata				0.5
Schizachyrium scoparium	54.0	94.8	54.6	47.3
Scleria oligantha		3.6		1.6
Scutellaria leonardii			1.5	0.5
Sericocarpus linifolius	10.9			
Silphium asteriscus	1.8			1.3
S. terebinthenaceum				8.5
Sisyrinchium albidum				2.2
Smilax bona-nox		3.6	x	0.5
S. glauca	1.6			
Solidago erecta	1.2			
S. nemoralis	3.0	13.3	12.2	
S. odora	1.2			
S. rigida				3.5
Sorghastrum nutans				13.9
Sporobolus clandestinus			25.9	
S. neglectus-vaginiflorus		x	9.9	4.6
Stylosanthes biflora	2.4	2.6	x	
Tragia cordata				0.5
Viola pedata var. *lineariloba*		2.6	x	

*x indicates presence on site outside plots.

Ninety-one taxa occurred on the four sites--50 each on the one loess site and the group of limestone sites. Coefficient of community among limestone sites was 29, but between the loess and the three limestone sites was 13 to 18, indicating the relative isolation of the two substrates from one another. Grasses only numbered three to seven taxa, but I.V. totaled 84-100 (about half of the total). Importance values of composites were also high (25 to 70) as might be expected from their importance in the flora. Legume importance varied among the limestone sites. Woody species importance was high and varied on limestone in spite of droughty conditions. *Schizachyrium* had the highest importance on each site, as was seen on Big Clifty Prairie (Bryant 1977). Although the coefficient of community between Big Clifty and my combined list is only 8.0, some species on the former list are prominent on mine: Aster patens, Parthenium integrifolium, and Euphorbia corollata. The aspect on the loess site here compares to the gentle topography of the loess cap at Big Clifty; Schizachyrium dominates both [see also Bryant (1981)].

There are two types of vegetation on our barrens: Schizachyrium-other grasses and Schizachyrium-forb. The loess is dominated by Schizachyrium but Andropogon gyrans, Parthenium integrifolium, and Panicum angustifolium are almost as important. Big Barren is dominated by Schizachyrium, Sporobolus clandestinus is second, and three forbs follow. Long Point Barren is dominated by Schizachyrium, Galactia volubilis, the succulent Optunia compressa, and other forbs follow in importance. At Carol Cabin Road barren Fimbristylis, Andropogon gerardii, and Sorghastrum are in second position. Descending order of frequency at Big Clifty is Schizachyrium and Smilax followed by five forbs (four composites and one legume). Little bluestem barrens sampled in the Central Basin and on the Cumberland Plateau of Tennessee are of the Schizachyrium--other grass, and Schizachyrium-forb types (DeSelm unpublished).

CONCLUSIONS

1. Two kinds of barren occur on the western Highland Rim. One type occurs on winter-wet, summer-dry, loess origin soils on the surface of the Rim. The second type occurs on shallow clayey soils over limestone on flat to sloping sites near the Tennessee River.
2. It is possible that both kinds of barrens are of Hypsithermal age--Transeau (1935) believed that the nearby Kentucky Barrens were part of the Prairie Peninsula of that age. However, the land surfaces are older than Holocene, and Braun (1928) and DeSelm (1981) believe that the age of such barrens is open to question.
3. Descriptions of these barrens are not known from the eighteenth century but they are well-known in nineteenth century scientific literature.
4. Of the 425 vascular taxa on the barrens, most are regional intraneous or southern taxa.
5. Percentages of northern, western, and local intraneous taxa on loess and limestone barrens, although few species are represented, are markedly different. Northern extraneous and local intraneous taxa are more numerous on limestone; western taxa are more numerous proportionally on loess.
6. Use of physical site factors proved successful in demonstrating gradient-like behavior of species groups across the mesic to xeric sequence of sites.

7. About half of the importance value of loess and limestone barrens is achieved by the dominant *Schizachyrium scoparium*, and other perennial grasses. On loess, *Andropogon gyrans* and other forbs and grasses are important. Two limestone barrens were dominated by *Schizachyrium*--other grasses and forbs, the other by *Schizachyrium*--forbs (including the succulent *Opuntia*). In this respect, they are similar to certain other Middle Tennessee barrens.

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A Floristic and Vegetation Characterization of the Bear Creek Natural Area, Stewart County, Tennessee

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KEY WORDS: Bear Creek, Land Between The Lakes, natural areas, plant communities, rare plants, Tennessee

ABSTRACT

The Bear Creek Natural Area is a 325-ha site within the TVA-managed Land Between The Lakes, a public conservation, education, and recreation facility in western Kentucky and Tennessee. Forested portions of the natural area represent a rare western extension of the Mixed Mesophytic Forest and harbor several rare, threatened, and endangered species. The site is further enhanced by great species diversity and a variety of habitat types ranging from wetlands to xeric ridges. It is a registered Tennessee Natural Area, a TVA Forest Study and Natural Area, and has been recommended in two National Park Service evaluations as a National Natural Landmark. A floristic list of 733 vascular species was published by the authors in 1987. This companion paper provides a history of the area, an analysis of the vascular flora, and a qualitative assessment of the plant communities.

INTRODUCTION

Land Between The Lakes (LBL) is a 68,800-ha peninsula between the impounded lower Cumberland and Tennessee rivers in southwestern Kentucky and northwestern Middle Tennessee. It has been managed since 1964 by the Tennessee Valley Authority (TVA) as a public conservation, education, and recreation facility. Prior to 1964, the area, then known as the "Land Between the Rivers", consisted of numerous privately-owned small farms, homes, communities, company-owned forests, and considerable federal holdings managed mostly for wildlife and waterfowl.

Bear Creek, a meandering, easterly-flowing stream, drains the southeastern sector of LBL and empties into the Cumberland River. The lower end of the creek flows through forested, dissected uplands, current and pre-TVA cultural communities, and extensive wetlands. The Bear Creek Natural Area, as recognized by Carpenter and Chester (1987) and hereinafter referred to as BCNA or "the study area", is a 325-ha portion of the lower Bear Creek drainage system.

The Bear Creek region was first recognized for its rare elements and rich and significant flora when Ellis et al. (1971) published a preliminary list of the LBL flowering plants. By 1973, TVA had designated the woodland portion a Forest Study Area and later, in 1985, included it as one of their Natural Areas (Tennessee Valley Authority 1973, 1985). Scott et al. (1980) evaluated the site for the Tennessee Department of Conservation and upon their recommendation, it was registered as a Tennessee Natural Area in accordance with the Tennessee Natural Areas Preservation Act. This designation provided for cooperative management and protection between the state and TVA (Tennessee Department of Conservation 1985).

The BCNA has also received national attention. Quarterman and Powell (1978) evaluated the Bear Creek woodlands as one of 179 potential National Natural Landmarks within the Interior Low Plateaus Physiographic Province. This site was recommended to the National Park Service for such designation. A follow-up study and evaluation by DeSelm et al. (1982) also strongly recommended designation and final approval is pending.

All evaluations found the site to be botanically significant for a number of reasons: (1) woodlands of mesic slopes and ravines are an attentuated outlier of the Mixed Mesophytic Forest and as such, represent the rare western form of that forest region; (2) forests are old-growth and no comparable, publicly-owned examples are known from the Western Highland Rim; (3) the presence of numerous rare, threatened, and endangered species; (4) great species diversity, including disjunctions and several taxa near the limit of their natural range; and (5) diversity of habitats ranging from extensive wetlands to dissected uplands with ravines, streambanks, slopes, and xeric ridges.

The vascular flora of BCNA has been studied extensively since 1978 and a floristic list published (Carpenter and Chester 1987). Based upon herbarium and literature studies and 80 collecting trips resulting in more than 1100 accessions, the list documented a flora of at least 733 species, representing 111 families and 388 genera. Field studies continue, with the objectives of delimiting community types, determining their composition, and monitoring floristic changes that will occur as the vegetation matures in the absence of anthropogenic influences.

It is the purpose of this paper to expand upon and provide descriptions, analyses, and interpretations of the data in the previously-published list. Together, these documents will furnish information required for future quantitative studies and provide a significant data pool that will (1) supplement our knowledge of the Tennessee flora, and (2) provide a historical record for later researchers. Discussion of the flora and plant communities is prefaced by data on location, vegetational setting, and history; physiography, geology, soils, and climate were discussed by Carpenter and Chester (1987).

The Study Area

Geographic Location: The BCNA is in Stewart County, in northwestern Middle Tennessee, 5.6 km north of U.S. Highway 79 (figure 1). It is centered at 36°31'15" north latitude and 87°34'30" west longitude, 8 km northwest of Dover, the county seat of Stewart County. It is bisected by Tennessee Highway 49 and extends westward from Lake Barkley (the impounded lower Cumberland River) on the east, to a point where Bear Creek, which meanders from the south, turns due east. The southern boundary is that of Land Between The Lakes and is delimited by various markers and survey lines. The northern boundary is marked by east-west roads (Blue Springs westward, Tip Top eastward) which meet at Highway 49. The area contains 325 ha and includes the 104 ha of forested slopes, ridges, and ravines adjacent to and south of Bear Creek which have been proposed for landmark status, a buffer zone of bottomlands north of the creek, and wetlands to the east.

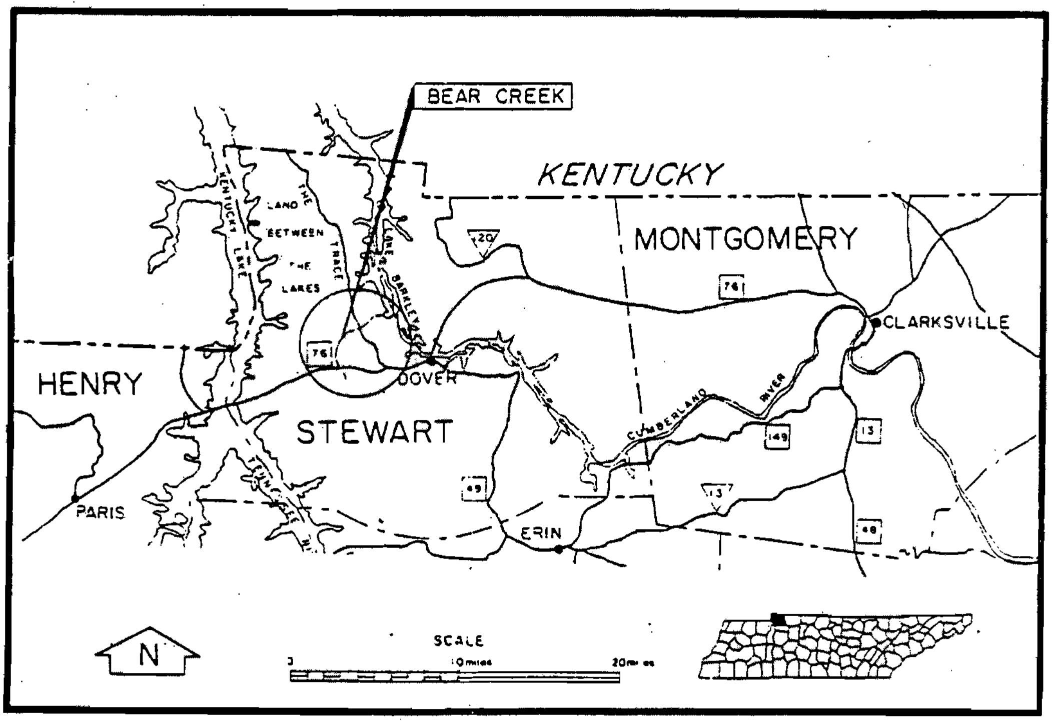

Figure 1. Geographic location of Bear Creek Natural Area

Vegetational Setting: The BCNA is within the Mississippian Plateau Section, Western Mesophytic Forest Region, Deciduous Forest Formation, of Braun (1950). The Western Mesophytic Forest Region extends from the western escarpment of the Cumberland Plateau to the loess bluffs of the Mississippi River. Its vegetation is transitional from the more mesic Mixed Mesophytic Region to the east and the more xeric Oak-Hickory Region to the west. Instead of a single climax, a mosaic of types occurs, with local climatic, topographic, and edaphic factors determining specific vegetation patterns. As a whole, the vegetation is less luxuriant than that of the Mixed Mesophytic Forest but more diverse than that of the Oak-Hickory. Mixed mesophytic conditions are circumscribed and rare, especially on the Western Rim: in fact, only a few remnant outliers exist today and most of these are disturbed by cutting and/or pasturing.

The Mississippian Plateau Section, occupying essentially the Highland Rim (figure 2), is dominated mostly by oak and oak-hickory phases (Eyre 1980). Numerous prairie openings once occurred, especially northward (Kuchler 1964). Studies by Duncan and Ellis (1969) and Jensen et al. (1973) showed that all northwestern Highland Rim forests are secondary and predominately oak-hickory. While Quercus alba is most abundant, other oaks, e.g.--Q. coccinea, Q. falcata, Q. marilandica, Q. prinus, Q. stellata, and Q. velutina, and hickories--e.g., Carya glabra, C. ovalis, C. ovata, and C. tomentosa, assume dominance on ridges and slopes. More mesophytic species such as Acer saccharum, Fagus grandifolia, and Liriodendron tulipifera become important on moist slopes and in ravines.

Once-extensive bottomland forests along the Cumberland River and tributaries now exist as remnants which indicate former dominance by Acer negundo, A. saccharinum, Fraxinus pennsylvanica, Platanus occidentalis, Populus deltoides, and Ulmus spp. Bottomland oaks and hickories include Quercus macrocarpa, Q. pagoda, Q. palustris, Q. shumardii, Carya cordiformis, C. laciniosa, and C. ovata. A few riverine wetlands are vegetationally significant but most are under agricultural stress.

Drier limestone bluffs, mostly adjacent to the rivers or major streams, have a high percentage of Juniperus virginiana, Fraxinus americana, F. quadrangulata, and various xerophytic oaks and hickories (Quercus prinus, Q. muehlenbergii, Carya glabra, and C. tomentosa). The Pennyroyal Plain (figure 2) is now mostly agricultural but once included numerous prairie openings or barrens interspersed with upland swampy woods. A few of these woodland remnants exist today and are dominated by such mesophytic oaks as Quercus bicolor, Q. pagoda, Q. palustris, and Q. phellos. Also, Acer rubrum, Liquidambar styraciflua, Nyssa sylvatica, and Populus heterophylla are often important.

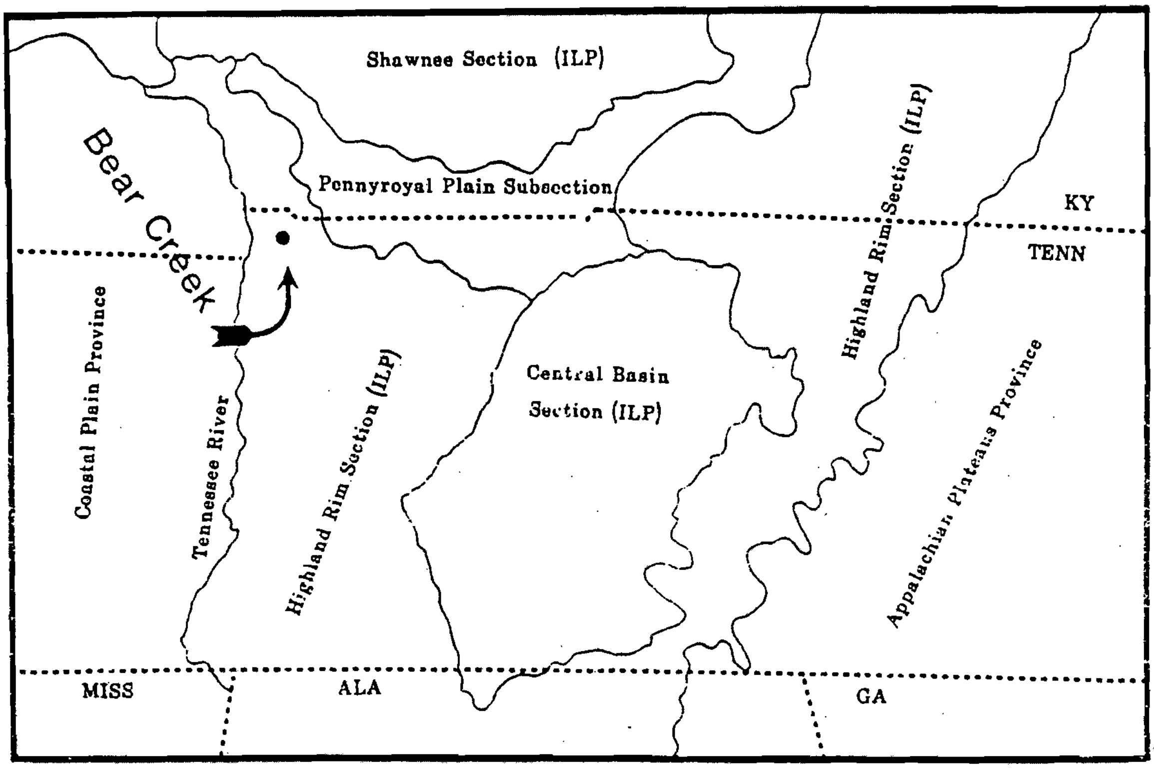

Figure 2. Physiographic location of Bear Creek Natural Area

Forests are mostly hardwoods but three pines are native to the area. Pinus virginiana is locally abundant on a few dry promontories above the Tennessee River and along the transitional hills above the Central Basin. Pinus echinata is locally abundant in Stewart County, while P. strobus is very rare to the east and north. Plantations of P. taeda are common and Taxodium distichum is scattered along the Tennessee River. Juniperus virginiana, the most common gymnosperm, occurs throughout in successional situations and on bluffs.

History

The LBL area may have been inhabited by humans for as long as 10,000 years; evidence indicates certain habitation since 5200 BC (Henry 1976). Remains of Mississippian Culture settlements are found in the Bear Creek bottomlands near the Cumberland River, and apparently several more recent Indian groups, including Chickasaws, Shawnees, and Cherokees utilized the area for hunting. While all Indian occupation ended prior to 1800, threats of attack from groups living west of the Tennessee River hindered settlement by Europeans until about 1812 (Henry 1976).

The first Europeans to visit the area were apparently French explorers who navigated the Cumberland and Tennessee rivers in the 1600s. These "Long Hunters" found the area to abound in game, including black bear and bison, and used the region extensively in the 1700s. However, settlement was slow, and Ross (undated), who lived on the east bank of the Cumberland River opposite the mouth of Bear Creek, described that region in 1808 as "... a wild, uninhabited district which had not yet attracted the attention of settlers and (which) was almost precisely in the same state it had been in for ages." He further noted that "... there was a wild, rugged district lying west of us between the Cumberland and Tennessee Rivers, about 12 miles in width, an almost unbroken solitude, after which commenced the Indian territory extending to the Mississippi River."

Stewart County was settled principally by North Carolinians, the first arriving about 1795. Many were survivors of the Revolutionary War and had been issued military grants of large land tracts (Goodspeed History Series 1886). Thomas Kirkman received one such grant for 2132 Bear Creek acres and purchased an adjacent 1666 acres from other grant recipients (Henry 1976). Probably all or part of BCNA was included in this ownership.

Due to an abundance of timber and mineral resources, Stewart County became a center for iron furnaces and rolling mills in the middle 1800s (Austin et al. 1953). The Peytona (Patonia, Patona, as orthographic variants) Furnace was established on Bear Creek in about 1845 and operated until the Civil War. By 1870 most of the area furnaces had closed due to depletion of both high-grade ore and timber required for charcoal to operate the furnaces.

The Bear Creek area was important early during the Civil War as an overland connector between two major Confederate fortifications. Fort Henry was 9.7 km to the west on the Tennessee River and Fort Donelson 6.4 km to the southeast on the Cumberland River. Both forts fell in 1862 to Union forces commanded by General U. S. Grant (Smith 1971).

The area developed little after the Civil War and closing of the iron industries. Land grant holdings fragmented into smaller farms, with tobacco, livestock, and small grains as major cash crops. A colony of Germans settled at the old Peytona Furnace site and attempted to grow grapes and fruit trees, with some initial success (Killebrew et al. 1874). Whiskey production became important in 1820 when Jacob Geuring built a large still, using Bear Creek waters for production. A few years later, George Boyd operated a similar facility and more clandestine operations continued into the twentieth century. Railroads never entered the area and no major cities developed. When LBL was acquired by TVA, the population consisted of 950 families and 2700 people (Smith 1971). This amounted to one family for each 179 acres or one person per 63 acres, an obviously low population density.

Most of the presently-forested Bear Creek acreage was probably harvested for charcoal production during the iron era and selectively cut later. Our first observations in 1967 showed no recent stumps or other signs of significant disturbance in the woodlands. The level, fertile bottomlands and terraces have almost certainly been under essentially continuous cultivation since settlement.

Since TVA assumed management, the woodlands have received little disturbance. Hunting is commonplace and a hiking trail traverses the western section but is not heavily used. Some trash dumping and wildflower digging mar roadsides, and local residents find the area desirable for "sang hunting." Many of the bottomlands that are dry enough for tillage are leased to and cultivated by area farmers. Some wildlife plantings and other wildlife management techniques are utilized, especially in bottomlands along the Cumberland River where waterfowl flocks are plentiful during migration seasons. Such wildlife as deer, small mammals, and turkey (the growing flocks perhaps descended from native remnants) abound. Reintroduced beaver construct dams on lower Bear Creek and its tributaries, often flooding small areas. In addition, water control at Barkley Dam periodically floods considerable lowland acreage.

DISCUSSION

The Flora

Floristic Summary: The known vascular flora of BCNA consists of 733 species, representing 388 genera and 111 families (Carpenter and Chester 1987). A statistical summary is given in table 1; a listing of species may be found in Carpenter and Chester (1987).

The pteridophyte flora is not particularly diverse and, with two exceptions, is comprised of expected species. *Ophioglossum vulgatum* is rare in the region, and *Azolla caroliniana* populations represent a disjunction from the Mississippi River drainage system. *Juniperus virginiana* is the only native gymnosperm. While *Pinus strobus*, *P. taeda*, and *Taxodium distichum* are native to Tennessee, or even to Stewart County in the case of *Taxodium*, these gymnosperms are represented only by planted specimens in BCNA. The angiosperm flora is large and diverse with several significant rarities, endangered species, and taxa at or near the limits of their natural ranges.

Table 2 lists the major families and shows that taxa of Asteraceae (composites) and Poaceae (grasses) clearly dominate, accounting for 168 (23 percent) of the species. The 16 families (14 percent of families) in table 2 account for 456 (62 percent) of the species. In addition, two families have nine species each, two have eight, four have seven, four have six, eight have five, ten have four, 13 have three, 20 have two, and 32 families are represented by only one species.

Genera containing the most species are listed in table 3. As expected, genera with wide ecological amplitudes, such as *Carex* and *Quercus*, dominate. The 26 genera in table 3 (seven percent of the genera) account for 195 (27 percent) of the species. In addition, 14 genera have four species, 32 have three, 70 have two, and 246 are represented by only one species.

Table 1. Statistical summary of Bear Creek Natural Area Flora

Group	Families	Genera	Introduced Species	Native Species	Total Species
Pteridophytes	7	14	0	20	20
Gymnosperms	3	3	3	1	4
Angiosperm					
Monocots	14	81	36	145	181
Dicots	87	87	85	443	528
Totals	111	388	123	610	733

Table 2. Major families of Bear Creek Natural Area flora

Family	Number of Genera	Number of Species
Asteraceae	37	85
Poaceae	41	83
Cyperaceae	6	44
Fabaceae	19	39
Lamiaceae	17	26
Rosaceae	11	25
Liliaceae	13	20
Brassicaceae	13	21
Ranunculaceae	11	19
Scrophulariaceae	13	18
Fagaceae	3	16
Apiaceae	9	13
Polygonaceae	4	13
Rubiaceae	5	12
Caryophyllaceae	7	12
Euphorbiaceae	4	10

The 136 woody species, consisting of 67 trees, 46 shrubs and small trees, and 23 woody vines, make up 19 percent of the flora. This is slightly less than the 21 percent reported by White (1982) for the Great Smoky Mountains National Park. As expected, taxa of *Quercus* (14) and *Carya* (7) dominate, but *Acer* (5), *Vitis* (5), and *Ulmus* (4) also contribute significantly.

Table 3. Major genera of the Bear Creek Natural Area flora

Genus	Number of Species	Genus	Number of Species
Carex	25	*Galium*	6
Quercus	14	*Scutellaria*	6
Cyperus	10	*Bidens*	5
Solidago	10	*Eragrostis*	5
Aster	9	*Euphorbia*	5
Panicum	9	*Juncus*	5
Eupatorium	8	*Ludwigia*	5
Lespedeza	8	*Paspalum*	5
Polygonum	8	*Scirpus*	5
Carya	7	*Setaria*	5
Desmodium	7	*Smilax*	5
Ranunculus	7	*Viola*	5
Cardamine	6	*Vitis*	5

The total flora of 733 species equals or exceeds that of similar areas elsewhere. For example, 734 subgeneric taxa were reported from the Obed Wild and Scenic River (Schmalzer et al. 1985), 680 from Savage Gulf (Wofford et al. 1979), 516 from Lilley Cornett Woods (Sole et al. 1983), and 655 from Shiloh National Military Park (Jones and White 1981). Chester (1986) found 645 species from the nearby Fort Donelson National Military Park.

Introduced Taxa: Based on origin and distributional data in Fernald (1950), 124 Bear Creek species (17 percent) are not indigenous and are designated in the checklist. About one-half of these 18 woody species and 106 herbs are natives of Europe or the Old World (62 species, or 50 percent). Other origins include Asia (24 species, 19 percent), Eurasia (16 species, 13 percent), Tropical America (8 species, 6 percent), South America (2 species, 2 percent), and India and Japan (1 species each, 1 percent). Ten species (8 percent) of the 124 are native to another region of the United States.

Families with introduced species include the Poaceae (27), Fabaceae (12), Asteraceae and Brassicaceae (9 each), Caryophyllaceae (6), Lamiaceae, Polygonaceae, and Rosaceae (5 each), and Scrophulariaceae (4). Three other families are represented by three introduced species, eight by two, and 17 by one.

Several interesting species groups are included within the introductions. Old homesites, lawns, gardens, and orchards are easily recognized by the presence of such perennial herbs and grasses as Cynodon dactylon, Festuca elatior, Glecoma hederacea, Hemerocallis fulva, Narcissus spp., Ornithogalum umbellatum, Poa pratensis, and by several woody species, e.g., Ailanthus altissima, Albizia julibrissin, Hibiscus syriacus, Ligustrum obtusifolium, L. sinense, Malus pumila, Morus alba, Paulownia tomentosa, Pinus strobus, P. taeda, Populus alba, Prunus persica, and Pyrus communis. Few of these species are threats to out-compete native vegetation. Such taxa as Albizia, Ailanthus, Ligustrum, and Paulownia have spread to roadsides and fields but are limited in distribution and abundance. Some (e.g., Cynodon, Populus, Hemerocallis) spread within narrow confines around old plantings and yet others (e.g., Malus, Pinus, Prunus, Pyrus) are represented only by the original plantings and will be eliminated eventually from the flora.

Another group of introductions includes species once planted for crop production that are now naturalized and regularly grow on roadsides and in fields. Examples are Dactylis glomerata, Festuca elatior, Lespedeza spp., Lolium multiflorum, Phleum pratense, Trifolium pratense, T. repens, and Vicia dasycarpa. In addition, some cultivars only appear as waifs on roadsides, river banks, and around campgrounds, but do not persist past frost (e.g., Glycine max, Helianthus annuus, Lycopersicum esculentum, and Triticum aestivum). Rosa multiflora, planted for wildlife and erosion control before TVA management, has spread extensively around cultural areas and is definitely a problem species. Since 1964, one bottomland near the Cumberland River has been planted in Taxodium distichum and such wildlife food species as Setaria italica and Echinochloa frumentacea are regularly planted and are also persistent and adventive.

The largest group of introduced species includes those brought in by accident, by intention, or for reasons unknown, that have become naturalized, especially in disturbed areas. Some are rarely observed (e.g., Arenaria serpyllifolia, Holcus lanatus), several are weedy but mostly insignificant (e.g., various taxa of the Brassicaceae), while others are exceptionally weedy and often occur in dense stands, to the detriment of native species (e.g., Arthraxon hispidus, Sorghum halepense, Xanthium strumarium). Species having the most influence on native vegetation are Lonicera japonica, which occurs throughout to some degree except in old-growth woodlands, and Ludwigia uruguayensis, which dominates many open marshes and swamps.

The number of introduced species may be used as a relative indication of past anthropogenic influence. Thus, the 17 percent from BCNA is not as great as the 22 percent reported from the heavily disturbed Fort Donelson National Military Park (Chester 1986), or the 20 percent from the Great Smoky Mountains National Park (White 1982). However, it is greater than the numbers reported from little-disturbed areas such as the Obed Wild and Scenic River, where only eight percent of the flora is not native (Schmalzer et al. 1985).

Plant Communities

The plant communities of BCNA may be subdivided under three broad topographic, cover, and land-use types: (1) wetlands, (2) dissected upland forests, and (3) cultural sites. Community types are summarized in table 4 and discussed below.

Table 4. Major plant communities of Bear Creek Natural Area

I. Wetlands

1. Vegetated Open Water
2. Nonvegetated Flats
3. Vegetated Flats
4. Shrub Swamps
5. Bottomland Hardwoods
6. Wet Meadows
7. Emergent Marshes

II. Upland Forests

1. Mesic Slope and Ravine Forests
2. Streambank and Lower Ravine Forests
3. Upper Slope and Ridge Forests
4. Limestone Outcrops and Bluffs

III. Cultural Communities

1. Cultivated Fields
2. Old Homesites, Fencerows, Gardens, and Orchards
3. Mowed Fields and Roadsides
4. Successional Fields

Wetlands: Extensive wetlands occur in the lower Bear Creek area, mostly in bottomlands along Lake Barkley (Cumberland River). Pool levels are lowered about five feet each autumn but many of the bottomlands are periodically flooded in winter and spring. In addition, natural depressions and pools and man-made subimpoundments may retain water throughout the year. In some cases, pool levels of the subimpoundments are manipulated for waterfowl habitat management. The following seven inundation and vegetation types described in the regional wetland classification system of Carter and Burbank (1978) are used to categorize the wetlands of BCNA.

1. Vegetated Open Water: This type is limited to permanent pools where the water is at least two m deep and the vegetation is restricted to floating and submerged species. A few such pools are present and are seasonally dominated by Azolla caroliniana, Lemna minor, and floating stems of Ludwigia uruguayensis.

2. Nonvegetated Flats: Seasonally dewatered flats occur along the reservoir and near the mouth of Bear Creek. A level, spongy alluvium is exposed by the gradual drawdown of Lake Barkley from late July throughout autumn. Areas near the receeding water line are often not exposed long enough before freezing weather for significant or identifiable ground cover to develop. Masses of stranded Potamogeton nodosus, mats of Ricciocarpus natans, and cotyledon-stage germlings of various species comprise this community.

3. Vegetated Flats: The nonvegetated flats grade into longer-exposed areas which are densely covered with a mixture of short (usually less than 10 cm in height), mostly annual, mat-forming species. Characteristic taxa are Amaranthus tuberculatus, Ammannia coccinea, Cyperus albomarginatus, C. aristatus, C. esculentus, Eragrostis hypnoides, Fimbristylis autumnalis, F. vahlii, Hemicarpha micrantha, Rorippa sessiliflora, Rotala ramosior, and Xanthium strumarium.

4. Shrub Swamps: Swamps dominated by shrubs and small trees abound in areas with saturated soil, usually along the outer edges of the fluctuation zone. Dense, often impenetrable stands of Cephalanthus occidentalis also may include Acer rubrum, Cornus amomum, Fraxinus pennsylvanica, Ilex decidua, and Salix nigra. Herbaceous species are few but Brunnichia cirrhosa and Smilax spp. are common woody vines.

5. Bottomland Hardwoods: Equated to the lower bottomland hardwoods type of Carter and Burbank (1978), these forests exist as remnant stands along the river, lower Bear Creek, or in bottomland depressions historically too wet for cultivation. Dominants include Acer negundo, A. saccharinum, Betula nigra, Carya cordiformis, Celtis laevigata, Fraxinus pennsylvanica, Populus deltoides, Platanus occidentalis, Quercus michauxii, Q. pagoda, Q. shumardii, Salix nigra, and Ulmus spp. (americana, rubra, and rarely, serotina). Although native Carya illinoensis is rarely found, an LBL record-sized specimen of 147.3 cm dbh is known from along the Bear Creek bottomlands. Asimina triloba, Cephalanthus occidentalis, and Lindera benzoin are common shrubs while Aristolochia tomentosa, Cocculus carolinus, and Smilax

rotundifolia are the most frequently encountered woody vines. Saturated soils or shallow flooding limit the spring herbaceous flora. Eupatorium rugosum dominates in the fall, but many other species may be present, including Aster pilosus, Boehmeria cylindrica, Carex grayii, Dicliptera brachiata, Impatiens capensis, Laportea canadensis, Lycopus virginicus, Polygonum cespitosum, Pluchea camphorata, and Tovara virginiana.

6. Wet Meadows: These low fields, most of which were under cultivation when in private ownership, are covered by shallow backwater or flooded in early spring but are typically open for colonization or growth of perennial herbs by May. Late spring rains usually maintain wet or saturated soils into the summer. The early to midsummer flora is a mixture of hydrophytes and mesophytes including Alopecurus carolinianus, Carex frankii, C. lupulina, C. lurida, C. squarrosa, C. vulpinoidea, Conobea multifida, Eleocharis obtusa, Euphorbia maculata, Gratiola neglecta, Hypericum mutilum, Juncus acuminatus, J. biflorus, J. marginatus, J. tenuis, Myosurus minimus, Oenothera laciniata, Ranunculus abortivus, R. parviflorus, R. pusillus, R. sardous, and Senecio glabellus.

Drying of the wet meadows results in a late-summer and fall flora dominated by composites and grasses. Included are Asclepias incarnata, Agrimonia parviflora, A. pubescens, Bidens cernua, B. frondosa, B. polylepis, B. tripartita, Cyperus strigosus, Diodia virginiana, Echinochloa crusgalli, Eupatorium coelestinum, E. perfoliatum, E. serotinum, Helenium flexosum, Heliotropium indicum, Leptochloa panicoides, Lippia lanceolata, Lysimachia ciliata, Panicum agrostoides, P. dichotomiflorum, Penthorum sedoides, Plantago lanceolata, P. virginica, Polygonum pensylvanicum, P. hydropiperoides, P. punctatum, Pluchea camphorata, Rumex crispus, Sorghum halepense, and Xanthium strumarium.

7. Emergent Marshes: Marshlands often grade imperceptibly into the wet meadows but differ in that standing water is present for most or all of the year; hence the vegetation includes a greater number of hydrophytic species. Ludwigia uruguayensis may be especially dense, and extensive stands of Paspalum distichum, Panicum agrostoides, and Leptochloa panicoides occur as the marshes dry around their periphery in summer and fall. Other common and often abundant species include Aster simplex, A. pilosus, Alisma subcordatum, Echinodorus cordifolius, Juncus effusus, Hibiscus militaris, H. moscheutos, Leersia oryzoides, Lobelia cardinalis, Ludwigia alternifolia, L. decurrens, L. peploides, Lycopus americanus, Mimulus alatus, Onoclea sensibilis, Sagittaria calycina, Saururus cernuus, Scirpus atrovirens, S. cyperinus, S. pendulus, and Typha latifolia.

Upland Forests: The deciduous forests on slopes, ridges, ravines, and streambanks adjacent to and south of Bear Creek include the 104 ha site proposed for landmark status by DeSelm et al. (1982) and are the least disturbed and most significant part of BCNA. They are old-growth, with diverse strata and with little evidence of past or present anthropogenic influences. The aspect is generally north-facing but several ravines extend southward from the creek, resulting in slopes with various exposures.

Based on topography, this wooded area may be subdivided into three categories, each with a distinctive flora. While various segregates and combinations of the dominants occur within each topographic category, a general uniformity of conditions (slope aspect and moisture) and species occurrences appears to warrant designation as complex communities. Careful, quantitative sampling will no doubt delimit and elucidate the several combinations of arboreal dominants within each of these types.

1. Mesic Slope and Ravine Forests: This luxuriant woodland is the attenuated western outlier of the Mixed Mesophytic Forest and occupies north-facing slopes and non-floodplain ravines. The canopy is dominated by Acer saccharum and Fagus grandifolia, but Carya ovata, Fraxinus americana, Juglans nigra, Liriodendron tulipifera, Nyssa sylvatica, Prunus serotina, Quercus alba, Q. rubra, and Ulmus rubra are of variable importance. Several other species may occur, including Juglans cinerea and Tilia heterophylla. The largest trees of the upland forests occur here; specimens of Fagus and Quercus alba exceed 93 cm dbh. Slopes with less northerly exposure, which are slightly drier, include most of the species mentioned, but oaks and hickories, especially Quercus alba, Q. falcata, Q. rubra, Carya ovata, C. glabra, and C. tomentosa, predominate.

Common small trees and shrubs include Aesculus glabra, Asimina triloba, Cercis canadensis, Cornus florida, Lindera benzoin, and Ostrya virginiana. The herbaceous flora is especially diverse, with a striking vernal aspect; included are mesophytic species of Claytonia, Dentaria, Erythronium, Iris, Mertensia, Pachysandra, Trillium, and Valeriana.

2. Streambank and Lower Ravine Forests: This woodland adjoins Bear Creek and its tributaries and also occupies the often gullied floors of ravines. The overstory is dominated by Acer saccharum, A. negundo, Liriodendron tulipifera, Liquidambar styraciflua, Platanus occidentalis, Ulmus americana, and U. rubra. However, any of the species mentioned for the mesic slope and ravine forests community may occasionally occur, as well as Carya cordiformis, C. laciniosa, Celtis laevigata, C. occidentalis, Fraxinus pennsylvanica, and Populus deltoides. The small-tree and shrub layer usually includes Asimina triloba, Carpinus caroliniana, Corylus americana, Euonymus americanus, E. atropurpureus, Hydrangea arborescens, Lindera benzoin, Staphylea trifolia, and rarely, Aesculus pavia. As in the mesic slope and ravine forests community, the herbaceous flora is significant and striking.

3. Upper Slope and Ridge Forests: Drier, upper slopes and the narrow ridges include a mixture of lower slope species and typical xerophytes. Gravel and rock outcrops are frequent and the open woodlands, especially on ridges, show more anthropogenic influence (old stumps, hiking trails). More porous, poorer soils have slowed recovery from pre-TVA cuttings in comparison to the more mesic, richer-soiled slopes. Also, dead trunks and sprouts of American chestnut indicate that this species was once at least scattered and perhaps a dominant member of the ridge forests.

Canopy dominants, in various combinations, include Acer saccharum, Carya glabra, C. tomentosa, Quercus alba, Q. prinus, Q. stellata, and Q. velutina. Scattered specimens of Carya ovata, Fraxinus americana, Nyssa sylvatica, Prunus serotina, and Quercus marilandica may be found. Small-trees and shrubs include Amelanchier arborea, Aralia spinosa, Hypericum hypericoides, Oxydendrum arboreum, Vaccinium stamineum, and V. vacillans.

The herbaceous flora is thin but commonly includes Aster patens, A. sagittifolius, A. undulatus, Antenaria plantaginifolia, Carex artitecta, C. digitalis, C. muhlenbergia, Coreopis major, Cunila origanoides, Cynoglossum virginianum, Desmodium nudiflorum, D. rotundifolium, Frasera caroliniensis, Hieracium gronovii, Lespedeza intermedia, Muhlenbergia sobolifera, Oxalis violacea, Podophyllum peltatum, Pteridium aquilinum, Scutellaria parvula, Solidago erecta, S. hispida, and S. ulmifolia.

4. Limestone Outcrops and Bluffs: Limestone outcrops are frequent and a few bluffs, up to 20 m in height, occur on north-facing slopes adjacent to and on the south side of Bear Creek. These mesic sites, often with seeps, may be considered part of the mesic slope and ravine forests community, but include a greater number of woody calciphiles such as Hydrangea arborescens, Quercus muehlenbergii, and Viburnum rufidulum. Ferns usually found here are Adiantum pedatum, Asplenium resiliens, A. rhizophyllum, Cystopteris bulbifera, C. protrusa, and Polypodium polypodioides. Characteristic herbs include Arabis canadensis, A. laevigata, Dicentra cucullaria, Dodecatheon meadia, Euphorbia commutata, Heuchera americana, H. villosa, Hystrix patula, Iris cristata, Parietaria pennsylvanica, Phacelia bipinnatifida, Sedum ternatum, and Uniola latifolia.

Cultural Communities: Present plant communities of BCNA which are the direct result of past or current anthropogenic influences are placed under the following types:

1. Cultivated Fields: Under lease agreements with area farmers, several bottomland and terrace fields are planted each year in soybeans, corn, and other small grains. Numerous weedy, mostly non-native species appear in early spring before tillage, including Arabidopsis thaliana, Capsella bursa-pastoris, Cerastium glomeratum, Draba brachycarpa, D. verna, Krigia oppositifolia, Lamium amplexicaule, Myosurus minimus, Ranunculus

abortivus, Senecio glabellus, Sibara virginica, Stellaria media, and Veronica peregrina. Three species of significance found in early spring in weedy, fallow fields are Lesquerella lescurii, Ranunculus pusillus, and Scirpus koilolepis, all rare for the area.

During summer and fall, various weedy species appear with the cultivars and around the fields, including Aster pilosus, Amaranthus hybridus, Acalypha ostryaefolia, A. virginica, Cassia obtusifolia, Digitaria sanguinalis, Ipomoea hederacea, Iva annua, Mollugo verticillata, Physalis spp., Rumex crispus, and Solanum carolinense. In addition, Ambrosia trifida, Erigeron canadensis, Sorghum halepense, and Xanthium strumarium often are especially dense and weedy.

2. Former Homesites and Farmsteads: Several old homesites and associated remnants of a small-farm area (gardens, lawns, fencerows, orchards) are vegetated by mixtures of weedy native and introduced species and are generally not floristically significant. However, even these disturbed areas include some native species worthy of note. For example, Carex shortiana is sometimes abundantly found in roadside ditches, Salix sericea in thickets, and Vitis cinerea in fencerows; all are extremely local species in the area.

Old lawns are easily recognized by plantings of such woody types as Acer saccharum and various exotic trees, perennial herbs, and lawn grasses (see section on introduced species). Former orchards still include often-diseased and broken trees of Malus pumila, Prunus persica, and Pyrus communis. While most of these areas are annually mowed, surrounding fencerows and thickets on terrain too rough for mechanized equipment are usually overgrown and impenetrable due to dense stands of such species as Ampelopsis cordata, Campsis radicans, Cynanchum laeve, Dioscorea batatas, Lonicera japonica, Parthenocissus quinquefolia, Polygonum scandens, Rosa setigera, Rubus argutus, Smilax glauca, S. rotundifolia, Vitis aestivalis, and V. vulpina.

3. Mowed Fields and Roadsides: Weedy but regularly-clipped or mowed fields, meadows, and roadsides include several naturalized cultivars (see section on introduced species). A few areas, such as entrance roadsides and the Visitor's Center lawn, are regularly mowed, and vegetated mostly by Festuca elatior and typical lawn weeds such as Cardamine hirsuta, Cerastium vulgatum, Lamium amplexicaule, L. purpureum, Oxalis stricta, Plantago aristida, P. lanceolata, Rumex acetosella, Stellaria media, Taraxacum officinale, Trifolium campestre, and Veronica arvensis. Areas less frequently mowed have such taller species as Achillea millefolium, Apocynum cannabinum, Ambrosia artemisiifolia, Arthraxon hispidus, Cassia fasciculata, Chrysanthemum leucanthemum, Daucus carota, Erigeron annuus, Eleusine indica, Geranium carolinianum, Galium aparine, Juncus tenuis, Melilotus alba, M. officinalis, Paspalum pubiflorum, Ranunculus sardous, R. crispus, Verbena simplex, Verbascum

blattaria, and V. thapsus.

4. Successional Fields: No upland successional fields occur in the study area. Some lowland areas have not been disturbed since TVA acquisition and now have dense stands of Acer negundo, A. saccharinum, and Fraxinus pennsylvanica. Other fields, usually low-lying, with saturated soil, are covered by swamp thickets. Succession in these low fields is apparently influenced mostly by fluctuating water regimes and differs significantly from typical old-field succession in the LBL area.

SIGNIFICANCE AND SUMMARY

The Bear Creek Natural Area is managed by the Tennessee Valley Authority as part of Land Between The Lakes, a public recreation, education, and conservation area. Consisting of about 325 ha, the forested slopes, ravines, and ridges constitute a State Natural Area in accordance with the Tennessee Natural Areas Preservation Act. It also has been designated a Forest Study and Natural Area by the TVA, and has been nominated to the National Park Service for designation as a National Natural Landmark.

This paper and the previously-published floristic study treat an area which includes the nominated area as well as a buffer zone of forests to the south, west, and east, and creek bottomlands, thickets, and wet meadows to the north. The extensive wetlands along lower Bear Creek eastward to the Cumberland River are also included. Although these wetlands are not part of the nominated area, they are floristically significant, are one of the largest existing wetlands in the lower Cumberland River Basin, and are a natural extension of the Bear Creek slopes.

The cultural history of the area is impressive and includes occupation by early Indian groups and regular usage by later tribes until European settlement. Documented human usage since the late 1700s includes large land grant awards to Revolutionary War veterans, an iron industry era, a Civil War legacy, and eventually a rural, low-population farming region prior to governmental purchase between 1964 and 1965.

The area is botanically and ecologically significant for a number of reasons, including:

1. The mesic slope and ravine forests are a western extension of the Mixed Mesophytic Forest into the Western Mesophytic Forest and contain a high percentage of Acer saccharum and Fagus grandifolia, with some Tilia heterophylla. Such extensions were always rare but are now almost completely lacking in the northwestern Highland Rim of the Interior Low Plateaus.

2. The old-growth and undisturbed state of the forests is significant, especially since the site is now in public ownership and will be protected. Although the forests are secondary, there is little evidence of recent anthropogenic influence, and recovery has progressed naturally since the early 1960s.

3. The vascular flora is unusually large and diverse. The documented presence of 733 species from such a small area is remarkable. With a few exceptions, the numerous introduced species represent little threat to the native vegetation at this time.

4. The presence of eleven rare, threatened, and endangered species adds significantly to the importance of the area. Included and discussed further by Carpenter and Chester (1987) are Cimicifuga rubifolia, Frasera caroliniensis, Hydrastis canadensis, Lesquerella lescurii, Lilium michiganense, Ludwigia leptocarpa, Panax quinquefolium, Phacelia ranunculacea, Spiranthes ovalis, Synandra hispidula, and Valeriana pauciflora. Numerous other species are rare on the Northwest Highland Rim. Some examples include Azolla caroliniana, Aesculus pavia, Carex shortiana, Caulophyllum thalictroides, Dicentra cucullaria, Dicliptera brachiata, Disporum lanuginosum, Lespedeza intermedia, Paspalum boscianum, Scirpus koilolepis, and Vitis cinerea, among several others.

5. Several species are near the limits of their natural ranges. Woody examples include Aesculus glabra, Euonymus atropurpureus, Juglans cinerea, Staphylea trifolia, and Tilia heterophylla. Herbaceous examples include Pachysandra procumbens, Prenanthes barbata, and Spiranthes grayi. Disjunctions are also known. For example, Azolla caroliniana is separated from its primary range in the Mississippi River Valley, and Aesculus pavia is disjunct from its range to the west and south.

6. The diversity of habitats, ranging from several wetland types to mesic slope and dry ridges, provides for an unusually broad range of community types within a relatively small area. Opportunities abound for long-term ecological research and monitoring as maturity occurs in the absence of anthropogenic influence.

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Taxonomic Implications of Morphological Variability Among the Red and Black Oaks of Land Between The Lakes

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KEY WORDS: coccinea, falcata, hybridization, marilandica, pagodaefolia, Quercus, velutina

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Among the most abundant trees of Land Between The Lakes are those belonging to Quercus subgenus Erythrobalanus (the red and black oaks). Species in this subgenus are dominant components of forests on mesic and dry sites and they often exhibit a wide range of morphological variability. Two problems were addressed in this study, problems which shed light on general taxonomic relationships among several of these taxa. First, variation in the Quercus falcata complex was examined by way of investigations of variation in both leaf and fruit/bud data sets. The results indicate that there are two taxa, illustrating parallel patterns of variation in leaf morphology, in this complex. However, these two taxa cannot be distinguished by fruit/bud characters. Second, leaf and fruit/bud data sets were used to evaluate phenetic relationships among four taxa, Q. falcata var. falcata, Q. coccinea, Q. marilandica, and Q. velutina, which often occur in the same communities. These analyses reveal that (1) leaf data and fruit/bud data provide different views of relationships among these taxa, (2) there is evidence of hybridization among three of these taxa, and (3) these phenetic relationships provide insight into which characters have been emphasized in various views of taxonomic and evolutionary relationships among these four taxa.

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INTRODUCTION

The Land Between The Lakes (LBL) region of Kentucky and Tennessee provides an unusual opportunity for the study of variation within and among species of oaks. As discussed by Chester et al. (1976) and Chester et al. (1987), the topographic features of the region, which may be described as dissected upland, have resulted in a variety of forest habitats, ranging from seasonally flooded lowlands, through mesic slopes, to xeric ridges. The general forest communities have been characterized by Jensen (1972) and Schibig (1972). As revealed by their descriptive studies, and by ordination of the same study sites via reciprocal averaging (Jensen 1979), oak taxa are dominant components of all communities except those on the most mesic sites (e.g., stream banks and seasonally flooded lowlands).

Jensen (1972) and Chester et al. (1987) have documented the diversity of oak taxa found in LBL. At least 20 species may be found growing in forests in or adjacent to this region. Of these, all but one (Quercus acutissima Carruthers) are native and may be found throughout the region. The species present are almost evenly divided between two subgenera of Quercus: 8 species belong to subgenus Quercus (the white and chestnut oaks) and the remaining 11 belong to subgenus Erythrobalanus (the red and black oaks). Both subgenera contain species which are rather rare or possibly not found in LBL (e.g., Q. bicolor Willd., Q. nigra L.) and others which are found in or near almost any community examined (e.g., Q. alba L., Q. velutina Lam.).

I have been a student of Quercus since the early 1970s and have focused my attentions on the red and black oaks of the eastern United States. This group consists of approximately 22 species ranging from those with only local (e.g., Q. arkansana Sarg.) or regional (e.g., Q. ellipsoidalis Hill) distributions to wide-ranging taxa found in almost all but the southernmost (e.g., Q. velutina) or northernmost (e.g., Q. marilandica Muenchh.) portions of that part of the United States. As might be expected, the diversity of species, and the broad distributions of many of them, are reflected in both within- and among-species morphological variation.

Anyone who has spent time studying trees and shrubs in the eastern United States, whether a weekend naturalist, professional taxonomist, or ecologist, has become aware of the problems of identifying native oaks. These problems arise for two reasons. First, there may be wide morphological variability, even at the population level, in the species encountered. Although it may be easy to recognize that the common black oak (Quercus velutina) is present in a particular community, one may wonder if all similar trees are of that species or if another morphologically similar species, perhaps scarlet oak (Q. coccinea Muenchh.) or blackjack oak (Q. marilandica), is also present. Despite the fact that each of these three taxa can be characterized by a combination of leaf, bud, and fruit characters, there is sufficient latitude in each that it is not always possible to draw clear lines between species. The second reason for difficulty is associated with the first: Is this broad morphological variation intrinsic to each species or is it the result of interspecific hybridization? Hybridization often has been proposed as the explanation for what appear to be overlapping patterns of morphological variation among species of oaks. This practice is viewed as excessive, and too often erroneous, by some authors (e.g., Muller 1951), but others have documented a wide variety of putative interspecific hybrids (e.g., Palmer 1948). The fundamental problem facing the plant taxonomist or ecologist studying mixed oak forests is that of being able to interpret morphological characters in such a way as to allow recognition of the species or hybrids present.

My colleagues and I have reported elsewhere (Jensen and Eshbaugh 1976a,b; Jensen 1977; Knops and Jensen 1980) results which indicate that morphological characters can be used (1) to detect the presence of clusters of Operational Taxonomic Units (OTUs) which correspond to classically recognized species and (2) to reveal patterns of continuous variation suggestive of hybridization between species. There is sufficient evidence from these studies of morphological variation, sometimes accompanied by congruent patterns of biochemical variation (e.g., Knops and Jensen 1980), to support the argument that hybridization often occurs in mixed oak communities and that not all species present are involved in the apparent hybridization. The ease with which some species pairs appear to hybridize, and the concurrent lack of hybridization between other species pairs, can provide insights into the origins of morphological variability within selected populations. Further, the patterns of morphological variation revealed by studies of vegetative and/or reproductive characters may allow a better understanding of existing classifications and views of evolutionary relationships among these taxa.

I do not intend to provide an analysis of morphological variation among all of the species in LBL. Rather, I will examine in this paper two problems in oak taxonomy which can be reasonably approached by conducting studies of various red and black oaks in LBL. The first problem relates to the status of specific and subspecific taxa in what may be called a species complex. The second problem focuses on patterns of variation among several taxa which are common components of communities found on xeric slopes and ridges in LBL. Both of these problems have been addressed in greater detail elsewhere (Jensen 1988, and unpublished). Here I wish to provide a more general overview of the two problems, briefly discuss the results of analyses based on morphological characters, and indicate why these studies, despite their being limited to LBL, have general taxonomic significance.

The first problem is that of how to interpret morphological variation in the _Quercus falcata_ Michx. complex. The nature of the problem is summarized in the following question: does this complex consist of one polymorphic species, two closely related species illustrating similar degrees of morphological variability, or four closely related species with a high degree of morphological overlap? I approached the problem by conducting multivariate analyses of two sets of morphological data for each of 79 trees in this complex: a set of 13 leaf characters and a set of 10 fruit/bud characters. The trees were sampled from 18 different habitats in LBL and presented a wide range of morphological variability. The data sets initially were analyzed by cluster analysis and principal components analysis (PCA).

Principal components analysis of leaf characters clearly suggests that there are two general groups among these 79 OTUs, each illustrating a high degree of variability. In contrast to a typical PCA, in which the major groups are separated by the first component (that which summarizes the greatest fraction of variation in the data), it is the second component, accounting for 23.8 percent of the total variation, which distinguishes these two groups. As revealed in figure 1, these groups illustrate parallel variation along component one. My interpretation of this analysis is that these two groups, which correspond to Quercus falcata var. falcata (sensu lato) and Q. falcata var. pagodaefolia (sensu lato), represent two species, each with considerable variation in leaf form. The other named variants in this complex represent extremes of leaf variation within each of these larger groups.

On the other hand, analysis of a data matrix consisting of fruit/bud characters does not allow recognition of the same groups. In fact, as shown in figure 2, there is no readily apparent group structure in the two-dimensional space defined by components one and two of PCA (higher components also fail to identify discrete groups). Thus we have a situation in which leaf morphology and fruit/bud morphology do not yield congruent views of among-OTU relationships.

Lack of agreement between data sets is also apparent in analyses conducted on sets of OTUs from three different communities in LBL (Jensen 1988). In this case the same sets of characters as used for the above analyses were used to examine variation among OTUs. Each community contained four taxa of Quercus subgenus Erythrobalanus: Q. coccinea, Q. falcata var. falcata, Q. marilandica, and Q. velutina. One result of these analyses is that leaf characters and fruit/bud characters are found to provide different views of phenetic relationships, not only among OTUs but among species as well. As an example, figure 3 illustrates the results of a cluster analysis, based on a matrix of OTU x OTU distances derived from leaf characters, for one of the communities. Relationships among the same OTUs, but derived from a matrix of fruit/bud data, are illustrated in figure 4. It is clear that these two data sets suggest distinctly different views of relationships among the major groups. In each phenogram, there are three major clusters: one of Q. falcata OTUs, a second of Q. marilandica OTUs, and a third containing OTUs of both Q. coccinea and Q. velutina.

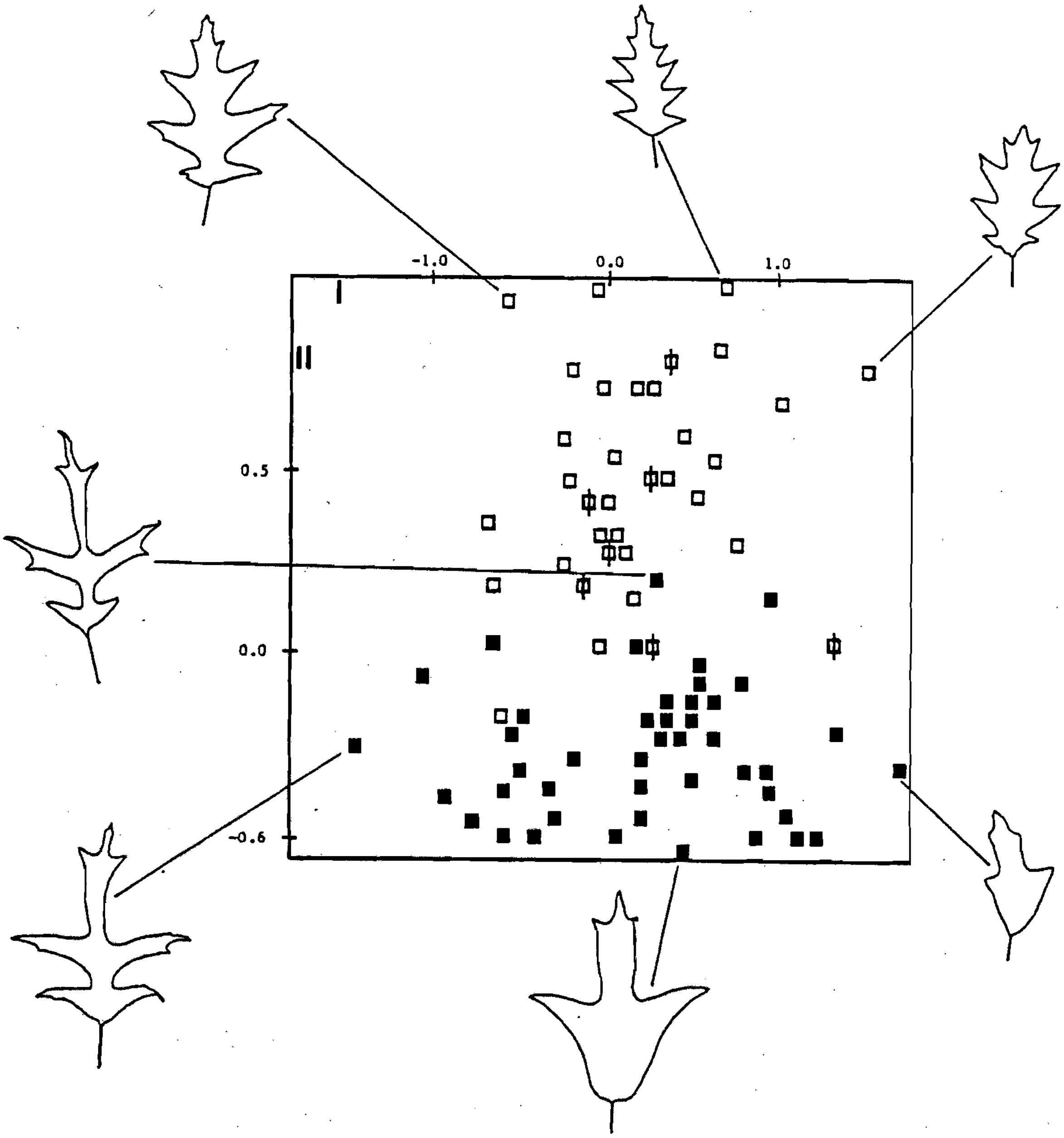

Figure 1. Projections of 79 OTUs of the Quercus falcata complex in the space defined by components I (37.4% of total variance) and II (23.8% of total variance) of a principal components analysis based on 13 leaf characters. Open squares = Q. falcata var. pagodaefolia, closed squares = Q. falcata var. falcata, squares with a vertical line = OTUs of uncertain affinity. Leaf images chosen as typical for that OTU. All leaf images have been reduced to 20% of their original size.

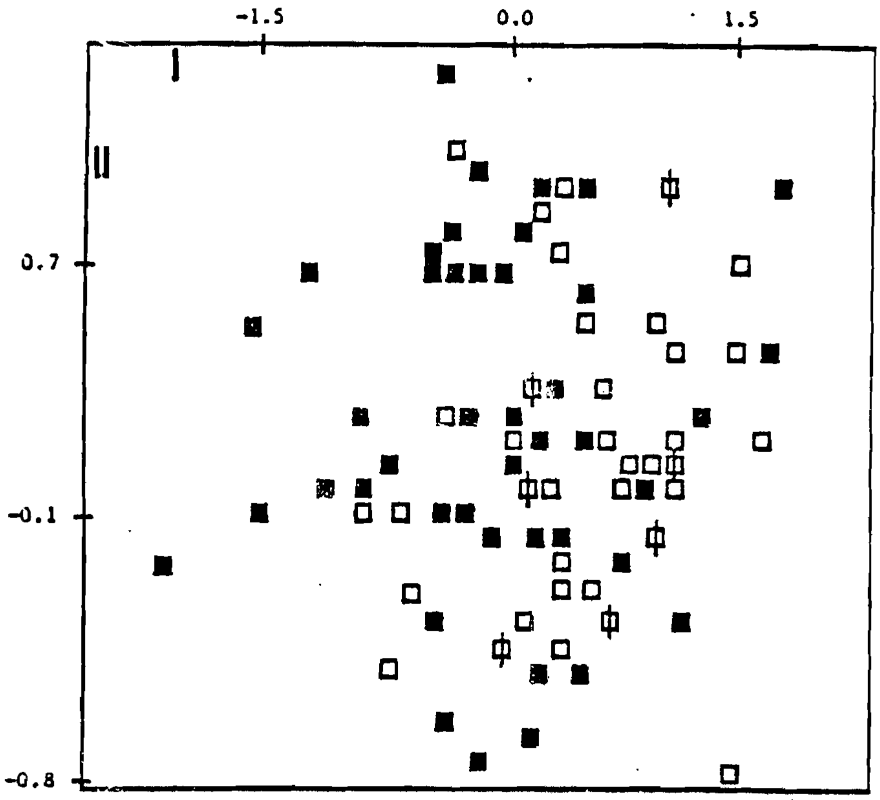

Figure 2. Projections of 79 OTUs of the *Quercus falcata* complex in the space defined by components I (46.7% of total variance) and II (18.7% of total variance) of a principal components analysis based on 10 fruit and bud characters. Symbols as in figure 1.

Two important observations may be made from the results depicted in figures 3 and 4. First, interpretations of relationships among these four species will be dependent upon which characters are analyzed. Leaf characters indicate that *Quercus falcata* is more like *Q. coccinea* and *Q. velutina* than is *Q. marilandica*, while fruit/bud characters provide conflicting views, viz. that *Q. falcata* and *Q. marilandica* cluster together but one OTU of *Q. velutina* is located in the *Q. marilandica* cluster. Second, regardless of which characters are employed, it is not possible to clearly differentiate *Q. coccinea* from *Q. velutina*. As noted in Jensen (1988), in each community examined the last two species illustrate overlap on any combination of the first three principal components for both sets of data. Further, while combining leaf and fruit/bud data sets in a single analysis strengthens the differentiation of *Q. falcata* and *Q. marilandica* from each other and from the *Q. coccinea*-*Q. velutina* cluster, the last two continue to exhibit overlap along all dimensions.

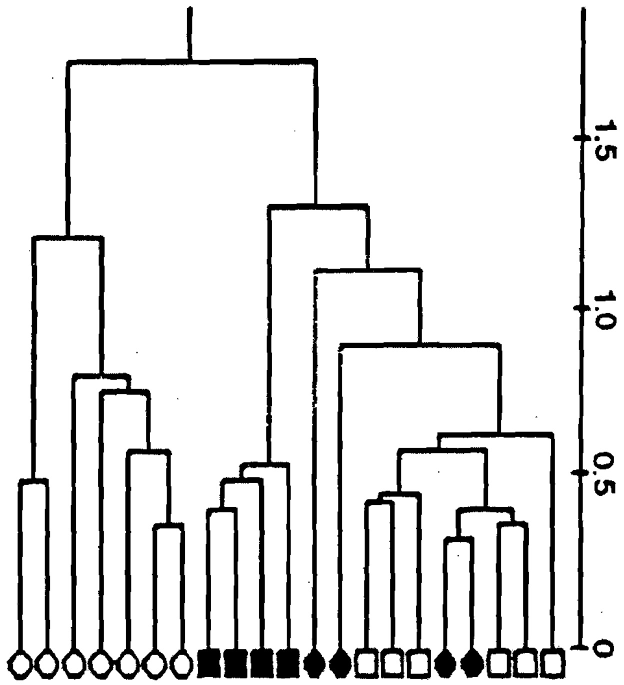

Figure 3. Phenogram from a cluster analysis of a taxonomic instance matrix based on 13 leaf characters. Twenty-one OTUs from a single community. Open squares = Q. coccinea, closed circles = Q. velutina, open circles = Q. marilandica, closed squares = Q. falcata var. falcata.

Before proceeding to a discussion of the implications of these analyses, there is an important point to be made with respect to my interpretations of these results. To place this point in context, let me pose a question: Is it likely that there are really only three species in this community on which the analyses presented in figures 3 and 4 are based? This is a legitimate question, especially from a historical perspective: Quercus velutina was once treated as a variety (var. tinctoria (Bartr.) A.DC. of Q. coccinea. My results suggest that that early synonymy may have been correct. Similar logic suggests that, since it is so difficult to distinguish the two commonly recognized species in the Q. falcata complex, perhaps these too should be treated as a single polymorphic species.

For each of these studies only trees with developing fruits were chosen, to ensure that a complete set of characters would be available for each OTU. Further, during the initial stage of the field work (conducted in mid-summer) each tree was tentatively assigned to a species or variety, that assignment being based largely on characters not included in these analyses. For example, Quercus falcata var. falcata and Q. falcata var. pagodaefolia differ in bark and leaf pubescence characters, and leaf pubescence serves to readily distinguish the former from Q. marilandica, Q. coccinea, and Q. velutina. Bark and twig characters can be used to differentiate among the last three: Q. marilandica typically has noticeably pubescent twigs and black, distinctly blocky bark and, while Q. coccinea may have twigs which are difficult to distinguish from those of Q. velutina, the latter has yellowish-orange inner bark not found in Q. coccinea. Thus, the symbols used to identify the OTUs in the accompanying illustrations are based solely on field observations and not on quantitative analysis of leaf, bud, or fruit characters.

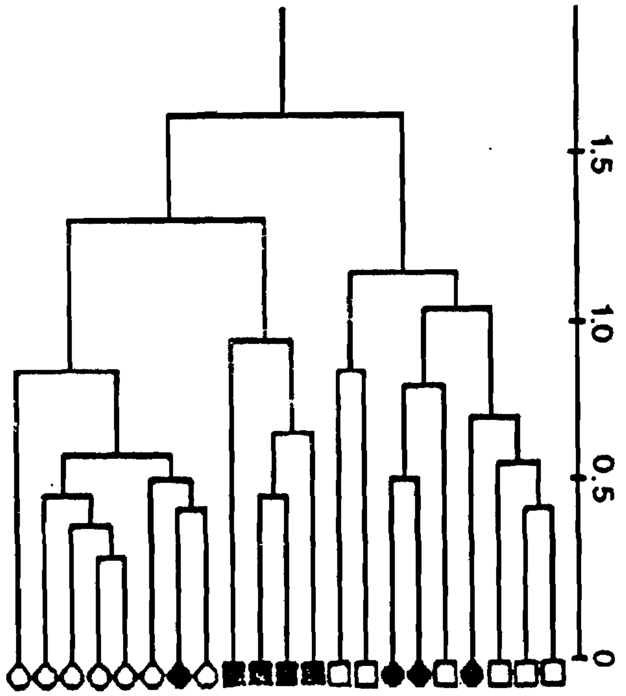

Figure 4. Phenogram from a cluster analysis of a taxonomic distance matrix based on 10 fruit and bud characters. OTUs and symbols as in figure 1.

However, bud and fruit characters--especially pubescence--were used during the fall collecting period to check my earlier identifications. While I was unable to use fruit and bud characters to confirm identifications in the Quercus falcata complex (I know of no qualitative characters of fruits or buds which can be used to distinguish the forms in that complex), those characters did prove useful for differentiating the four taxa identified in the xeric communities discussed in Jensen (1988). For example, Q. falcata, Q. marilandica, and Q. velutina all are characterized by rather large (typically 6 mm long or longer), uniformly pubescent buds, while Q. coccinea typically has smaller buds which are pubescent only on the upper half. Another field character which (based on my observations of these taxa throughout their ranges) illustrates almost perfect constancy is that the inner surface of the acorn cup of Q. coccinea is essentially glabrous while that of the other three taxa is uniformly, and most often densely, covered with simple hairs. Finally, another reasonably good field character for identifying Q. coccinea is the presence of concentric rings at the apex of the nut.

The analyses reported in Jensen (1988), and summarized here, were based solely on quantitative characters. This was done to ensure objectivity for each analysis; though there may be small measurement errors, there are no errors deriving from subjective evaluations such as degree of leaf or bud pubescence or the colors and patterns noted for bark and twigs. Also, in each analysis all characters were treated equally by standardization to mean of 0.0 and variance of 1.0. Therefore, among-OTU phenetic relationships seen in phenograms or ordinations are not biased by the characters used to make field identifications.

The distribution of qualitative characters among these OTUs is best viewed in light of their phenetic relationships as revealed by analyses of quantitative characters. Figure 5 demonstrates this by indicating the distribution of two qualitative characters: (1) the presence/absence of concentric rings at the apex of the nut and (2) the inner surface of the acorn cup being either essentially glabrous or pubescent. [The phenogram was derived from a matrix of fruit/bud characters (Jensen 1988)]. These two characters are viewed as markers for Quercus coccinea and, as seen in figure 5, all OTUs having these characters are found in the large cluster containing only OTUs field-identified as Q. coccinea, Q. velutina, or as putative hybrids. However, it is also clear that not all OTUs having these two features come together in a single, well-defined cluster; thus, we might conclude that these two characters are not species-specific, or that their distribution among these OTUs is evidence of past hybridization, or that Q. coccinea and Q. velutina simply cannot be differentiated by the quantitative characters analyzed. My view, based on observations of both of these taxa in a variety of communities and habitat types, is that local hybridization disrupts the species-specific distribution of these characters.

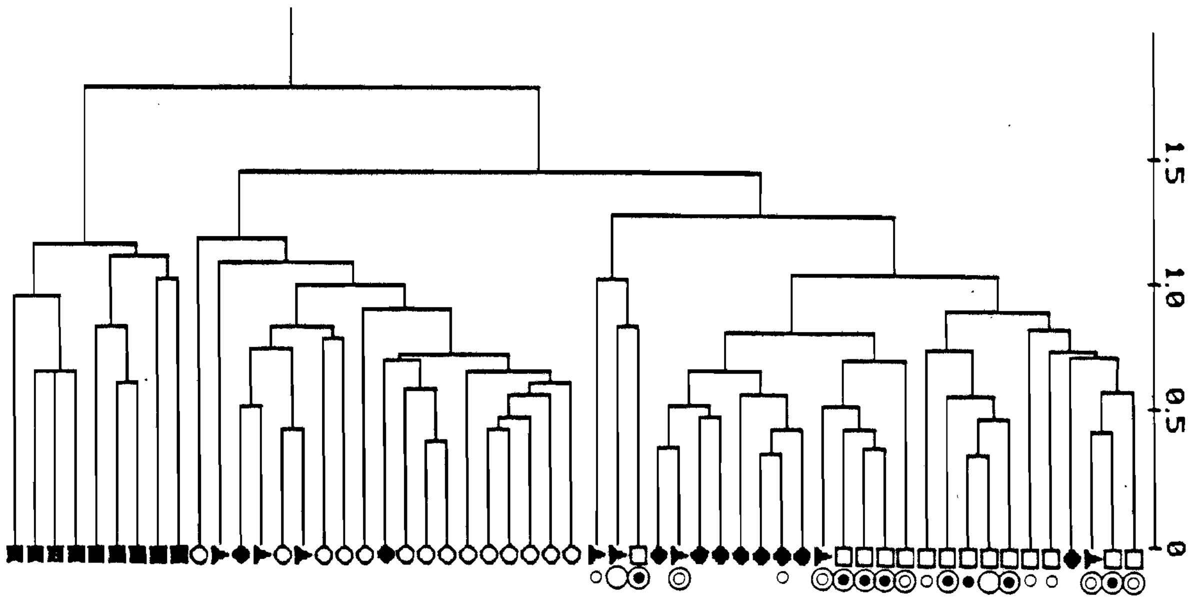

Figure 5. Distribution of two qualitative characters (pubescence of inner surface of cup, presence of rings of pits at nut apex) associated with Q. coccinea on a phenogram from a cluster analysis of a taxonomic distance matrix based on 10 fruit and bud characters. Fifty-five OTUs from three communities. OTU symbols as in figure 1 with the triangle = putative hybrids. Symbols to right of OTUs: Large open circle identifies OTUs for which the inner surface of the acorn cup is essentially glabrous; small open circle identifies OTUs which have faint rings at the apex of the nut; small solid circle identified OTUs which have conspicuous rings at the apex of the nut.

I believe the results of these analyses can provide valuable insights to the taxonomy of these oaks, especially when placed in the context of Burger's (1975) view of the species concept in Quercus. In a nutshell, Burger (1975) suggested that the morphological species concept in Quercus works because plant taxonomists have recognized the existence of species, and infraspecific taxa, by reference to suites of characters which can be detected throughout the geographic range of each taxon. That is, while there may be differences between individual trees of Q. velutina existing in Texas and in New York, there is an aspect of the phenotype of each which is consistent with the argument that these trees share a common ancestry and are members of a monophyletic group. Our ability to classify trees from distinctly different, and often geographically remote, habitats into the same species may be taken as prima facie evidence of their common heritage. This does not preclude the possibility that local and/or disjunct populations of a species may be genetically different. The wide-spread co-occurrence of populations of closely related and open-pollinated taxa almost ensures that there will be, as a result of local hybridization, at least local introgression. However, despite the effects of local introgression, which I believe must be accepted as commonplace in the taxa examined here, there is a certain consistency of species differences.

The fact that quantitative characters can be used to discriminate among trees identified on the basis of qualitative characters provides evidence that there are clearly different phenotypes which can be analyzed and interpreted objectively. As noted for the Quercus falcata complex, it is possible to recognize the two species (Q. falcata and Q. pagoda) throughout their ranges, and there is an ecological distinction which coincides with their morphological--both qualitative and quantitative--differences. The fact that the two taxa overlap both ecologically and phenotypically may be interpreted as evidence of common ancestry and incomplete reproductive isolation. Such an interpretation would be consistent with the observed results in that, despite a reasonably consistent set of morphological differences, there are parallel patterns of variation in leaf shape and size in both taxa.

Phenotypic relationships among Quercus falcata, Q. coccinea, Q. marilandica, and Q. velutina in LBL are consistent with observations made in other areas where these species co-occur, and are instructive with respect to the bases for different taxonomic interpretations. First, Q. falcata is usually easily distinguished from the other three by a number of characters, and the quantitative analyses conducted confirm this. There is no suggestion, in my analyses, of hybridization involving Q. falcata and these other three taxa. However, both quantitative and qualitative data suggest that the other three taxa may be hybridizing.

The observed patterns of quantitative variation suggest that Quercus velutina is hydrizing with both Q. coccinea and Q. marilandica , but the last two do not appear to be hybridizing with each other. Further, it appears, as noted in Jensen (1988), that hybridization is occurring in only one of the three communities examined. Morphological and biochemical data have been used to support the hypothesis of hybridization between Q. marilandica and Q. velutina in other communities (Cooperrider 1957, Jensen and Eshbaugh 1976a, Knops and Jensen 1980), but the results discussed here are the first such evidence of hybridization between Q. coccinea and Q. velutina [although this hybrid combination has been provided formal taxonomic status (Laughlin 1967)]. Despite my having examined patterns of morphological variation among these taxa in a variety of other variety of other communities [Jensen et al. (1984), Knops and Jensen (1980), Jensen (unpublished)], the current studies were the first in which quantitative characters failed to allow differentiation of Q. velutina and Q. coccinea. Should this be interpreted as an indication that something unusual is evident in LBL? Probably not. There is no reason to suspect that hybridization, or patterns of character variation which would suggest hybridization, will be seen everywhere these taxa occur together. What these results imply is that under some conditions, not yet fully understood, hybridization may occur, while at other times it may not. As noted in Jensen (1988), only one of the three communities examined yielded trees which appeared to be of hybrid origin (based on both quantitative and qualitative characters). These three communities appear very similar, with nothing to suggest that hybridization would be more likely in one than in the others.

Clearly, the analyses I conducted do not allow rejection of the hypothesis that hybridization is occurring in all three communities. It must be remembered that only mature, fruit-bearing trees were sampled. It is possible that hybrids were present but immature and/or sterile. Among the more interesting questions which can be addressed by conducting more extensive studies of communities such as these are (1) is there other evidence of hybridization beyond that available from morphological studies, (2) are there detectable ecological differences, e.g., edaphic or microclimatic, which may influence the production of hybrids, and (3) if hybrids are produced, is there evidence of selective forces which inhibit survival of F_1 or later generation hybrids? These questions can only be answered by conducting more extensive studies of patterns of variation within and among mixed-species communities such as those studied by Jensen (1988). Such studies must focus on additional sources of evidence such as electrophoresis of proteins and isozymes, presence/absence of phenolic compounds, and cytological differences among trees within each community.

Finally, the phenetic results presented here shed light on relationships depicted in various attempts to classify and/or evaluate evolutionary relationships among these taxa. Specifically, why have there been disagreements among plant taxonomists regarding the relationships among Quercus velutina, Q. marilandica, and Q. falcata? Trelease (1924) placed each of these taxa in a distinct series, but indicated that the last two were more closely related to each other than to Q. velutina. Muller (1951), on the other hand, treated Q. velutina as a member of series Marilandicae, a relationship not supported by others. Rehder (1927) placed Q. falcata and Q. velutina in his series Rubrae (along with Q. coccinea and a number of other taxa) while segregating Q. marilandica in series Nigrae. Camus (1952-54) followed Trelease (1924) by treating these taxa as members of four different series, although the species composition of each series was not the same as proposed by Trelease (1924). Jensen (1983), in a preliminary attempt at conducting cladistic analyses of the relationships among the red and black oaks of eastern North America, found evidence for placing Q. coccinea, Q. falcata, and Q. velutina in one clade (although not as sister species), with Q. marilandica in a different clade. Interestingly, phenetic analysis of the same data indicated that Q. marilandica is more like Q. coccinea and Q. velutina than is Q. falcata (Jensen 1983).

The above views of relationships among these four taxa all seem to place greater emphasis on leaf characters than on fruit characters. The phenograms presented in figures 3 and 4 demonstrate the dichotomy created by emphasizing either leaf or fruit characters. When leaf characters are examined, the pattern is clearly one in which, as reported by Trelease (1924), Rehder (1927), and Camus (1952-54), there is a close relationship among Quercus falcata, Q. coccinea, and Q. velutina. However, fruit/bud characters provide support for (1) Muller's (1951) treatment of Q. marilandica and Q. velutina as members of a single series and (2) the phenetic relationships reported by Jensen (1983). Although the data base employed by Jensen (1983) had an almost equal representation of leaf characters and fruit/bud characters, phenetic and cladistic analyses emphasized different characters. As noted in Jensen (1988), combining all characters for a single analysis yields phenetic relationships suggestive of the relationships seen in Trelease (1924), Rehder (1927), and Camus (1952-54). These authors apparently placed greater emphasis on leaf characters than on fruit characters. Muller's (1951) view of a close relationship between Q. marilandica and Q. velutina was probably based instead mostly on fruit/bud characters.

Despite the fact that these studies are based on samples of OTUs from a restricted geographic region, the results may have broader taxonomic implications. First, the pattern of variation in the Quercus falcata complex in LBL is consistent with what is seen on a broader scale throughout the range of these taxa. The conclusion that there are two species in this complex is certainly supported by the analyses reported here. Second, not only does it appear that there is evidence of hybridization involving three taxa (Q. velutina, Q. marilandica, and Q. coccinea), but also that patterns of variation differ from community to community. Third, the failure of these analyses to allow recognition of distinct clusters corresponding to Q. coccinea and Q. velutina suggests that these two taxa represent (1) a single, highly variable species complex, or (2) two species which illustrate parallel evolution in quantitative characters, or (3) two species which, in many habitats, are imperfectly isolated reproductively. Finally, the results of these quantitative phenetic studies suggest that different sets of characters have been weighted, either consciously or unconsciously, by other taxonomists attempting to summarize relationships among these taxa.

I believe that studies such as these, which focus on local patterns of variation, will continue to prove valuable for making general taxonomic investigations and are essential for developing a sound understanding of evolutionary processes. I am not, of course, the first to make such an observation. Raven (1976) reached much the same conclusion, stating that "...a concerted effort must be made to determine the forces that do indeed hold together the morphological/ecological units that we recognize as species..." Only by conducting quantitative studies of local populations and communities will we develop an understanding of the degree and significance of morphological variation. Studies such as those reported here serve to confirm the wisdom of Raven's (1976) recommendations.

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The Woody Plants, Amphibians, and Reptiles of Camp Roy C. Manchester, Marshall County, Kentucky

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KEY WORDS: amphibians, Camp Roy C. Manchester, Marshall County, Kentucky, reptiles, woody plants

Abstract

Camp Roy C. Manchester, Boy Scouts of America, is a recreational area and wildlife refuge comprising 120 hectares at the intersection of Jonathan Creek and Kentucky Lake in Marshall County, Kentucky. The camp consists primarily of a series of xeric ridges and intermittent stream valleys, which are covered by second growth forests and fields. Over the last decade, several aspects of the camp's woody flora and herpetofauna have been documented and are reported herein. These records represent a major addition to the knowledge of these groups in Marshall County.

INTRODUCTION

Camp Roy C. Manchester is a recreational area, wildlife refuge, and tree farm which has been used by Four Rivers Council, Boy Scouts of America, since the late 1950's. Centered at approximately 36° 50′ N, 88° 10′ W, Camp Manchester is accessible by Kentucky highway 914 (Boy Scout Road). The camp consists of roughly 120 ha (depending on the level of Kentucky Lake) and forms an interstream divide between Jonathan Creek and Kentucky Lake in Marshall County, Kentucky. Nearly 40 ha are owned by the Boy Scouts; the remainder is rented from the Tennessee Valley Authority (T.V.A.). Permanent human inhabitants number two. The land was occupied and farmed prior to ownership by the Boy Scouts and T.V.A. Presently the land consists of second growth timber, old homesites, trails and roadways, scattered pine plantings, old farmlands, and cleared areas used as campsites or instructional areas during summer camps. Henson Cemetery was located on the camp, but the graves were relocated because the site lies below the maximum pool elevation of Kentucky Lake. Two old farm ponds remain but are slowly being choked by vegetation.

The southwestern one-third of Camp Manchester, bordering Jonathan Creek, is composed of narrow ridges with steeply sloping sides. These ridges tend to be xeric, and their forests predate occupation by the Boy Scouts. The highest ridge extends nearly 40 m above Kentucky Lake and Jonathan Creek. These ridges and the sides of the intermittent stream valleys between them are dominated by oaks and hickories. The northern one-third of the camp has considerably less relief and a more mixed mesophytic community. Remnants of fence rows dissect the second growth. The species composition of the forest stand owned by the Boy Scouts (which occupies the highest ridge) is as follows: _Quercus alba_ 40 percent, _Quercus_ spp. (red oaks) 25 percent, _Carya_ spp. 15 percent, and 20 percent minor species such as _Quercus stellata_, _Nyssa sylvatica_, and _Platanus occidentalis_ (Schmidt 1980). Soils of alluvial origin along the lake shore support a swamp-like forest.

The entire upland portion of the camp is coated by a thin blanket of loess in which a dendritic stream system has developed. Along the ridgetops, the loess is underlain by gravelly coastal plain deposits. Resting unconformably under the loess and coastal plain deposits are the McNairy formation, the St. Louis formation, the Warsaw formation, and the Fort Payne formation. Sands and gravels of McNairy origin are becoming exposed along intermittent streams in the northern half of the camp. Also in this portion of the camp, the St. Louis and the Warsaw limestone residuums are becoming exposed along Kentucky Lake. A few tiny outcrops of gravel, possibly from the Tuscaloosa formation, can be found with chert residuum from the Fort Payne formation along ridges near the camp's entrance and Jonathan Creek. A series of east-west faults traverse the midsection of the camp (Wolfe 1964). The site of the former Jonathan Creek Indian village, occupied circa A.D. 1350, is at the southern end of what is now Indian Island (or Boy Scout Island) just off the shore of the camp (Webb 1952). Pottery sherds and arrow points occasionally wash out on the camp shores and on Indian Island. The surfaces of Indian Island and the peninsula at the intersection of Jonathan Creek and Kentucky Lake are alluvial in origin. Data from the vegetation on the portion of the island directly east of the camp is included herein.

Brandon and Bodine soils have formed on the ridges and hillsides bordering Jonathan Creek. These soils are well-drained and extremely susceptible to erosion, especially along Jonathan Creek, where slopes approach sixty percent (Humphrey et al. 1973). Brandon soils extend along the ridges through the middle of the camp. The gently-sloping northern one-third of the camp has soils belonging to the Brandon-Loring-Lax association. Grenada soils have developed on the level surface of Indian Island, with its high water table.

The climate of the camp can be summarized as temperate, humid, and continental. The mean annual precipitation is about 122 cm and is fairly well distributed throughout the year. Winters and summers are mild. The average annual temperature is approximately 15 degrees C (Humphrey et al. 1973).

This report is the culmination of ten years of work in surveying various aspects of the biota of Camp Roy C. Manchester. Several hours in the field were logged by scouts in earning nature- and ecology-related merit badges. Consequently, the majority of field hours were amassed during the months of June and July when summer camps were in session. Work during other seasons was performed almost entirely by the author. No accounts of the woody flora or herpetofauna of Camp Manchester have appeared previously. The ultimate goal of this research is to produce a series of merit-badge booklets to aid in the instruction of merit badges in the summer camp program.

Woody Plants

Camp Roy C. Manchester has a rich woody flora composed of a known 104 species in 36 families. Braun (1950) places the camp in the Western Mesophytic Forest Region, a transition region between the Mixed Mesophytic Forest to the east and the Oak-Hickory Forest of the Ozarks to the west. Overall, oaks dominate the camp's woody flora, representing about 11 percent of all species identified. Non-native species comprise 18 percent of the woody species. The richness of the woody flora of Camp Manchester is comparable to that reported in other recent surveys of nearby areas: 136 species from Bear Creek Natural Area in Stewart County, Tennessee (Carpenter and Chester 1987) and just over 125 species from Calloway County, Kentucky (Woods 1983). Camp Roy C. Manchester is a member of the American Tree Farm System. A five-km trail passes through essentially all the habitats of the camp, and woody plants along the trail are currently tagged with temporary species identification labels (permanent ones are planned).

Table 1 is a list of the woody plants known to occur on Camp Roy C. Manchester. [Common and scientific names generally follow Fernald (1950)]. Voucher specimens are presently housed with the author until arrangements for a permanent collection at the camp are complete.

Table 1. Woody plants known to occur on Camp Roy C. Manchester, Marshall County, Kentucky

Vernacular Name[1]	Scientific Name[1]
Red Cedar	_Juniperus virginiana_
Loblolly Pine	_Pinus taeda_*
Eastern White Pine	_Pinus strobus_*
Baldcypress	_Taxodium distichum_
Bristly Greenbrier	_Smilax bona-nox_
Sawbrier	_Smilax glauca_
Common Greenbrier	_Smilax rotundifolia_
Black Willow	_Salix nigra_
Sand-bar Willow	_Salix interior_
Small Pussy-Willow	_Salix humilus_
Cottonwood	_Populus deltoides_
Pignut	_Carya glabra_
Pecan	_Carya illinoensis_
Shagbark-Hickory	_Carya ovata_
Mockernut	_Carya tomentosa_
Black Walnut	_Juglans nigra_
Common Alder	_Alnus serrulata_
River-Birch	_Betula nigra_
American Hazelnut	_Corylus americana_
American Hop-Hornbeam	_Ostrya virginiana_
White Oak	_Quercus alba_
Scarlet Oak	_Quercus coccinea_
Southern Red Oak	_Quercus falcata_
Cherrybark Oak	_Quercus pagoda_
Shingle-Oak	_Quercus imbricaria_
Over-cup Oak	_Quercus lyrata_
Black Jack	_Quercus marilandica_
Pin-Oak	_Quercus palustris_
Red Oak	_Quercus rubra_
Post-Oak	_Quercus stellata_
Black Oak	_Quercus velutina_
Sugarberry	_Celtis laevigata_
Hackberry	_Celtis occidentalis_
American Elm	_Ulmus americana_
Slippery Elm	_Ulmus rubra_
Winged Elm	_Ulmus alata_
Osage Orange	_Maclura pomifera_*
Paper-Mulberry	_Broussonetia papyrifera_*
Red Mulberry	_Morus rubra_
Mistletoe	_Phoradendron flavescens_
Ladies'-eardrops	_Brunnichia cirrhosa_
Tulip-Poplar	_Liriodendron tulipifera_
Pawpaw	_Asimina triloba_
Sassafras	_Sassafras albidum_
Wild Hydrangea	_Hydrangea arborescens_

Table 1. (Continued)

Vernacular Name	Scientific Name
Sweet Gum	Liquidambar styraciflua
Sycamore	Platanus occidentalis
Downy Serviceberry	Amelanchier arborea
Cockspur-Thorn	Crataegus crus-galli
Pear Hawthorn	Crataegus calpodendron
Wild Plum	Prunus americana
Chickasaw Plum	Prunus angustifolia
Peach	Prunus persica*
Black Cherry	Prunus serotina
Wild Crab	Pyrus angustifolia
Apple	Pyrus malus*
Common Pear	Pyrus communis
Multiflora Rose	Rosa multiflora*
Prairie-Rose	Rosa setigera
Carolina Rose	Rosa carolina
Domestic Rose	Rosa sp.*
Bramble	Rubus sp.
Northern Dewberry	Rubus flagellaris
Silk-tree	Albizzia julibrissin*
False Indigo	Amorpha fruticosa
Redbud	Cercis canadensis*
Honey-Locust	Gleditsia tricanthos
Black Locust	Robinia pseudo-acacia*
Wisteria	Wisteria frutescens
Bush Lespedeza	Lespedeza bicolor*
Tree-of-heaven	Ailanthus altissima*
Shining Sumac	Rhus copallina
Smooth Sumac	Rhus glabra
Poison Ivy	Rhus radicans
Possum-Haw	Ilex decidua
Box-Elder	Acer negundo
Red Maple	Acer rubrum
Silver Maple	Acer saccharinum
Sugar Maple	Acer saccharum
New Jersey Tea	Ceanothus americanus
Virginia Creeper	Parthenocissus quinquefolia
Frost-Grape	Vitis vulpina
Summer-Grape	Vitis aestivalis
Black Gum	Nyssa sylvatica
English Ivy	Hedera helix*
Devil's-walking-stick	Aralia spinosa
Red Willow	Cornus amomum
Flowering Dogwood	Cornus florida
Sparkleberry	Vaccinium arboreum

Table 1. (Continued)

Vernacular Name	Scientific Name
Common Persimmon	Diospyros virginiana
Mock-orange	Styrax americana
White Ash	Fraxinus americana
Green Ash	Fraxinus pennsylvanica Var. subintegerrima
Privet	Ligustrum vulgare*
Common Periwinkle	Vinca minor*
Common Lilac	Syringa vulgaris*
St. Andrew's Cross	Ascyrum hypericoides
Shrubby St. John's-wort	Hypericum spathulatum
Trumpet Creeper	Campsis radicans
Buttonbush	Cephalanthus occidentalis
Japanese Honeysuckle	Lonicera japonica*
Coralberry	Symphoricarpos orbiculatus
Common Elder	Sambucus canadensis
Southern Black-haw	Viburnum rufidulum

*Introduced species
1. Scientific and vernacular names generally according to Fernald (1950)

Amphibians and Reptiles

Camp Roy C. Manchester is poorly suited for many species of amphibians. Only 12 species have been identified compared to 25 from LBL (Snyder 1972) and just under 50 in Kentucky (Barbour 1971). To date, the only amphibian reported in the literature for Marshall County, Kentucky is Pseudacris triseriata feriarum (Upland Chorus Frog) (Barbour 1957). Prior to this study, 17 species of amphibians were known to occur in Marshall County, according to the Kentucky Department of Fish and Wildlife Resources. The xeric nature of the ridges which comprise much of the camp severely limits the type and number of amphibians which might inhabit the area. No springs, permanently-flowing streams, or caves have been located. In this survey, winter-breeding salamanders especially may have been overlooked because collecting occurred mainly during the summer.

However, Camp Manchester has a rich reptilian fauna represented by a known 31 species. This is a major fraction of the 54 species reported for Kentucky by Barbour (1971) and of the 41 species reported from across Kentucky Lake in Land Between The Lakes by Snyder (1972). A distinct lack of literature records for reptiles in Marshall County also exists, the county being represented by an account of Cemophora coccinea (Scarlet Snake) from the nearby Girl Scout camp (Fuller and Barbour 1962). Mention of a specimen of Agkistrodon piscivorus (Cottonmouth) from Marshall County has also appeared in a table in a recent article in the Kentucky Happy Hunting Ground (MacGregor 1986). The Kentucky Department of Fish and Wildlife Resources listed 31 species as known to occur in Marshall County, prior to this work.

In the following list of amphibians and reptiles, common and scientific names are those presented by Collins et al. (1982) (table 2). In conformance with national Boy Scout policy, all captured specimens (including venomous snakes) were released. A collection of dead-on-road and other similarly acquired specimens, representing the majority of species of the camp's herpetofauna, is presently housed by the author while arrangements for a permanent collection are underway. Further documentation is by photographs, also presently housed with the author. The specimen of Pituophis m. melanoleucus listed below is in the collection of Dr. C. D. Wilder.

Table 2. Amphibians and reptiles known to occur on Camp Roy C. Manchester, Marshall County, Kentucky

Vernacular Name[1]	Scientific Name[1]
Central Newt	Notophthalmus viridescens louisianensis
Longtail Salamander	Eurycea l. longicauda
Eastern Zigzag Salamander	Plethodon d. dorsalis
Slimy Salamander	Plethodon g. glutinosus
Bullfrog	Rana catesbeiana
Green Frog	Rana clamitans melanota
Southern Leopard Frog	Rana sphenocephala
Eastern Narrowmouth Toad	Gastrophryne carolinensis
Blanchard's Cricket Frog	Acris crepitans blanchardi
Cope's Gray Treefrog	Hyla chrysoscelis
Fowler's Toad	Bufo woodhousei fowleri
Dwarf American Toad	Bufo americanus charlesmithi
Stinkpot	Sternotherus odoratus
Eastern Mud Turtle	Kinosternon s. subrubrum
Common Snapping Turtle	Chelydra s. serpentina
Painted Turtle	Chrysemys picta*
Ouachita Map Turtle	Graptemys pseudogeographica ouachitensis

Table 2. (Continued)

Vernacular Name	Scientific Name
Eastern River Cooter	Pseudemys c. concinna
Red-eared Slider	Pseudemys scripta elegans
Eastern Box Turtle	Terrpene c. carolina
Midland Smooth Softshell	Trionyx m. muticus
Eastern Spiny Softshell	Tronyx s. spiniferus
Northern Fence Lizard	Sceloporus undulatus hyacinthinus
Five-lined Skink	Eumeces fasciatus
Broadhead Skink	Eumeces laticeps*
Ground Skink	Scincella lateralis*
Six-lined Racerunner	Cnemidophorus s. sexlineatus
Diamondback Water Snake	Nerodia r. rhombifera
Midland Water Snake	Nerodia sipedon pleuralis
Midland Brown Snake	Storeria dekayi wrightorum
Northern Redbelly Snake	Storeria o. occipitomaculata*
Eastern Garter Snake	Thamnophis s. sirtalis
Western Earth Snake	Virginia valeriae elegans
Midwest Worm Snake	Carphophis amoenus helenae
Southern Black Racer	Coluber constrictor priapus
Mississippi Ringneck Snake	Diadophis punctatus stictogenys
Gray Rat Snake	Elaphe obsoleta spiloides
Eastern Hognose Snake	Heterodon platyrhinos
Prairie Kingsnake	Lampropeltis c. calligaster
Black Kingsnake	Lampropeltis getulus niger
Rough Green Snake	Opheodrys aestivus
Northern Pine Snake	Pituophis m. melanoleucus*
Northern Copperhead	Agkistrodon contortrix mokeson
Southern Copperhead	Agkistrodon c. contortrix

*New county record
1. Scientific and vernacular names according to Collins et al. (1982)

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Vegetation of the Jackson Purchase of Kentucky Based on the 1820 General Land Office Survey

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ABSTRACT

Information contained in William Henderson's 1820 General Land Office Survey (GLO) of the "Lands West of the Tennessee River" (the Jackson Purchase of Kentucky) was used in an effort to reconstruct the vegetation at that time. Although Henderson recorded nearly 50 species and well over 10,000 trees, the shortcomings of his data allow neither density nor basal area determinations. Oaks comprised over 60 percent of the trees with post oak, black oak, blackjack oak, white oak, and red oak ranking highest. Hickories made up 11 percent of the total. Other commonly mentioned trees were gum, dogwood, elm, ash, poplar, black gum, and maple. Henderson made a few brief notes regarding the landscape; however, he did not characterize the barrens or prairies known to occur. Trees listed in the 1820 GLO survey compare favorably to those mentioned in the geological surveys and county histories for the Jackson Purchase which were written during the 1880s.

Introduction

General Land Office (GLO) surveys have been used to reconstruct the presettlement vegetation or the early vegetation patterns in a number of states, i.e., Alabama (Jones and Patton 1966, Rankin and Davis 1971), Illinois (Anderson 1970, Anderson and Anderson 1975, Kaminski and Jackson 1978, Rodgers and Anderson 1979, Leitner and Jackson 1981), Indiana (Blewett and Potzger 1950, Potzger and Potzger 1950, Potzger et al. 1956, Lindsey 1961, Lindsey et al. 1965, Crankshaw et al. 1965), Louisiana (Delcourt 1976, Delcourt and Delcourt 1974), Michigan (Kenoyer 1930, 1934, 1940, 1942; Dick 1936; Bourdo 1956; Hushen et al. 1966), Minnesota (Grimm 1984), Missouri (Howell and Kucera 1956, Wuenscher and Valiunas 1967), Ohio (Sears 1925, Shanks 1953, Ogden 1965, Gordon 1969), and Wisconsin (Cottam 1949, Stearns 1949, Ellarson 1949, Neuninschwander 1957). GLO surveys preserved a systematic record of great biological value because they recorded witness trees and other vegetation (Sears 1925) in a particular area at or near the time of settlement when the landscape was free of extensive human (European) modifications.

GLO surveys were first authorized in 1785 primarily as a systematic plan for the Northwest Territory (Rosebloom and Weisenberger 1969). By that date, much of Kentucky had been settled and the absence of a systematic survey led to many of the land disputes that followed initial settlement. The only region of the state laid off in sections using GLO methods was the "Lands West of the Tennessee River", now known as the Jackson Purchase. This region, and a similar area in Tennessee, had been purchased from the Chickasaw Indians in 1818. The GLO survey was conducted by William Henderson in 1820. The instructions given to the surveyors varied over time, but generally specified 4 bearing (witness) trees, both at township corners and at section corners on township and range lines. One of these trees was to stand in each of the 4 sections common to a corner. The surveyors were to record the distance to each tree and to estimate the diameter of each tree. The usual practice was to set two trees when the townships were laid out and the others when the lines of subdivisions were tied in. Frequently only two or three bearing trees actually were reported (Bourdo 1956). Where no trees were present, such as in prairie areas, posts were set at the corners.

Not all GLO surveys were without bias and some surveys were fraudulent or mistake-filled (Bourdo 1956). Henderson began his survey in the manner outlined above, but after a few sections stopped recording distances to trees and estimating diameters. For this reason his data are not usable for density (trees/hectare) or basal area (m^2/ha) determinations. In spite of this shortcoming, Henderson's survey contains considerable information which we report here. We compare the GLO survey to the descriptions of the landscape contained in county histories and Kentucky Geological Surveys that were written not long after the original survey.

This paper is preliminary to a more detailed analysis of the plant communities, species associations, and phytogeographical patterns in the Jackson Purchase developed from GLO information.

The Environment of the Jackson Purchase.

The Jackson Purchase is a 6144 km^2 area in extreme western Kentucky. It is bounded on the east by the Tennessee River, on the north by the Ohio River, on the west by the Mississippi River, and on the south by the Tennessee State Line at $36^{o}30'$ north latitude (figure 1). Fenneman (1928) placed the Jackson Purchase in his Coastal Plain Province, indicating its distinctness from the rest of Kentucky. McFarlan (1943) referred to this coastal plain region as the area of outcrop of the unconsolidated or only semi-consolidated sediments of the Cretaceous and Tertiary. These gravelly deposits are generally covered by loess deposits of varying thicknesses, although on the hilly uplands the highly ferruginous gravels outcrop at the surface (Davis 1923).

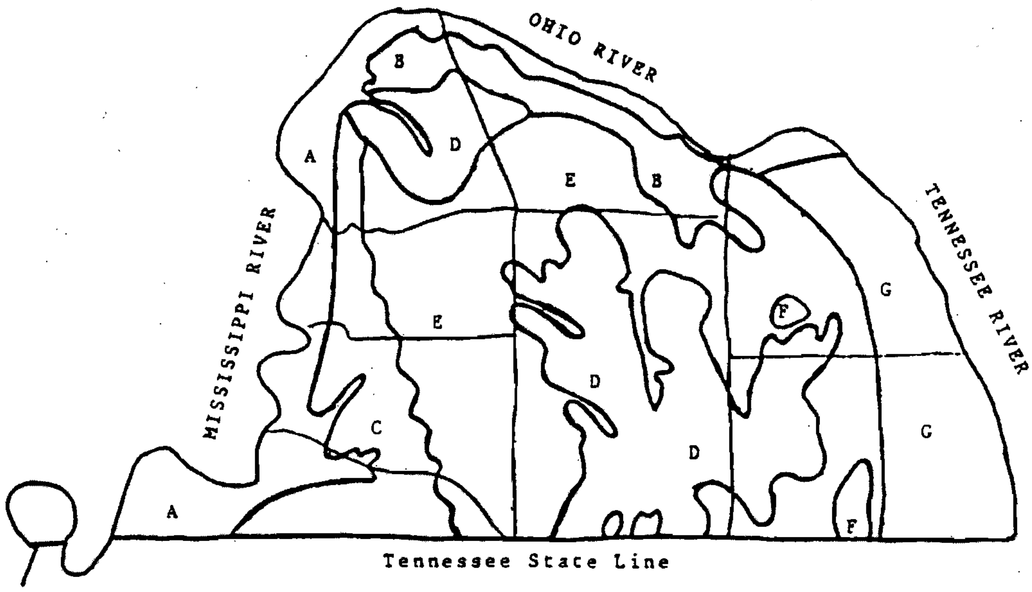

Figure 1. A map of the Jackson Purchase Region of Kentucky with subdivisions after Davis (1923).
A. The Big Bottoms, B. The Second Bottoms, C. The Cane Hills, D. The Barrens, E. The Oak and Hickory Uplands, F. The Flatwoods, and G. The Breaks of the Tennessee

Floodplains along the major rivers are large in extent, and alluvial deposits are widespread. Swamps are numerous along the major streams (McFarlan 1943) and along the Mississippi, river bluffs up to 30 m in height are capped with deep loess deposits.

Topographically, the Jackson Purchase is an undulating plain except for a couple of low ridge lines (McFarlan 1943). Elevation varies from about 100 m to 120 m.

Most of the soils are formed in loess overlying the gravelly sediment. Other soils are formed in cherty limestone residuum, especially along the Tennessee River. Alluvial soils are wide-spread.

The climate of the Jackson Purchase is a rather mild, temperate, humid continental type. The average temperature is about 15°C and the average precipitation is 120 cm (Newton and Sims 1964).

METHODS

A copy of the GLO survey was obtained from the Kentucky Historical Society. For this paper, all trees listed in the survey--not just the witness trees--were counted and their percent composition calculated. Henderson used common names and often lumped certain species groups. Scientific names were equated with many of Henderson's common names.

All notes or comments made by the surveyors regarding the landscape were reviewed. Other historical descriptions of the landscape found in histories and geological surveys were used to evaluate the accuracy of the GLO findings.

RESULTS

Based on Henderson's field notes, it is apparent that his survey cut across a number of habitat types. He identified, "rolling barrens", "rolling timbered land", "swampy land", "lake", and various combinations such as "part barren, part second rate land", "part timbered, part barrens", and "part broken, part swampy". Often he included the descriptives, "first rate", "second rate", and "third rate" when evaluating the quality of the land. His habitat system appears to be consistent with the swamps, sloughs, barrens, prairies, and well-timbered lands listed by other writers.

Henderson recorded 10,330 trees in his survey. Collectively, the oaks (Quercus) accounted for 61.33 percent of the trees present. Post oak (Q. stellata, 15.64 percent), black oak (Q. velutina, 13.47 percent), blackjack oak (Q. marilandica, 11.10 percent), white oak (Q. alba, 10.90 percent), red oak (Q. rubra, 7.70 percent) and Spanish oak (Q. falcata, 1.65 percent) were the leading oak species (table 1). Those 6 species accounted for 98.6 percent of the oaks. The hickories (Carya spp., 11 percent) were lumped, with no indication of species. Collectively, the oak-hickory component totaled 72.33 percent of the trees mentioned. Braun (1950) noted that were it not for the loess bluffs, she would have included the Jackson Purchase in her Oak-Hickory Forest Region instead of in the Western Mesophytic Forest.

Table 1. Number (N) and percent composition of trees in the 1820 GLO survey of the Jackson Purchase of Kentucky

Tree Species	N	percent
Post Oak *Quercus stellata*	1616	15.64
Black Oak *Q. velutina*	1391	13.47
Blackjack Oak *Q. marilandica*	1147	11.10
White Oak *Q.alba*	1126	10.90
Red Oak *Q. rubra*	795	7.70
Spanish Oak *Q. falcata*	170	1.65
Chestnut Oak *Q. prinus*	4	0.04
Water Oak *Q. nigra*	30	0.29
Swamp Oak *Q. bicolor*	30	0.29
Willow Oak *Q. phellos*	3	0.01
Pin Oak *Q. palustris*	8	0.08
Box Oak *Q. michauxii*	1	0.01
Oak *Q.* spp.	13	0.13
Hickory *Carya* spp.	1136	11.00
Gum *Nyssa* or *Liquidambar*	502	4.86
Black Gum *Nyssa sylvatica*	204	1.97
White Gum *N. aquatica*	9	0.09
Sweet Gum *Liquidambar styraciflua*	76	0.74

Table 1. (Continued)

Tree Species	N	percent
Sugar Tree *Acer saccharum*	26	0.25
Maple *A. saccharinum* or *A. rubrum*	200	1.94
Elder *A. negundo*	31	0.30
Boxelder *A. negundo*	3	0.03
Beech *Fagus grandifolia*	58	0.56
Dogwood *Cornus florida*	437	4.23
Persimmon *Diospyros virginiana*	29	0.28
Poplar *Liriodendron tulipifera*	206	1.99
Sassafras *Sassafras albidum*	63	0.61
Ironwood *Carpinus caroliniana*	46	0.45
Hornbeam *Ostrya virginiana*	17	0.16
Ash *Fraxinus* spp.	241	2.33
Elm *Ulmus* spp.	363	3.51
Cypress *Taxodium distichum*	56	0.54
Sycamore *Platanus occidentalis*	24	0.23
Cottonwood *Populus deltoides*	50	0.48
Willow *Salix nigra*	49	0.47
Birch *Betula nigra*	12	0.12
Wild Cherry *Prunus serotina*	10	0.10
Plum *P. americana*	1	0.01
Mulberry *Morus rubra*	29	0.28
Chestnut *Castanea dentata*	4	0.04

Table 1. (Continued)

Tree Species	N	percent
Walnut *Juglans nigra*	22	0.21
Locust *Gleditsia triacanthos*	9	0.09
Black Locust *Robinia pseudoacacia*	3	0.03
Redbud *Cercis canadensis*	23	0.22
Linn *Tilia* spp.	3	0.03
Hackberry *Celtis occidentalis*	46	0.45
Pawpaw *Asimina triloba*	6	0.06
Privy Bush *Foresteria acuminata*	1	0.01
Haw *Crataegus* or *Viburnum*	1	0.01
Totals	10,330	100.01

Other species of fairly common occurrence according to the survey were gum (*Nyssa* or *Liquidambar*?), dogwood (*Cornus florida*), elm (*Ulmus* spp.), ash (*Fraxinus* spp.), poplar (*Liriodendron tulipifera*), black gum (*Nyssa sylvatica*), and maple (*Acer rubrum* or *A. saccharinum*). In general, these species have relatively wide ecological amplitudes.

At present it is not possible to correlate tree species with specific habitats or associations. However, those species of wet habitats include cypress (*Taxodium distichum*), willow (*Salix nigra*), birch (*Betula nigra*), pin oak (*Q. palustris*), willow oak (*Q. phellos*), water oak (*Q. nigra*), box oak (*Q. michauxii*), white gum (*Nyssa aquatica*), cottonwood (*Populus deltoides* or *P. heterophylla*), and sycamore (*Platanus occidentalis*). Species typical of mesic situations include beech (*Fagus grandifolia*), sugar tree (*Acer saccharum*), linn (*Tilia americana* or *T. heterophylla*), wild cherry (*Prunus serotina*), tulip poplar (*Liriodendron tulipifera*), black walnut (*Juglans nigra*), and chestnut (*Castanea dentata*). Understory species in addition to dogwood included redbud (*Cercis canadensis*), hornbeam (*Ostrya virginiana*), ironwood (*Carpinus caroliniana*), pawpaw (*Asimina triloba*), haw (*Crataegus* or *Viburnum*), and plum (*Prunus americana*). Successional species--

persimmon (Diospyros virginiana) and black locust (Robinia pseudo-acacia)--were also recorded in the survey.

Those sections where Henderson set posts should be interpreted as treeless tracts, barrens, or prairie. These were apparently extensive since a number of posts were set across the Jackson Purchase.

DISCUSSION

Henderson's 1820 General Land Office survey was not the first survey to be conducted in the Jackson Purchase. Richards and Berry (1885) wrote, "As early as 1783-84 the legislature of Virginia authorized the 'laying of land warrants' along the Mississippi, Ohio and other rivers for the benefits of the soldiers of that State who had served in the Revolutionary war, and immediately thereafter surveyors visited the country for the purpose of 'locating' said warrants; but owing to the hostility of the Indians they carried their operations no further than 'establishing corners' at various points along the river. The first of these warrants was laid on the Mississippi River, in what is now Hickman County, and embraced an area of 4,000 acres, which served as the basis for all warrants subsequently located in this part of the State." In 1795, General George Rogers Clark received a land grant of 37,000 acres in McCracken County which was also surveyed (Richards and Berry 1885). We mentioned these two earlier surveys as points of reference, because they are other examples of information that might be used to more clearly define the vegetation of local areas within the Jackson Purchase.

Henderson's failure to record the distances to trees, and their diameters, limits the usefulness of his data. However, the GLO survey appears to be relatively complete in terms of species recorded and habitats identified, relative to other reports (DeFriese 1884a, 1884b; Richards and Berry 1885; Loughridge 1888; Davis 1923; Braun 1950). According to Braun (1950), the Mississippi Embayment section of her Western Mesophytic Forest Region displays a mosaic of unlike vegetation types including prairies, oak-hickory forest, swamp forest, and mixed mesophytic communities. She noted that the oak and oak-hickory forest communities occupied a considerable part of the rolling uplands and that composition varied in relation to topography and soils. DeFriese (1884a) also noted that "topography has more and geology less, to do with the distribution and general character of the timbers" in the Jackson Purchase than elsewhere in Kentucky. He reported that a change of fifteen feet was sufficient to produce a change in timber composition.

DeFriese (1884a) recognized the relationship between distribution of the Coastal Plain pebbles [the Lafayette gravel of Davis (1923)] and the presence of blackjack and scrub (post and Southern red) oaks: where pebbles were found on the soil surface, these oaks dominated the community. Davis (1923) found the gravels to be widely distributed across the Purchase and generally close to the surface except where covered by loess. This distribution may help explain the abundance of these species in the GLO survey.

Davis (1923) produced a map identifying 7 subregions of the Jackson Purchase (figure 1). Portions of every county fell within his Oak and Hickory Uplands subregion. DeFriese (1884a) reported that 32 percent of the timber was white oak and <15 percent black oak. These percentages differ somewhat from the GLO data. For the uplands, Braun (1950) found hickories to almost always be present with the oaks. However, DeFriese (1884a) noted the greatest abundance and quality of hickory not on the uplands, but along streams. Both DeFriese (1884a) and Braun (1950) mentioned that tulip poplar was a frequent constituent of white oak communities. Elsewhere on the uplands, Braun (1950) reported that beech and sugar maple were rare, except in the loess hills [the Cane Hills of Davis (1923)], which harbored the most mesophytic association of species (Loughridge 1888). Neither DeFriese (1884a) nor Loughridge (1888) considered beech important in the Purchase.

The low percentages of many hydric species suggests that they were localized and not widespread. Braun (1950) recognized an extension of her Southeast Evergreen Forest Region in the Jackson Purchase with the presence of species more typical of the southeast swamps. These swampy areas were common in the interior of the bottom region (Big Bottoms, figure 1), especially along the Mississippi River (Loughridge 1888).

Most early reports mention the extensiveness of prairie in the Jackson Purchase (DeFriese 1884a, Richards and Berry 1885, Loughridge 1888, Davis 1923, Dicken 1935). These reports identify the importance of annual fires in maintaining grass and discouraging tree invasion. Richards and Berry (1885) found that in certain "burnt districts" white oak almost disappeared. Shortly after settlement and the cessation of fires, the prairies were invaded by blackjack, black, and red oaks, and other shrubby growth (Loughridge 1888). This replacement of prairie by forest was rapid, occurring generally within 30 years. Henderson failed to note the effect of fire during his survey.

The distribution of species as assessed from the GLO survey compares favorably to the known distributions of a number of rare or uncommon species in the Jackson Purchase. Linn (<u>Tilia</u> spp.) was recorded in low numbers. Little's (1970) maps show that the ranges of American basswood (<u>Tilia americana</u>), white basswood (<u>T. heterophylla</u>), chestnut oak (<u>Q. prinus</u>), chestnut (<u>Castanea dentata</u>), and black locust (<u>Robinia</u>

pseudo-acacia) extend into extreme western Kentucky. DeFriese (1884b) and Loughridge (1888) reported a few chestnuts, and both reported black locust from several locations. Loughridge (1888) noted that black locust "springs up" on lands that were once under cultivation. Even beech and sugar maple, which Braun (1950) listed as rare on the uplands, were reported in limited numbers in the GLO survey.

Not all of the tree species known for the extreme western portion of Kentucky were listed in the GLO survey. The purpose of the survey was not to identify trees, but rather to survey land. The field studies that followed the GLO survey often filled in the species lists, which can now serve as a check by which we can judge the GLO survey. Several examples of tree species known for the Jackson Purchase, but not listed in the survey could be mentioned. We cite only one--catalpa. Loughridge (1888) reported catalpa from the swamps. Wharton and Barbour (1973) list *Catalpa speciosa* as present but uncommon in the Jackson Purchase region.

The findings from this preliminary analysis of the 1820 General Land Office survey present a picture that appears to be somewhat different from the Jackson Purchase today. According to DeFriese (1884a,b) much of the original timber had been cut over by 1878. Modifications of the landscape through the control of fire, agricultural practices, lumbering, and drainage have continued. Further studies of both the GLO survey and current vegetation will add to our understanding of man's impact on the environment, and perhaps the development of improved land management practices.

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CONTRIBUTED PAPERS

SESSION II - ZOOLOGY

Saturday 12 March 1988

Moderated by:

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Summer and Fall Activity of the Herpetofauna Around Woodland and Old Field Ponds in Land Between The Lakes

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ABSTRACT

Terrestrial activity of the herpetofauna at a woodland and an old field pond in TVA's Land Between The Lakes was monitored from July through December, 1987. Drift fences with pitfall traps were used to intercept animals moving to and from ponds. Nine abiotic factors were tracked and compared to shifts in activity levels. Twenty-five species (15 amphibians and 10 reptiles) were encountered at each pond. Twenty-one of these were found at both ponds, and four were unique to each pond. Amphibians accounted for 97 percent of the 985 captures at the woodland pond and 98 percent of 1718 captures at the old field pond. Frogs outnumbered salamanders at both ponds, but were more abundant at the old field pond (93 percent) than at the woodland pond (66 percent). Lizards outnumbered all other reptiles combined at both ponds (26 of 32 at woodland pond, 28 of 36 at old field pond).

The same six species (_Gastrophryne_ _carolinensis_, _Hyla_ _versicolor_ complex, _Rana_ _catesbeiana_, _Ambystoma_ _maculatum_, _R_. _sphenocephala_, and _Notophthalmus_ _viridescens_) occurred most frequently at each pond, accounting for 88 and 79 percent of the captures at woodland and old field ponds, respectively. But their relative importances at the two ponds differed (_A_. _maculatum_ dominating at the woodland pond, _G_. _carolinensis_ and _H_. _versicolor_ complex codominant at the old field pond). Outward movements outnumbered inward movements at both ponds (1.5 to 1 at woodland pond, 4 to 1 at old field pond), due primarily to egression of recently metamorphosed _A_. _maculatum_, _G_. _carolinensis_, and _H_. _versicolor_ complex. Overall, activity at both ponds decreased throughout the study period; the sharpest drops came in October when the mean minimum daily air temperature fell below 6° C. A marked dip in activity occurred at the woodland pond in August, involving a slowdown in _A_. _maculatum_ egression.

Results suggest the following: 1) similar herptile faunas utilize both pond types, but differences exist in the relative importance of species; 2) movement in relation to ponds is mainly outward during the period (summer and fall) due to egression of recently metamorphosed individuals; and 3) levels of activity decrease throughout the period, along with temperature.

The Breeding Birds of Forested Habitats of the Central Basin of Tennessee

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KEY WORDS: breeding birds, Central Basin, detectability, distribution, relative abundance

ABSTRACT

In the spring and summer of 1984, bird populations on 31 sites in the Central Basin of Tennessee were sampled using the Finnish line transect and variable circular plot methods. Sites sampled were chosen randomly and represent a wide range of forested habitats across the geographical breadth of the Central Basin. At least 1 individual of 105 species, 2 or more of 90 species, and 10 or more of 58 species were recorded. Sixty-eight species bred on or near the sites. Common species are examined in terms of their detectability, relative abundance, and distribution.

INTRODUCTION

In the spring and summer of 1984, the Ecological Services Division of the Tennessee Department of Conservation conducted a biological survey of selected forested tracts in the Central Basin of Tennessee. The objectives of this study were:

1. to search for high quality natural area sites;
2. to identify occurrences of rare plant and animal species, communities, and natural features;
3. to determine the distribution, frequency, and relative abundance of breeding bird species in forest habitats in the Central Basin;
4. to test hypotheses concerning relationships of certain bird species to particular forest

The first two objectives are broad goals of the Ecological Services Division in their natural resources inventory of the state's physiographic provinces. Discussion of the fourth objective is the subject of the paper by Hamel et al. (this symposium). The purpose of this paper is to present results of the third objective.

The Central Basin of Tennessee has long been the subject of ornithological investigation. Alexander Wilson first documented bird species in the area in 1810. The Tennessee Ornithological Society was founded in Nashville in 1915 and its members have since compiled bird records of the Central Basin through incidental observations, Breeding Birds Survey routes, Tennessee's Breeding Bird Atlas, and Christmas Bird Counts. One comprehensive checklist (Parmer 1985) summarizes these data.

Although the Central Basin has a rich ornithological history, this is the first systematic attempt to examine relative densities of breeding birds on a representative sample of forested sites in the Central Basin. These results provide baseline data on the natural communities of the area and will assist the Tennessee Department of Conservation in land use planning, and identification of high quality natural areas.

STUDY AREA AND METHODS

The Central, or Nashville, Basin occupies an area of approximately 13,000 square kilometers in parts of 22 counties in central Tennessee. DeSelm (1976) identified an Inner and an Outer Basin. The Inner Basin is approximately 168 km through a north-south axis and 65 km through an east-west axis. Vegetation is primarily cedar glade. The Outer Basin is found along the boundaries of the Highland Rim. Vegetation is primarily deciduous forest. The primary bedrock of the area is limestone of Ordovician Age. The Central Basin characteristically has shallow soils and is typically flat limestone glade country interspersed with knobs, sinkholes, and caves. The average elevation is 182-210 m; some knobs reach heights of 330-360 m (Miller 1974).

Sites were selected to represent a diversity of forest types across the geographic breadth of the Central Basin. To accomplish site selection, a random number generator (SAS, 1982) was used to generate 2500 random pairs of latitude and longitude coordinates. These were then plotted on USGS topographic quad sheets. Each site was screened against the following criteria:

1. natural forest
2. twenty years old or older
3. relatively homogeneous composition
4. eight ha or larger.

Other sites were chosen nonrandomly because of their well known natural area qualities. These two processes together yielded a set of 32 sites that sampled the breadth of the forest communities, and geographical extent of the Central Basin.

Vegetation measurements were made on 0.1 ha plots on 32 sites in the Central Basin. Diameter at breast height (dbh) was recorded for all trees with a dbh greater than 12.5 cm. A count was made of understory trees 2.5-12.5 cm dbh. Height and percent coverage of the herbaceous and shrub layers were estimated by visual assessment and clinometer on a 0.025 ha subplot. Presence or absence of canopy and subcanopy vegetation directly overhead was noted at points along a diagonal on the 0.1 ha plot to measure canopy closure. All of these measures supplied a general picture of vertical structure. Dominant species were also noted for each layer (Durham et al. 1985).

The Finnish line transect method (Jarvinen and Vaisanen 1975) and the variable circular plot method (Reynolds et al. 1980, Hamel 1984) were used to estimate the relative abundance of bird species. Transects were established on each of 31 sites. Transect azimuth and distance were chosen by visual assessment to best represent the site's characteristics. From two to five plots were selected randomly from a grid system on 26 of 31 sites for variable circular plot counts. Two visits were made to each site to estimate relative abundance of bird species. However, because of logistical constraints, both visits were made to a site within the same week. Ford sampled 29 sites, and Hamel sampled two.

RESULTS

Vegetation data for our study were collected from 102 plots on 32 sites. Three physiographic series were identified; broadleaf forest, mixed broadleaf-needleleaf forest, and limestone cedar glade. Broadleaf forests were characterized by dominant canopy species such as oak (*Quercus* sp.), hickory (*Carya* sp.), elm (*Ulmus* sp.), maple (*Acer* sp.), and ash (*Fraxinus* sp.). Mixed broadleaf-needleleaf forests were characterized by ash and red cedar (*Juniperus virginiana*). Red cedar often occurred in pure stands. Limestone cedar glades were characterized by two communities, with herbs, mosses, and grasses-forbs being major components. A detailed discussion of these physiographic series may be found in Pearsall et al. (1985) and Somers et al. (1986).

Bird counts were made on 61 transects on 31 sites, and on 177 variable circular plots on 26 of 31 sites, between 10 April and 30 June 1984. One site was sampled for vegetation but not for birds, due to time and logistical constraints. There were 5576 individual birds observed on transect counts, or an average of 91.4 individuals per count. At least 1 individual of 105 species, 2 or more of 90 species, and 10 or more of 58 species were observed. Important families represented were: warblers (27 species), woodpeckers (7 species), and vireos (6 species).

Sixty-eight species probably bred on or near the sites. The remaining 37 species were winter residents or transient species. Of the breeding species, 11 were warblers, 5 were woodpeckers, and 3 were vireos (appendix 1).

Transect data were analyzed by species detectability (conspicuousness), relative abundance, and frequency. Ten species were recorded an average of 2.7 or more times on each transect. These species ranged from 2.7 Summer Tanagers (scientific names appear in the appendix) per count to 8.7 Blue Jays per count. Twenty-two species were recorded an average of 2.6 or fewer times on transect counts; eight of those were transient species. Breeding residents occurring an average of 2.6 or fewer times per transect were Wood Duck (3), Turkey Vulture (1), Cooper's Hawk (1), American Woodcock (2), Great Horned Owl (1), Common Nighthawk (1), Chuck-will's-widow (2), Eastern Kingbird (1), Purple Martin (1), Rough-winged Swallow (1), Northern Mockingbird (1), Northern Parula (1), Yellow-throated Warbler (1), and American Redstart (1).

Density estimates are based on a series of calculations involving the number of individuals found and their distances from the transect line (Jarvinen and Vaisanen 1975). Ten species averaged more than about 10 pairs per 40 ha. Species with the highest densities included Summer Tanager with 24 pairs per km^2 and Carolina Chickadee with 55 pairs per km^2. Seven of the 10 species with estimated densities of 10 or more pairs per km^2 were also found on the list of species most often recorded. Examples of species with marked disparities between these two measures of bird populations are American Crow and Rufous-sided Towhee; although both were encountered 285 times in the study, the towhee's density was estimated to be 15 times greater than that of the crow.

Eleven species were found on at least 25 sites (80 percent of the sites) across the Central Basin. Species with the most widespread distribution ranged from Great Crested Flycatcher on 25 sites to Blue Jay and Tufted Titmouse on all 31 sites. Six of these species are also on the list of species with highest densities. Some species were spaced more evenly across the landscape than others; this is reflected in the differences between these two measures. Thus, 101 Brown-headed Cowbirds occupied 29 of 31 sites, while 206 Wood Thrushes occurred on 22 sites, and 144 Field Sparrows were found on 19 sites. The ten highest-ranking species by each measure are compared in table 1.

Eleven parulids were found that appeared to breed on or near the sites. Kentucky Warblers were the most common warbler, with 103 individuals recorded on 25 sites, or 17.4 pairs per km^2. Prairie Warblers were also common, but not as widespread as Kentucky Warblers, with 63 individuals occurring on 13 sites, or 14.5 pairs per km^2. The rarest breeding warbler was the Black-and white, found on a single site near a large sinkhole.

Northern Parulas were also rare, with only two observed, one on each of two sites. Ford had some difficulty distinguishing Kentucky Warbler songs from Ovenbird songs, so Ovenbird numbers have been omitted because of this uncertainty. However, Hamel followed up on several sites and observed Ovenbirds occurring on five sites.

Table 1. Species ranked by detectability, relative density, and distribution. Species are listed from highest to lowest, and are based on transect count results.

Detectability[1]	Relative density[2]	Distribution[3]
Blue Jay	Carolina Chickadee	Blue Jay
Northern Cardinal	Northern Cardinal	Tufted Titmouse
Tufted Titmouse	Red-eyed Vireo	American Crow
American Crow	Blue Jay	Northern Cardinal
Rufous-sided Towhee	Tufted Titmouse	Common Grackle
Red-bellied Woodpecker	Rufous-sided Towhee	Brown-headed Cowbird
Carolina Chickadee	Blue-gray Gnatcatcher	Red-bellied Woodpecker
Red-eyed Vireo	Indigo Bunting	Carolina Chickadee
Wood Thrush	Downy Woodpecker	Rufous-sided Towhee
Summer Tanager	Summer Tanager	Downy Woodpecker
		Great Crested Flycatcher

1 Detectability represents a species' conspicuousness, or how easy it is to detect in the forest (i.e. loud calls, etc.). This list represents average number of individuals per transect count and ranges from 8.7 Blue Jays per count to 2.7 Summer Tanagers per count.

2 Relative density estimates are based on a series of calculations involving the number of individuals found and their distances from the transect line. This list represents pairs per km^2 and ranges from Carolina Chickadee with 55 pairs per km^2, to Summer Tanager with 24 pairs per km^2.

3 Distribution is the number of sites the species occurred on out of a possible 31 sites. This list ranges from Blue Jay and Tufted Titmouse, found on all 31 sites to Great Crested Flycatcher, found on 25 of 31 sites.

DISCUSSION

DeSelm (1976) recognized five major vegetation categories in the Central Basin; cedar glade and barrens complex, oak forest, mixed deciduous forest, wetlands, and secondary forests. On privately owned lands these habitats characteristically occupy three topographic positions; steep ridges or valleys, tops of knobs, and limestone flats (cedar glades). The topographic relief of these areas makes them generally unsuitable for agriculture or urban development. Vegetative communities on ridges and knobs are frequently stressed by logging or grazing pressures, or both. Although soils in cedar forests are too thin to support crop production, the land is often grazed by domestic goats. Forested lands not occupying these topographic positions are usually abandoned agricultural lands with secondary forest.

Forested public lands in the Central Basin are managed by city, state, and federal governments for many purposes. Generally, these tracts are larger and exhibit a higher degree of diversity than private woodlots. Nine sites in this study were on public lands. These lands included Cedars of Lebanon State Park and Forest, Warner Parks, and Radnor Lake State Natural Area.

On an individual species basis, there were no correlations found when comparing bird species densities with vegetation measurements. We propose two explanations for this. Logistics required that sites be visited for bird censuses twice within the same week. This presented serious problems in relative abundance calculations because of fluctuations in transient species' populations and individual species' nesting patterns. Also, sites were, on average, small. This resulted in some counts being confounded by edge species heard from interior forest counts on some sites.

Nonetheless, breeding bird species' abundance, distribution, and species-site relationships in forested habitats of the Central Basin do reflect overall landscape patterns. Species consistently found in cedar glade communities included White-eyed Vireo, Prairie Warbler, Indigo Bunting, Rufous-sided Towhee, and Field Sparrow. In deciduous forests occupying steep ridges or tops of knobs, species consistently found included Yellow-billed Cuckoo, Red-bellied Woodpecker, Tufted Titmouse, and Summer Tanager. Discussion of community associations and predictions can be found in Hamel et al. (this symposium).

We discuss here 10 individual bird species encountered during this study. This discussion treats four species for which our data coincide with general ideas about species distribution and abundance, three species that do not fit general ideas about species distribution and abundance, and three species that are known to occur in the Central Basin but were not encountered during our study.

Prairie Warblers occurred commonly in our sample, second among warblers after Kentucky Warbler. Peaks in Prairie Warbler densities seem to coincide with the Inner Basin, especially Rutherford and Wilson counties, where cedar glade forest dominates. These two species occurred together on 10 sites. The Prairie (but not Kentucky) Warbler is also a dominant species in glade habitats of the Ozark Plateau (Evans and Kirkman 1981). Cerulean warblers also occurred in our study, though only on sites in the Outer Basin. Those areas presented more variable topography and bigger trees. Two of those sites were on public lands (Warner Parks). Hairy Woodpeckers occurred widely across the Central Basin, with higher densities in the deciduous forest woodlots than in the cedar glades. Pileated Woodpeckers also occurred widely across the Central Basin, but densities were higher on public lands than on private lands. The distribution and relative abundance patterns of the four species discussed above, as revealed in our data, reflect commonly held views (Bierly 1980, Parmer 1985).

Discrepancies occurred, however, for at least three species. Ovenbirds and Worm-eating Warblers are generally thought to occur only on the western edge of the Central Basin, and Broad-winged Hawks only in the Outer Basin (Bierly 1980, Parmer 1985). We found Ovenbirds on 5 sites and Worm-eating Warblers on 11 sites across the Basin. Broad-winged Hawks were found on four sites. All three are area sensitive species. Their occurrence in broader distributions than expected for the Central Basin may reflect public land distribution and tract size.

At least three species that are known to occur in the Central Basin were not encountered on transects. Louisiana Waterthrushes occur near streamsides in forests, and are considered fairly common across Tennessee (Bierly 1980). Possibly because of the clearing of land on sloping hillsides and the resultant treeless creek banks and margins, and heavy cattle use of streams, this species was not encountered on our transects. Likewise, Blue Grosbeaks are expanding their range north and have experienced significant increases in populations since 1965 (Robbins et al. 1986). Evans and Kirkman (1981) list Blue Grosbeak as common on similar habitats in Arkansas, but the species did not occur on transects in our study. We do not know why. Finally, Lark Sparrows historically occurred on sites like this and are known to occur now in small populations in the Central Basin (Ruth McMillian, pers. comm.), though none were found on our sites. This may be due to the fact that the species has experienced range-wide population declines (Robbins et al. 1986) resulting from grazing, early hay cutting, or plowing. Tennessee has listed the species as In Need of Management (Eagar and Hatcher 1980).

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Appendix 1. Species encountered on transects and/or variable circular plot counts in the Central Basin of Tennessee, 10 April-30 June 1984, showing number of sites on which each species was recorded, number of individuals on transect counts, density estimates of selected species, and residency status

	Number of sites on which recorded $\geq$ once[1]		Total number of individuals on all transects		
SPECIES	TRAN[2]	VCP[3]	TRAN	Density Estimate (pairs per km^2)	Residency Status
Wood Duck (*Aix sponsa*)	1	0	3		PR[4]
Black Vulture (*Coragyps atratus*)	4	7	4		PR
Turkey Vulture (*Cathartes aura*)	1	3	1		PR
Cooper's Hawk (*Accipiter cooperii*)	1	0	1		PR
Broad-winged Hawk (*Buteo platypterus*)	3	2	4		PR
Red-tailed Hawk (*Buteo jamaicensis*)	4	2	4		PR
Wild Turkey (*Meleagris gallopavo*)	0	1	0		PR
Northern Bobwhite (*Colinus virginianus*)	18	19	53	1.8 $\pm$ .4[7]	PR
Killdeer (*Charadius vociferus*)	0	1	0		PR
American Woodcock (*Scolopax minor*)	1	0	2		PR
Mourning Dove (*Zenaida macroura*)	17	17	66	1.8 $\pm$ .8	PR
Yellow-billed Cuckoo (*Coccyzus americanus*)	17	19	143	10.7 $\pm$ 4.3	5/1-SR[5]
Great Horned Owl (*Bubo virginianus*)	1	2	1	.6 $\pm$ .9	PR

Appendix 1. (Continued)

	Number of sites on which recorded ≥ once		Total number of individuals on all transcects		
SPECIES	TRAN	VCP	TRAN	Density Estimate (pairs per km^2)	Residency Status
Barred Owl (*Strix varia*)	2	1	1		PR
Common Nighthawk (*Chordeiles minor*)	1	0	1		5/10-SR
Chuck-will's-widow (*Caprimulgus carolinensis*)	1	1	2	1.3 ± 0.0	4/25-SR
Chimney Swift (*Chaetura pelagica*)	10	2	13		4/11-SR
Ruby-throated Hummingbird (*Archilochus colubris*)	0	2	0		5/1-SR
Belted Kingfisher (*Ceryle alcyon*)	0	1	0		PR
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	1	3	1		PR
Red-bellied Woodpecker (*M. carolinus*)	28	24	271	20.2 ± 7.9	PR
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	-	-	4		WR[6]-4/11
Downy Woodpecker (*Picoides pubescens*)	26	20	101	23.3 ± 10.3	PR
Hairy Woodpecker (*P. villosus*)	14	10	18	5.9 ± 4.8	PR
Northern Flicker (*Colaptes auratus*)	22	19	61	.6 ± .4	PR
Pileated Woodpecker (*Dryocopus pileatus*)	24	19	58	.3 ± .2	PR
Eastern Wood Pewee (*Contopus virens*)	15	12	65	4.1 ± 1.4	5/1-SR

Appendix 1. (Continued)

	Number of sites on which recorded ≥ once		Total number of individuals on all transects		
SPECIES	TRAN	VCP	TRAN	Density Estimate (pairs per km^2)	Residency Status
Yellow-bellied Flycatcher (*Empidonax flaviventris*)	-	-	1		5/11-5/11
Acadian Flycatcher (*E. virescens*)	4	2	23	3.2 ± 1.4	5/1-SR
Eastern Phoebe (*Sayornis phoebe*)	8	2	9	1.9 ± 2.2	PR
Great Crested Flycatcher (*Myiarchus crinitus*)	25	22	110	12.5 ± 6.0	4/13-SR
Eastern Kingbird (*Tyrannus tryannus*)	1	0	1		4/30-SR
Purple Martin (*Progne subis*)	1	2	1	.6 ± .9	4/10-SR
Northern Rough-winged Swallow (*Stelgidopteryx serripennis*)	1	1	1		5/13-SR
Blue Jay (*Cyanocitta cristata*)	31	26	533	35.0 ± 8.4	PR
American Crow (*Corvus brachyrhynchos*)	30	26	285	1.8 ± .6	PR
Carolina Chickadee (*Parus carolinensis*)	28	24	269	65.1 ± 22.5	PR
Tufted Titmouse (*P. bicolor*)	31	26	512	31.9 ± 7.9	PR
White-breasted Nuthatch (*Sitta carolinensis*)	12	8	29	3.0 ± 2.2	PR
Brown Creeper (*Certhia americana*)	-	-	5		WR-4/13
Carolina Wren (*Thryothorus ludovicianus*)	25	16	61	6.0 ± 3.3	PR

Appendix 1. (Continued)

SPECIES	Number of sites on which recorded ≥ once: TRAN	VCP	Total number of individuals on all transects: TRAN	Density Estimate (pairs per km^2)	Residency Status
Winter Wren (*Troglodytes troglodytes*)	–	–	1		WR-4/20
Golden-crowned Kinglet (*Regulus satrapa*)	–	–	1		WR-4/20
Ruby-crowned Kinglet (*R. calendula*)	–	–	6		WR-4/13
Blue-gray Gnatcatcher (*Polioptila caerulea*)	17	10	119	26.8 ± 13.4	4/10-SR
Veery (*Catharus fuscescens*)	–	–	5		5/1-5/17
Swainson's Thrush (*C. ustulatus*)	–	–	16		4/20-5/18
Hermit Thrush (*C. guttatus*)	–	–	0		WR-4/10
Wood Thrush (*Hylochichla mustelina*)	22	17	206	21.9 ± 7.3	4/24-SR
American Robin (*Turdus migratorius*)	11	6	36	6.2 ± 4.0	PR
Gray Catbird (*Dumetella carolinensis*)	11	4	21	2.8 ± 2.1	PR
Northern Mockingbird (*Mimus polyglottos*)	1	1	1		PR
Brown Thrasher (*Toxostoma rufum*)	16	14	35	6.0 ± 5.7	PR
Cedar Waxwing (*Bombycilla cedrorum*)	0	1	0		PR
European Starling (*Sturnus vulgaris*)	4	2	5		PR

Appendix 1. (Continued)

	Number of sites on which recorded ≥ once		Total number of individuals on all transects		
SPECIES	TRAN	VCP	TRAN	Density Estimate (pairs per km^2)	Residency Status
White-eyed Vireo (*Vireo griseus*)	16	10	43	4.9 ± 2.8	4/23-SR
Solitary Vireo (*V. solitarius*)	-	-	6		4/11-5/23
Yellow-throated Vireo (*V. flavifrons*)	5	1	11	.8 ± .7	4/23-SR
Warbling Vireo (*V. gilvus*)	0	1	1		4/18-SR
Philadelphia Vireo (*V. philadelphicus*)	-	-	4		5/10-5/15
Red-eyed Vireo (*V. olivaceus*)	23	19	234	40.3 ± 10.9	4/25-SR
Blue-winged Warbler (*Vermivora pinus*)	2	2	4	.4 ± .3	5/1-SR
Tennessee Warbler (*V. peregrinus*)	-	-	38		4/11-5/21
Nashville Warbler (*V. ruficapilla*)	-	-	19		5/1-5/10
Northern Parula (*Parula americana*)	1	1	2	2.6 ± 1.3	5/1-SR
Yellow Warbler (*Dendroica petechia*)	-	-	3		5/3-SR
Chestnut-sided Warbler (*D. pensylvanica*)	-	-	9		5/1-5/14
Magnolia Warbler (*D. magnolia*)	-	-	7		5/3-5/22
Cape May Warbler (*D. tigrina*)	-	-	1		4/24-5/11

Appendix 1. (Continued)

SPECIES	Number of sites on which recorded ≥ once: TRAN	VCP	Total number of individuals on all transects: TRAN	Density Estimate (pairs per km^2)	Residency Status
Yellow-rumped Warbler (*D. coronata*)	-	-	29		WR-5/14
Black-throated Green Warbler (*D. virens*)	-	-	21		4/11-5/1
Blackburnian Warbler (*D. fusca*)	-	-	4		5/1-5/24
Yellow-throated Warbler (*D. dominica*)	-	-	1		4/25-SR
Prairie Warbler (*D. discolor*)	11	7	63	14.5 ± 5.3	4/12-SR
Palm Warbler (*D. palmarum*)	-	-	3		4/24-5/24
Bay-breasted Warbler (*D. castanea*)	-	-	9		5/9-5/17
Blackpoll Warbler (*D. striata*)	-	-	9		4/23-5/16
Cerulean Warbler (*D. cerulea*)	3	0	9		6/1-SR
Black-and-white Warbler (*Mniotilta varia*)	1	1	32	1.7 ± 0.0	4/10-SR
American Redstart (*Setophaga ruticilla*)	-	-	2		5/19-5/24
Worm-eating Warbler (*Helmitheros vermivorus*)	-	-	12		4/10-SR
Ovenbird (*Seiurus aurocapillus*)	16	16	16	14.2 ± 5.9	4/20-SR
Northern Waterthrush (*S. noveboracensis*)	-	-	0		5/3-5/3

Appendix 1. (Continued)

SPECIES	Number of sites on which recorded ≥ once: TRAN	VCP	Total number of individuals on all transects: TRAN	Density Estimate (pairs per km^2)	Residency Status
Kentucky Warbler (*Oporornis formosus*)	19	16	103	17.4 ± 5.8	4/10-SR
Common Yellowthroat (*Geothlypis trichas*)	3	1	4		4/23-SR
Hooded Warbler (*Wilsonia citrina*)	3	4	13	1.2 ± .7	5/3-SR
Canada Warbler (*W. canadensis*)	-	-	3		5/9-5/16
Yellow-breasted Chat (*Icteria virens*)	8	9	23	3.9 ± 3.0	4/30-SR
Summer Tanager (*Piranga rubra*)	22	21	169	26.7 ± 6.8	4/23-SR
Scarlet Tanager (*P. olivacea*)	13	12	36	8.4 ± 6.1	4/23-SR
Northern Cardinal (*Cardinalis cardinalis*)	29	24	532	49.5 ± 13.0	PR
Rose-breasted Grosbeak (*Pheucticus ludovicianus*)	-	-	13		4/18-5/17
Indigo Bunting (*Passerina cyanea*)	21	20	137	33.8 ± 15.9	5/1-SR
Rufous-sided Towhee (*Pipilo erythrophthalmus*)	28	23	285	31.1 ± 12.2	PR
Chipping Sparrow (*Spizella passerina*)	5	0	5	.3 ± .4	PR
Field Sparrow (*S. pusilla*)	19	17	144	10.1 ± 3.1	PR
White-throated Sparrow (*Zonotrichia albicollis*)	-	-	9		WR-5/3

Appendix 1. (Continued)

	Number of sites on which recorded ≥ once		Total number of individuals on all transects		
SPECIES	TRAN	VCP	TRAN	Density Estimate (pairs per km^2)	Residency Status
Red-winged Blackbird (*Agelaius phoeniceus*)	-	-	6		PR
Eastern Meadowlark (*Sturnella magna*)	2	3	4		PR
Common Grackle (*Quiscalus quiscula*)	29	26	134		PR
Brown-headed Cowbird (*Molothrus ater*)	29	24	101	20.5 ± 8.6	PR
Northern Oriole (*Icterus galbula*)	1	-	11	1.4 ± 2.3	5/1-SR
Purple Finch (*Carpodacus purpureus*)	-	-	0		WR-4/19
American Goldfinch (*Carduelis tristis*)	18	21	48	4.0 ± 3.5	PR
Evening Grosbeak (*Coccothraustes vespertinus*)	-	-	14		WR-5/4

[1] Number of sites on which found not included for transient species or winter residents. Density estimates not available for some species.
[2] TRAN - transect count (possible 31 sites)
[3] VCP - variable circular plot (possible 26 sites)
[4] PR - Permanent resident
[5] SR - Summer resident
[6] WR - Winter resident
[7] ± - 95 percent confidence limits

Model Predictions of Bird Community Composition in Middle Tennessee

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KEY WORDS: Central Basin, forest type, habitat suitability landscape scale, Mixed Mesophytic forest, oak-hickory, red cedar, stand condition class, vegetation structure

ABSTRACT

Vegetation measurements from 31 study sites of Ford and Hamel (this symposium) were used to assign those sites to cells of several vegetation classification schemes for which predictions of bird community compositions have been published or summarized. Observed and predicted bird community compositions were compared for the following: two systems that predict species occurrence on the basis of vegetation type, one summary of published empirical census data, one system that predicts individual species occurrence from a combination of habitat factors, and several additional empirical and prediction data sets for mature oak-hickory forest. Examination of the comparisons revealed areas in which each system could be improved, as well as species for which no system was adequate. Among the latter was Prairie Warbler (Dendroica discolor), one of the most abundant parulids in middle Tennessee. The result is a cautionary tale about some of the pitfalls of experimental vs. descriptive natural

history, especially when land management decisions are involved.

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INTRODUCTION

The concept that a knowledgeable naturalist or ornithologist can take a look at a particular habitat or location and prepare a list of the birds that should occur in the site is a commonplace one. If true, the concept is a major underpinning to the possibility of predicting the occurrence of individual species, the general composition of avian communities, and hence to the identification of areas worthy of protection or to the identification of desired management alternatives for particular tracts of land. A major symposium was recently devoted to this and related issues (Verner et al. 1986). Other attempts to identify community assembly rules have also been made (Haefner 1981).

The Ecological Services Division of the Tennessee Department of Conservation is responsible for identifying significant natural areas in Tennessee, for enacting protection for rare plants and plant communities, and for assisting the Tennessee Wildlife Resources Agency in its efforts to protect the rare animals of the state. A major thrust of the research program of the Division has been to examine physiographic provinces of Tennessee, to evaluate lands for significance as natural areas, and to examine relationships of wildlife communities, particularly bird communities, to plant communities.

The examination of the natural communities of the Central Basin (Pearsall et al. 1985, Somers et al. 1986, Ford and Hamel this symposium) provided an extensive set of bird community composition and vegetative community data. Our purpose here is to compare the observed composition of the breeding bird communities in the Central Basin with hypothetical and empirical data sets from the region and outside. We evaluate the performance of these other data sets as predictors of the bird community composition of forested sites in the Central Basin. Results of tests permit comparison of the predictor sets in terms of success and surprise (defined below) rates; and allow examination of assumptions, strategies of prediction, pitfalls, and expectations of successful performance of various predictive models of bird community composition.

METHODS

Predictions of bird community composition involved three distinct steps. First, we identified candidate prediction data sets. Second, we assigned Central Basin study sites to appropriate, or apparently appropriate, cells in the vegetative community classification scheme utilized by each prediction data set. Third, we extracted the bird lists for the appropriate cells of the vegetation scheme from the candidate prediction data sets.

We selected four synthetic models of bird community composition and four empirical data sets. The models were those designed for the (1) southern Atlantic Coastal Plain (Hamel et al. 1982), (2) southeastern United States (Dickson et al. 1980), (3) Ozarks (Evans and Kirkman 1981), and (4) Central Basin of Tennessee (Pearsall et al. 1985). We chose not to use the model of DeGraaf et al. (1980) because the region of interest in that model, the northeastern United States, does not include Tennessee. Empirical data sets for mature oak-hickory forest were taken from studies in Arkansas (Wooten 1981), Kansas (Cink and Boyd 1979, 1981; Boyd and Cink 1980, Boyd et al. 1982), South Carolina (Hamel 1984, Hamel et al. 1986), and the southern Atlantic Coastal Plain (LeGrand and Hamel 1980). Each of the above models and empirical data sets presents a list of predicted (or observed) species for the appropriate vegetation type. The empirical data sets present frequencies and densities for species on the list. One predictor set (Hamel et al. 1982) further groups species according to proposed habitat suitabilities.

A final predictive model is one first proposed by LeGrand and Hamel (1980). This model predicts occurrence of individual species on the basis of the following five-factor equation:

$$S=\{FT \times SCC \times [(PC+VC+GLU)/3]\}^{1/3}, \text{ where}$$

S = Suitability of Occurrence in Habitat
FT = Forest Type
SCC = Stand Condition Class
PC = Physiographic Class
VC = Vegetative Concealment
GLU = Ground Land Use,

in which the values for factors in the equation are proposed relative suitabilities of the forest type, etc., observed on a particular study site. Suitabilities are expressed on a three step scale as marginal, suitable, or optimal for occurrence of the species, in fashion identical to that of Hamel et al. (1982).

Evaluation of the predicted vs. observed data sets involved several further steps. First, bird community observations were summarized into a set of frequency of occurrence data by species for each cell of each prediction scheme used. We chose frequency of occurrence rather than abundance measures of species occurrence because interpretation of frequency data does not require accounting for the many intervening variables inherent in interpretation of density transformations of census data (Ralph and Scott 1981). We used data on the combined occurrence of species observed on the sites either on transect counts, point counts, or otherwise observed on the sites (Ford and Hamel this symposium), with the following exceptions: obvious transients, species seen only passing overhead, and American Goldfinches (Carduelis tristis) were excluded. These adjustments were necessitated by the early start of fieldwork when transients were still moving through on their way north, the lack of actual habitat use by "passing" species, and the late commencement of breeding by goldfinches. On several sites accipiters of undetermined species were observed. We assigned these to Copper's Hawk (Accipiter cooperii) for purposes of evaluating predictions; this means that possible occurrence of Sharp-shinned Hawk (A. striatus) was not evaluated. For the purposes of this work, we compared predicted and observed data at the scale of the vegetation classification cell rather than at the scale of the individual study site. Further work at the finer scale is needed.

Second, predicted lists were adjusted to exclude those species that do not occur as breeding birds in the Central Basin of Tennessee.

Third, comparison of predicted vs. observed occurrence resulted in four possible outcomes for each species in each vegetation type (1) predicted and found--a "hit," (2) predicted but not found--a "miss," (3) found but not predicted--a "surprise," or (4) neither predicted or found. We ignored category (4) because of the difficulty involved in determining the full species pool for all prediction sets. Each of the other categories was treated as follows: (1) success rate was the proportion of predicted species that were found and (2) surprise rate was the proportion of observed species that were not predicted. In this sense, the more effective models simultaneously maximized success rate and minimized surprise rate. For comparing the models we also calculated accuracy rate as successes/(successes + surprises + misses).

Fourth, in the case of one vegetation type--mature or sawtimber oak-hickory forest (called Hardwood forest in Pearsall et al. 1985)--several further examinations were possible, for 12 of the study sites fell into this category. We compared frequency of occurrence by suitability prediction of Hamel et al. (1982), and compared frequency of occurrence of individual species in the Tennessee Central Basin to that in Kansas and South Carolina oak-hickory forests.

Finally, we examined patterns of success vs. surprise rates for species with low success rates for a subset of predictive models. We proposed explanations for these patterns in terms of sampling error, in terms of patterns of forest distribution in the Central Basin, in terms of differences between Central Basin forest communities and those of areas for which predictor sets were derived, or in terms of differences in the habitat distributions of the species between regions.

RESULTS

Success rates calculated over 24 prediction sets for 12 vegetative communities ranged from 0.41 to 0.93 (table 1), with a median of 0.71. Surprise rates ranged from 0.09 to 0.58, with a median of 0.25. Mean success, surprise, and accuracy rated were calculated for three prediction schemes (LeGrand and Hamel 1980, Hamel et al. 1982, and Pearsall et al. 1985). Mean success rated ranged from 0.57 for Pearsall et al. (1985) to 0.78 for LeGrand and Hamel (1980). When values were excluded for vegetation types represented by only single study sites, mean success rates ranged from 0.62 (Pearsall et al. 1985) to 0.76 (LeGrand and Hamel 1980). Mean surprise rates for prediction schemes ranged from 0.28 (Pearsall et al. 1985) to 0.31 (LeGrand and Hamel 1980). When values were excluded for vegetation types represented by only single study sites, mean surprise rates for all three schemes were 0.20.

Table 1. Comparison of predicted and observed bird community composition of selected vegetation types of the Central Basin of Tennessee

Source of Prediction Vegetation Type[1]	Sample Sites	 Species	Success Rate	Surprise Rate	Accuracy Rate
LeGrand and Hamel 1980 Empirical Summary					
Elm-Ash-Cottonwood Forest					
Poletimber	1	66	0.72	0.54	0.39
Cove Hardwood Forest					
Sawtimber	8	72	0.52	0.12	0.49
Oak-Hickory Forest					
Poletimber	5	74	0.82	0.28	0.62
Oak-Hickory Forest					
Sawtimber	12	89	0.93	0.19	0.76
Mixed Pine-Hardwood Forest					
Sawtimber	4	69	0.77	0.21	0.64
Loblolly-Shortleaf Pine Forest					
Poletimber	1	55	0.90	0.50	0.47

Table 1. (Continued)

Source of prediction Vegetation Type[1]	Sample Sites	Sample Species	Success Rate	Surprise Rate	Accuracy Rate
Hamel et al. 1982					
Elm-Ash-Cottonwood Forest Poletimber	1	70	0.69	0.58	0.36
Cove Hardwood Forest Sawtimber	8	74	0.64	0.14	0.58
Oak-Hickory Forest Poletimber	5	69	0.71	0.24	0.58
Oak-Hickory Forest Sawtimber	12	82	0.77	0.14	0.68
Mixed Pine-Hardwood Forest Sawtimber	4	74	0.82	0.27	0.64
Loblolly-Shortleaf Pine Forest Poletimber	1	46	0.69	0.46	0.44
Bridges et al. 1985					
Mixed Mesophytic Forest Young Stand	1	48	0.50	0.34	0.40
Mixed Mesophytic Forest Mature Stand	8	74	0.73	0.12	0.66
Hardwood Forest Young Stand	5	71	0.47	0.32	0.38
Hardwood Forest Mature Stand	12	79	0.62	0.12	0.57
Mixed Hardwood-Redcedar Forest Mature Stand	4	70	0.67	0.25	0.54
Redcedar Forest Young Stand	1	41	0.41	0.50	0.29
Evans and Kirkman 1981					
Oak-Hickory Forest Old Growth Stand	12	83	0.82	0.37	0.55
Dickson et al. 1980					
Oak-Hickory Forest Sawtimber	12	78	0.86	0.56	0.41
Wooten 1981, empirical findings					
Oak-Hickory Forest Sawtimber	12	78	0.48	0.12	0.45

Table 1. (Continued)

Source of prediction Vegetation Type[1]	Sample Sites	Sample Species	Success Rate	Surprise Rate	Accuracy Rate
Kansas[2] empirical data					
Oak-Hickory Forest					
Sawtimber	12	82	0.71	0.15	0.63
Hamel 1984, empirical data					
Oak-Hickory Forest					
Sawtimber	12	78	0.68	0.09	0.64
This Study, Species by Species Predictions					
Variety of Combinations of Identified Characteristics	31	30-78	0.58	0.37	0.40

[1] Vegetation types are those utilized by the sources of the predictions. Study sites in this study were assigned to appropriate vegetation types on the basis of basal areas of canopy trees.
[2] Kansas data are those of Boyd and Cink, 1980; Cink and Boyd, 1979, 1981; and Boyd et al. 1982.

The prediction of occurrence of species by relative habitat suitability class for sawtimber oak-hickory forest (Hamel et al. 1982) indicated that surprise species occurred at frequencies equivalent to those of species predicted to be in marginal habitat, that species predicted to be in suitable habitat occurred with a higher average frequency, and species predicted to be in optimal habitat occurred at the highest average frequency. These differences were significant at $P = 0.05$ (figure 1).

Relative frequencies of species' occurrences in sawtimber oak-hickory forest in this study and the empirical data sets from Kansas (Cink and Boyd 1979, 1981; Boyd and Cink 1980; Boyd et al. 1982) and South Carolina (Hamel 1984) were compared with correlation analysis. Frequencies in South Carolina and Tennessee were most closely correlated ($r = 0.88$, $n = 78$, $P < 0.001$), followed by those in Tennessee and Kansas ($r = 0.63$, $n = 82$, $P < 0.001$). Still highly correlated ($r = 0.56$, $n = 72$, $P < 0.001$), species frequencies in South Carolina and Kansas were less correlated than those between the Tennessee study sites and those east and west of the Central Basin.

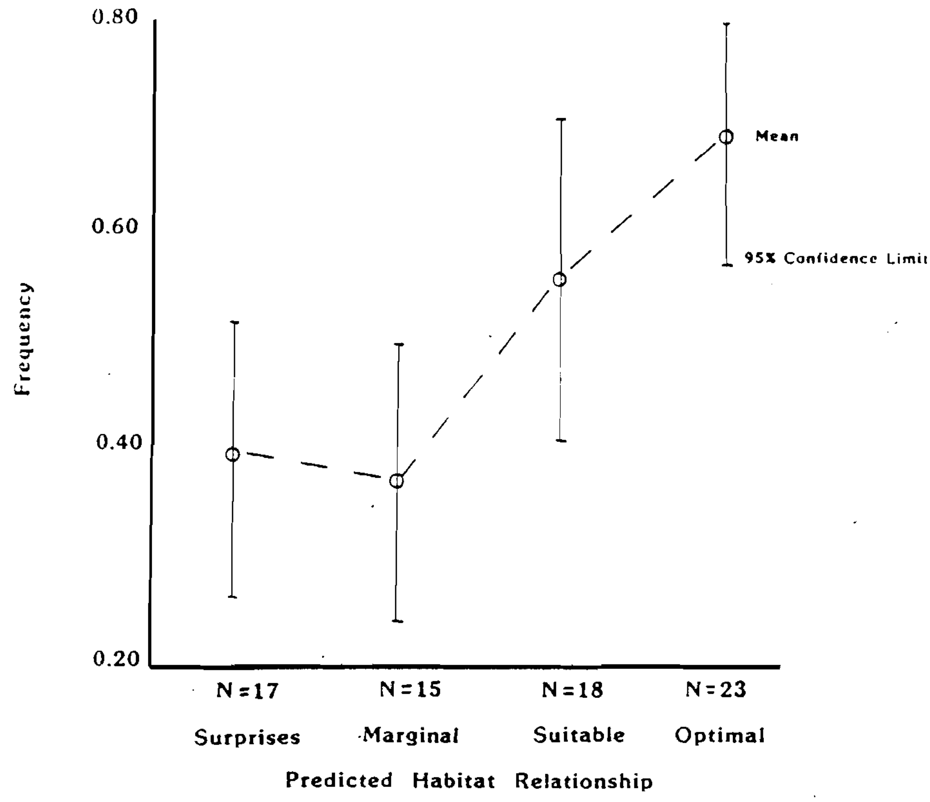

Figure 1. Mean frequency of occurrence of species on 12 study sites in mature oak-hickory forest in the Central Basin of Tennessee. Species are grouped according to the predicted habitat suitability (Hamel et al. 1982)

Comparison of four prediction data sets with four empirical data sets for 12 study sites in mature oak-hickory forest indicated that success rates were higher in the predictive data sets (mean = 0.77 vs. 0.70), but that surprise rates were much lower (mean = 0.14 vs. 0.30) and accuracy rates higher (mean = 0.62 vs. 0.55) in the empirical data sets. The sample sizes of data sets are too small for meaningful statistical comparison of these results.

Prediction of species occurrence from five general habitat factors resulted in 16 different combinations of the five factors among the 31 study sites. Sample sizes for each habitat combination were low, with a maximum of four sites in each of two habitat categories. Success rate (mean = 0.58 +/-

0.02, median 0.62) and accuracy rate (mean = 0.40 +/- 0.02, median 0.45) were lower, and surprise rate higher (mean = 0.37 +/- 0.06, median 0.34) than those for the other models.

Of 105 species predicted or observed in the Central Basin: (a) 44 were considered hits in fewer than half of at least five prediction/observation combinations; (b) 14 species were considered hits less than half of the time on samples of fewer than five; (c) 29 species occurred as surprises much more often than as misses, regardless of membership in category (a) above. Categories (a) and (c) comprise species whose failure to occur or to be predicted provide raw material for future improvements of model predictions of the birds of the Central Basin (table 2).

Table 2. Species for which sample size exceeded five prediction sets and either success rate was below 50 percent or surprises outnumbered misses.

Species	Sample Size	Number Misses	Number Surprises	Explanation
Green-backed Heron *Butorides striatus*	10	10	0	Unanticipated Traits/Needs
Black-crowned Night-Heron *Nycticorax nycticorax*	7	7	0	Unanticipated Traits/Needs
Wood Duck *Aix sponsa*	13	4	6	Unanticipated Traits/Needs
Black Vulture *Coragyps atratus*	20	2	10	Unanticipated Traits/Needs
Turkey Vulture *Cathartes aura*	21	0	5	?
Sharp-skinned Hawk *Accipiter striatus*	7	7	0	?
Cooper's Hawk *A. cooperii*	17	5	5	?
Red-shouldered Hawk *Buteo lineatus*	8	8	0	Forest Interior Species
Ruffed Grouse *Bonasa umbellus*	8	8	0	Unanticipated Traits/Needs
Wild Turkey *Meleagris gallopavo*	14	14	0	Forest Interior Species
Northern Bobwhite *Colinus virginianus*	21	0	13	Edge Species
Killdeer *Charadrius vociferus*	8	0	8	Edge Species

Table 2. (Continued)

Species	Sample Size	Number Misses	Number Surprises	Explanation
American Woodcock *Scolopax minor*	13	11	1	Unanticipated Traits/Needs
Mourning Dove *Zenaida macroura*	21	0	6	?
Common Nighthawk *Chordeiles minor*	11	0	9	Unanticipated Traits/Needs
Chimney Swift *Chaetura pelagica*	19	1	9	?
Ruby-throated Hummingbird *Archilochus colubris*	20	14	0	Unanticipated Traits/Needs
Belted Kingfisher *Ceryle alcyon*	9	3	4	Unanticipated Traits/Needs
Red-headed Woodpecker *Melanerpes erythrocephalus*	16	4	6	?
Red-bellied Woodpecker *M. carolinus*	20	1	5	?
Acadian Flycatcher *Empidonax virescens*	15	6	2	Forest Interior Species
Eastern Phoebe *Sayornis phoebe*	18	2	9	Edge Species
Eastern Kingbird *Tyrannus tyrannus*	6	3	3	Edge Species
Purple Martin *Progne subis*	13	1	8	?
Rough-winged Swallow *Stelgidopteryx serripennis*	7	1	4	?
Barn Swallow *Hirundo rustica*	9	2	4	?
Gray Catbird *Dumetella carolinensis*	21	1	8	?
Northern Mockingbird *Mimus polyglottos*	14	2	9	Edge Species
Brown Trasher *Toxostoma rufum*	21	0	9	?
Cedar Waxwing *Bombycilla cedrorum*	11	5	4	?
European Starling *Sturnus vulgaris*	16	1	7	Edge Species
White-eyed Vireo *Vireo griseus*	21	0	13	Edge Species
Blue-winged Warbler *Vermivora pinus*	9	0	8	Unanticipated Traits/Needs

Table 2. (Continued)

Species	Sample Size	Number Misses	Number Surprises	Explanation
Northern Parula *Parula americana*	14	11	0	Forest Interior Species
Yellow Warbler *Dendroica petechia*	13	4	8	Unanticipated Traits/Needs
Yellow-throated Warbler *D. dominica*	14	8	3	Forest Interior Species
Prairie Warbler *D. discolor*	20	0	15	Edge Species
Cerulean Warbler *D. cerulea*	7	4	1	Forest Interior Species
American Redstart *Setophaga ruticilla*	16	7	3	Forest Interior Species
Louisiana Waterthrush *Seiurus motacilla*	13	4	3	Unanticipated Traits/Needs
Kentucky Warbler *Oporornis formosus*	19	1	5	Unanticipated Traits/Needs
Common Yellowthroat *Geothlypis trichas*	15	2	10	Edge Species
Hooded Warbler *Wilsonia citrina*	17	8	2	Forest Interior Species
Yellow-breasted Chat *Icteria Virens*	18	1	13	Edge Species
Indigo Bunting *Passerina cyanea*	21	0	8	Edge Species
Rufous-sided Towhee *Pipilo erythrophthalmus*	21	0	6	Edge Species
Chipping Sparrow *Spizella passerina*	16	2	8	Edge Species
Field Sparrow *S. pusilla*	21	0	17	Edge Species
Red-winged Blackbird *Agelaius phoeniceus*	13	4	7	Edge Species
Eastern Meadowlark *Sturnella magna*	6	0	6	Edge Species
Common Grackle *Quiscalus quiscula*	21	0	6	Edge Species
Orchard Oriole *Icterus spurius*	9	3	4	?
Northern Oriole *I. galbula*	16	1	9	Unanticipated Traits/Needs
American Goldfinch *Carduelis tristis*	8	8	0	Unanticipated Traits/Needs

DISCUSSION

The majority of prediction sets available for examination in this study were organized as lists of species either observed (in empirical data sets) or predicted to occur (in synthetic data sets). These models provide a list of species for a predetermined, invariant habitat type. Such a scheme that performed at median rates was able to predict 77 percent of species that were observed, and the median vegetation type included only 71 percent of the species that were predicted. These success rates are higher, and surprise rates lower, than would obtain in predictions for individual study sites with their concomitantly shorter species lists.

We tested here, for the first time, an alternative formulation of a community model that associated each species with a small number of large-scale habitat factors and compiled predicted lists from measures of the habitat on individual study sites. This latter model performed about as well as one of the standard models (Pearsall et al. 1985), but not nearly as well as other standard models (e.g., LeGrand and Hamel 1980). Examination of the output of this latter model indicated several areas in which its construction was faulty, but where improvement can be made. For example, originally constructed for southern Atlantic Coastal Plain habitats, the model did not include adequate evaluation of red cedar forests, and too few potential stand condition classes were evaluated thoroughly for each species.

Models such as those described and tested here do not consider possible effects on bird species of a number of factors such as: recent climatic trends; annual weather variation; long-term land-use changes, such as reforestation or forest fragmentation in the temperate zone, and deforestation and forest fragmentation in the tropics; direct and indirect consequences of pesticide applications; and regional or local movements occasioned by changes in abundance of food or other resources. The attempt in this work is to determine the accuracy rates achievable when these factors, whose importance is not denied, are excluded from explicit consideration. Later addition of their effects can then be used to assess the extent of possible improvements in model performance which they might provide.

Preliminary tests, such as this one, have been conducted in only a small number of cases. Dedon et al. (1986) experienced accuracy rates of 51 abd 38 percent on 80 fixed-radius plots in California black oak (*Quercus kelloggii*) and mixed-conifer habitats in California. Raphael and Marcot (1986) reported accuracy rates of 35-78 percent for breeding birds, 21-69 percent for wintering birds, 72-76 percent for reptiles and amphibians, and 69-81 percent for mammals, on 191 study sites in seral stages of Douglas-fir (*Pseudotsuga menziesii*) forest in California. We are unaware of other such tests in the South. These results indicate that assessment of "standard" or "acceptable" accuracy rates of species-habitat-relationship models cannot yet be made, and evince the need for more testing and validation of models such as these before they can be used with assurance by land managers and workers involved in impact assessments.

From the belief that prediction errors are more useful for model improvements and for understanding avian biology, we now proceed to discuss primarily those species (table 2). We make what we believe are convincing arguments about groups of these species, but they are at best hypotheses. At worst they are "just-so" stories.

Three classes of explanations seem consistent with our results. First, many species consistently reported as surprises are birds commonly associated with edge habitats, with old fields, or with open areas. Second, many species recorded consistently as misses are species that either are commonly considered forest interior species, species of large forested tracts, neotropical migrants, or a combination of these three. Third, some species recorded commonly as surprises, and others reported commonly as misses, represent species whose distributions in the Central Basin are different from those anticipated by the framers of the various predictor sets or those obtaining in the regions in which empirical data sets were taken. A fourth group of species includes those for whose unpredictability we have no ready explanation.

Consistent Surprise Species

The group of surprise species commonly considered typical of edge includes at least 17 species (table 2). Several patterns may explain their appearance on the lists. First, a large proportion of the forest habitats of the Central Basin have undergone extensive disturbance from logging, or grazing, or both (Pearsall et al. 1985). Such disturbances have created the sorts of dense undergrowth favored by species such as White-eyed Vireo (Vireo griseus), Yellow-breasted Chat (Icteria virens), and Rufous-sided Towhee (Pipilo erythrophthalmus). Second, many of the study sites were situated on the tops of limestone knobs, where they appeared as veritable "toupees of trees." Such locations provide, at best, harsh growing conditions; consequently, the forests have more open aspect than they would in more favorable growing conditions. Third, eastern red cedar (Juniperus virginianus) is a frequent component of Central Basin forests and presents, even as a large tree, a growth form suited to species such as Prairie Warbler (Dendroica discolor). Fourth, some of the species, particularly Indigo Buntings (Passerina cyanea), seem to have invaded habitats different from those envisioned by framers of the prediction data sets. Occurrence of this "edge" species throughout forested tracts in the Central Basin truly was a surprise.

Fifth, interacting with each of the above factors is the reality of small tract size in the Central Basin. Because tracts are small, locating a transect in the forest out of earshot of surrounding habitats is virtually impossible. Thus many of the surprises, particularly Killdeer (Charadrius vociferus) and Eastern Meadowlark (Sturnella magna), represent species overheard in their usual habitats outside the study sites.

Consistently Missed Species

The group of consistently missed species includes a number of birds meriting particular mention because of concern for their future conservation. These "forest interior migrants" are represented by Acadian Flycatcher (Empidonax virescens) and at least five parulids, including Northern Parula (Parula americana), Yellow-throated Warbler (Dendroica dominica), Cerulean Warbler (D. cerulea), American Redstart (Setophaga ruticilla), and Hooded Warbler (Wilsonia citrina). The small size of Central Basin tracts as represented by our study sites (mean = 111 +/- 70 ha) provides relatively little true forest interior for species that are dependent on, or at least associated with, such conditions. In this group, Cerulean Warbler is perhaps the clearest example, having been found on only three sites--two in the Warner Parks in Nashville (among the largest forested sites in Davidson County) and one in Rock Springs on the extreme northeastern edge of the Central Basin.

Other examples of birds associated with large tracts that were commonly missed are Red-shouldered Hawk (Buteo lineatus) and Wild Turkey (Meleagris gallopavo). Current land use patterns in the Central Basin appear to provide little habitat for the long-term persistence of species such as those in this group.

Species with Unanticipated Traits or Unmet Needs

A third category of species includes those repeatedly missed or consistently occurring as surprises, and for which the Central Basin provides much better, or much worse, conditions than those envisioned by the framers of the predictions. For example, species usually associated with forests near water, such as Green-backed Heron (Butorides striatus), Black-crowned Night-Heron (Nycticorax nycticorax), Wood Duck (Aix sponsa), Belted Kingfisher (Ceryle alcyon), and Louisiana Waterthrush (Seiurus motacilla), were frequently missed because our sites were typically not near water. Conversely, Central Basin habitats apparently provide better conditions than expected for species such as Black Vulture (Coragyps atratus), Common Nighthawk (Chordeiles minor), Blue-winged Warbler (*Vermivora pinus*), and Prairie Warbler. Elucidating reasons for this situation will be the object of important future research.

Unpredictable Species

Another group of species, represented by Ruby-throated Hummingbird (*Archilochus colubris*), Chipping Sparrow (*Spizella passerina*), and Northern Oriole (*Icterus galbula*), occurred or did not occur in ways that are easily explained.

CONCLUSIONS

Predictive models of avian community composition of two sorts were examined. Each provided insight into the composition of avian communities in the Central Basin, and the context of study sites on which community measurements were made. Median success rate for models was between 55 and 75 percent, while median surprise rate was between 25 and 45 percent. Improvements in each of these figures is believed possible.

Failures of predictions led to examination of several groups of species. That examination produced implications for understanding the context of Central Basin habitats and bird communities. First, the very fragmented nature of Central Basin habitats produced species lists which included numerous edge species that were not predicted. Second, and related to the first, these habitats were apparently sufficiently fragmented that conditions were not good for forest interior species in the Central Basin. Third, differences in observed and expected distributions of several species suggested that conditions or behaviors of the birds differed between the regions for which predictions were made and those of the Central Basin.

ACKNOWLEDGEMENTS

We dedicate this work to the memory of Charlie Wooten, who got to spend too little time in the field with us. We acknowledge the diligent work of those who prepared the prediction data sets, particularly Harry LeGrand and Daryl Durham. The ideas presented here have been improved by spirited discussions with our colleagues both at Clemson and in Nashville.

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Eagle Management at Land Between The Lakes

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- - - - - - - - - - - - - - - - ABSTRACT - - - - - - - - - - - - - - - -

Bald Eagle populations fluctuated in the Cumberland and Tennessee River valleys following national downward trends because of widespread and indiscriminate pesticide use, habitat destruction, and illegal shooting. Bald eagle nests disappeared in the late 1950s. During the late 1960s and early 1970s, known population levels of wintering eagles reached a low, and then began a climb upward.

Sanctuaries were established on Kentucky Lake and Lake Barkley in the 1960s to give eagles acceptable protection from harassment after Kentucky Woodlands National Wildlife Refuge closed. The Kentucky-Tennessee Eagle Management Team was formed in 1978 to coordinate wintering eagle population surveys throughout Kentucky and Tennessee, and increase conservation/ education programs and eagle management and research in the region. A Bald Eagle hacking program was begun in 1980 in an effort to re-establish a viable nesting population in the LBL region. A total of 37 eaglets has been fledged at LBL through 1987.

Nesting started again in the LBL region in 1983 and has produced a total of 22 eaglets through 1987. An LBL nest initiated in 1984 has produced 4 eaglets. Hacking at LBL will continue until 1990, when a sufficient number of eagles will have survived, and an adequate number of productive nests should have been established.

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The History of American Bison and Bison at Land Between The Lakes

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-ABSTRACT-

The American bison is known to exist as two subspecies, *Bos bison bison* (the plains bison) and *Bos bison athabasca* (the wood bison). No other ungulate has been known to have reached as high a population as *Bos bison*, with estimates ranging from 60 to 120 million. Bison ranged almost throughout North America in great herds until they began to be decimated by settlers in the early 1700s. By 1800 the bison was essentially absent east of the Mississippi River. By 1900 the great western herds were gone, with fewer than a thousand bison alive. Recovery of the bison was initiated by private individuals and private organizations until, in 1908, Teddy Roosevelt persuaded Congress to act to preserve the bison. Approximately 100,000 bison, including both subspecies, exist in North America today.

Land Between The Lakes maintains a herd of approximately 50 bison as an example of a species which once thrived in Kentucky and Tennessee, was driven almost to extinction, and then was returned to adequate populations through private and governmental conservation. Details of the history, conservation, and present status of American bison will be presented.

Larval Damselfly Coexistence With Green Sunfish

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ABSTRACT

We tested the hypothesis that larval damselflies (Odonata: Zygoptera) cannot coexist with fish predators specialized at exploiting fauna of littoral vegetation [e.g., green sunfish, (Lepomis cyanellus)]. In July and October of 1986 we sampled larval Odonata of 18 ponds at the Tennessee Valley Authority's Land Between The Lakes in western Tennessee and Kentucky. Three ponds were selected with each of the following six sets of characteristics: vegetated--with green sunfish, with other sunfish, and with no sunfish; and non-vegetated--with green sunfish, with other sunfish, and with no sunfish. The percent of Odonata (volume/sample) comprised of Zygoptera showed no

"vegetation effect" in July ["vegetated" (13 percent) = "non-vegetated" (13 percent)], but there was an apparent difference in October ["vegetated" (11 percent) > "non-vegetated" (1 percent), P = 0.056]. There were no significant "fish effects", and the rank order of the means was not consistent with predictions of the "green sunfish hypothesis"--in both months the largest percentage of Zygoptera was found in ponds with green sunfish!

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INTRODUCTION

In their review of factors influencing the species composition of larval Odonata assemblages, Johnson and Crowley (1980) suggested that "...the ratio of dragonflies (Anisoptera) to damselflies (Zygoptera) in a community may depend on the presence or absence of fish considered to be weed-bed specialists." This hypothesis was suggested by the observation that damselflies seemed under-represented in Dick's Pond (Benke and Benke 1975) and Lake Isaqueena (Nestler 1980) in comparison with Hodson's Tarn (Macan 1964) and Bays Mountain Lake (Johnson and Crowley 1982). The fish communities in the first two of those sites included weed-bed specialists (Werner 1984)--green sunfish (Lepomis cyanellus) in Lake Isaqueena, and dollar sunfish (L. marginatus), in Dick's Pond. The "green sunfish hypothesis" suggested that mortality attributable to such specialized predators depleted the larval damselfly densities, whereas less-vulnerable dragonflies survived to dominate the odonate assemblage.

The survey of aquatic macroinvertebrates of Land Between The Lakes being sponsored by Austin Peay State University's Center for Field Biology of Land Between The Lakes provided an excellent opportunity to test the "green sunfish hypothesis". Land Between The Lakes (LBL) consists of approximately 70,000 ha of second-growth oak-hickory forest and open fields on a peninsula between Kentucky Lake and Lake Barkley in western Kentucky and Tennessee. It is administered by the Tennessee Valley Authority for outdoor recreation and environmental education. Many aspects of its natural history are described in detail by other contributors to this symposium. Our interest was in the more than 400 small ponds scattered throughout the peninsula.

METHODS

Field Collections

On 8-9 July 1986 we examined nearly 50 ponds throughout LBL and selected 18 for our study. Two factors contributed to our choice of ponds: presence or absence of aquatic vegetation, and the fish assemblage present. Aquatic macrophytes were considered a potentially important feature of odonate habitat because they provide oviposition sites for most damselflies and a refuge from fish predators for many odonates. Based on visual inspection of the vegetation, and field identification (by Forsythe) of small fish collected by seining, we selected three ponds (table 1) that appeared to represent each combination of the following conditions: vegetated--with green sunfish (*Lepomis cyanellus*), with other sunfish (*L. macrochirus* and/or *L. microlophus*), and with no sunfish; and non-vegetated--with green sunfish, with other sunfish, and with no sunfish (some of the "no sunfish" ponds did contain other fish species judged to be non-insectivorous). The largest of the ponds (no. 63) had a surface area of about 0.6 ha; the rest were considerably smaller. Two (nos. 13 and 15) were farm ponds frequented by cattle; the others were fish ponds or water holes utilized by wildlife. Two (nos. 18 and 25) were in wooded areas, while the rest were at least partially in the open.

Table 1. Ponds at Land Between The Lakes that were selected to represent certain vegetation and fish categories (see text). Numbers are those assigned by the survey of aquatic macroinvertebrates, Center for Field Biology of Land Between The Lakes, Austin Peay State University, Clarksville, Tennessee.

	VEGETATED	NON-VEGETATED
GREEN SUNFISH	15 17 23	5 24 32
OTHER SUNFISH	28 63 76	6 10 26
NO SUNFISH	13 27 45	18 25 75

During two intensive field collecting trips in July and October 1986, one of us (Watson) collected macroinvertebrates from each of the study ponds using a triangular net swept across the bottom a distance of approximately 0.6 m. All sweep-net samples were taken in the same way by the same individual, and care was taken to sample different areas and habitats within each pond. During July, four to six samples were taken in each pond; this was reduced to three per pond for the October sampling. Odonate larvae were removed from the sweepings by hand-picking from a white enamel tray in the field; some that escaped detection were recovered by sugar-flotation (Anderson 1959) in the laboratory. In addition to the larval collections, an effort was made to collect a representative sample of the adult Odonata flying in the vicinity of each pond.

Laboratory Procedures

Odonate larvae were preserved in vials containing 80 percent ethanol to prevent breakage of fragile caudal lamellae, structures essential for identification of damselfly larvae. They were identified to species using published keys (Needham 1903, Needham and Westfall 1955, Walker 1953), and reference collections of specimens from Bays Mountain Park (Sullivan County, Tennessee) developed by Johnson during previous research in that locality (cf., Johnson et al. 1980). Adult collections were used to corroborate larval identification.

For testing the "green sunfish hypothesis", we measured the volume displaced by all larval Zygoptera or Anisoptera collected from each pond on each date. These figures were divided by the number of standard sweep-net samples represented in each total; thus our estimates of relative density are expressed as milliliters per sweep-net sample. This measure tends to give more weight to the less-numerous, late-instar survivors than to the more-numerous, very small (and hard-to-identify), early instars that might dominate an analysis based strictly on numbers of individuals. We consider it the appropriate measure of success in the presence of predacious fish.

Statistical Analyses

Estimates of density (volume per sweep-net sample) were subjected to a two-way analysis of variance using rerandomization procedures (1000 runs; cf. Johnson et al. 1987) to estimate probabilities associated with null hypotheses concerning main effects ("vegetated" vs. "non-vegetated"; "green sunfish" vs. "other sunfish" vs. "no sunfish") and interaction terms ("vegetated/non-vegetated" by "green sunfish/other sunfish/no sunfish" combinations). Rerandomization is especially appropriate for data such as these which are not normally distributed (Edgington 1987). Separate analyses were conducted for Zygoptera and Anisoptera for both the July and October samples. Similar analyses were also conducted for the percentage of odonate density comprised of Zygoptera.

Lists of odonate taxa present in at least one sample from each pond were used to calculate Dice's Similarity Index (Anderberg 1973) for the odonate assemblages in each pair of ponds. These indices were then subjected to cluster analysis (using average linkage between groups; SPSS-X Release 2.2) to identify groups of ponds that shared similar odonate assemblages.

RESULTS AND DISCUSSION

Vegetation and Fish Effects

There were significant "vegetation effects" and "fish effects" on larval odonate densities in July (figure 1). "Vegetation effects" were particularly clear: the ponds with aquatic macrophyte vegetation had significantly greater densities of larval damselflies ($P = 0.018$) and larval dragonflies ($P = 0.001$). The fact that this difference appears to have been especially great in "no sunfish" ponds suggests that the role of vegetation in providing oviposition sites may have been more important than its role as a refuge from fish predators.

"Fish effects" are nearly significant in the analysis of July densities, and their pattern is intriguing: "no sunfish" ponds had the greatest densities of larval dragonflies ($P = 0.051$) as one might expect, but the highest damselfly densities were found coexisting with green sunfish ($P = 0.074$), in direct contradiction to the "green sunfish hypothesis"! The vegetation X fish interaction is not significant. Though all of these trends evident in the July data are suggested by the October data, none is close to being significant ($P > 0.1$).

Similar two-way analyses of variance for the percentage of odonate density comprised of Zygoptera (percent Zygoptera) provide a more direct test of the prediction of the "green sunfish hypothesis" (Johnson and Crowley 1980). There was no apparent "vegetation effect" on percent Zygoptera in July ["vegetated" (12 percent) vs. "non-vegetated" (14 percent); $P = 0.942$]. But in October, damselfly larvae comprised a larger percentage of odonate densities where there were aquatic macrophytes ["vegetated" (11 percent) > "non-vegetated" (1 percent); $P = 0.056$].

Though none of the "fish effects" were statistically significant at the 95 percent level of confidence, the rankings of mean percent Zygoptera values nonetheless stood in direct contradiction to the "green sunfish hypothesis": the July figures were green sunfish (27 percent) > no sunfish (8 percent) > other sunfish (6 percent), $P = 0.283$; the figures for October were green sunfish (11 percent) > other sunfish (9 percent) > no sunfish (5 percent), $P = 0.963$.

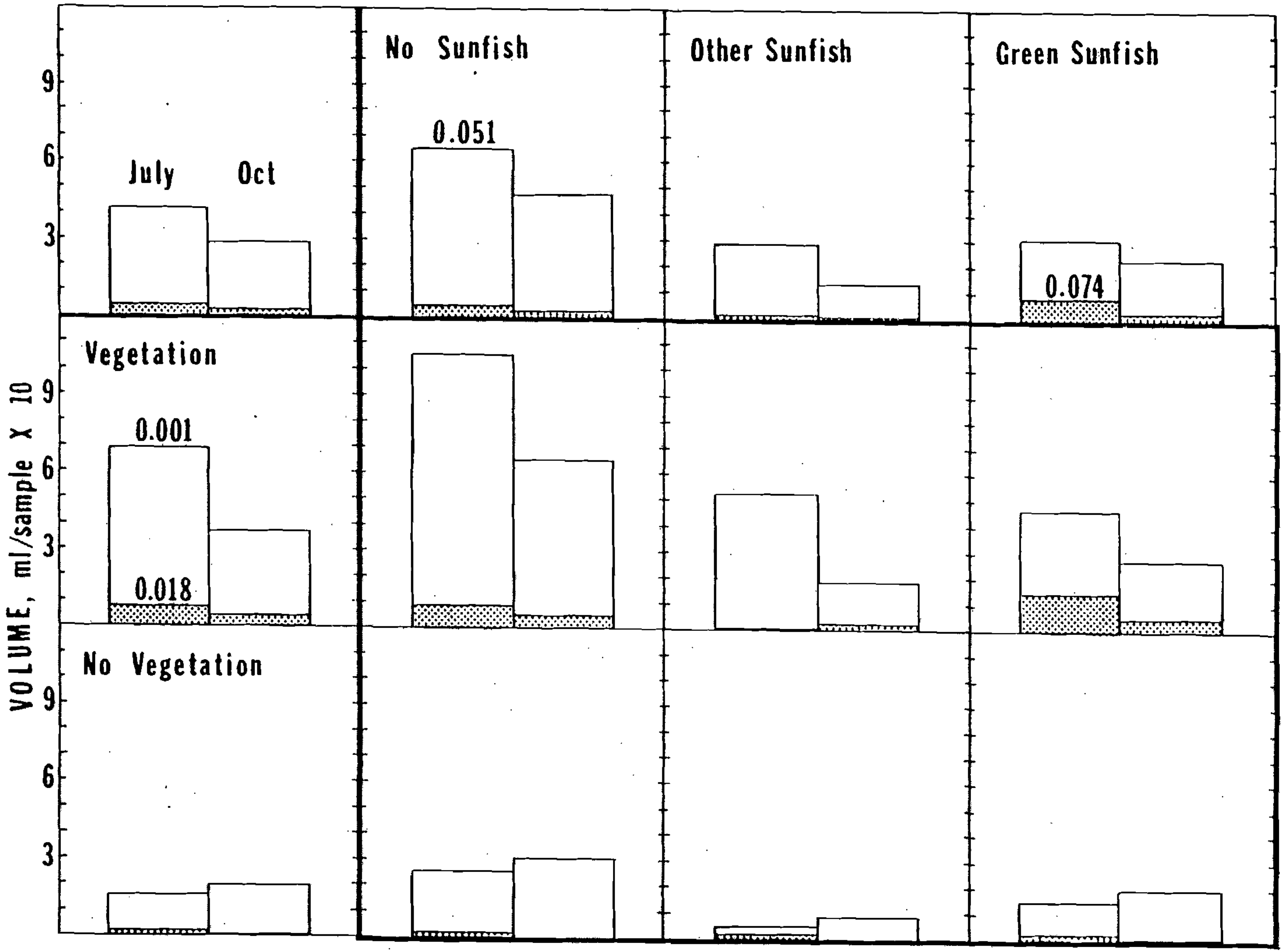

Figure 1. Results of two-way analyses of variance showing vegetation effects, fish effects, and vegetation X fish interaction effects on the density of larval Anisoptera (open) and Zygoptera (shaded) in July and October 1986. Each bar represents the mean density (volume/sample) of larval Odonata in three ponds (table 1). Numbers above the larger of the means being compared indicate the probability that an observed effect is attributable to chance of P 0.10; those just above the shaded area refer to Zygoptera densities; those above the open areas, to Anisoptera densities.

Considering the preliminary nature of this survey, the possibility that some ponds may have been misclassified (see below), and the relatively low statistical power associated with low numbers of replications and high variance in such field work (Toft and Shea 1983), we think it prudent to interpret probabilities of type I error less than 0.10 ("fish effects" on larval densities in figure 1) as indicative of effects that are likely to be biologically significant. Therefore, we conclude from these results that both vegetation and the type of fish assemblage influence the densities of larval odonates found in ponds at LBL. But there is no evidence to support the hypothesis (Johnson and Crowley 1980) that damselfly populations are depressed in ponds with green sunfish. In fact, the evidence suggests the opposite conclusion--that damselfly population densities are enhanced in ponds with green sunfish. We are reminded of T. H. Huxley's famous lament, "...the great tragedy of Science--the slaying of a beautiful hypothesis by an ugly fact..." (Huxley 1870).

Searching for Alternative Patterns

In an effort to search for patterns that might suggest alternative hypotheses concerning factors that influence odonate assemblage structure, we used records of the presence or absence of the 19 odonate taxa identified in our larval collections to calculate an index of the similarity of odonate assemblages for each pair of ponds in our study (table 2). These data were then subjected to a cluster analysis which linked ponds with the most similar assemblages. The resulting dendrogram is presented in figure 2, along with the densities of Anisoptera and Zygoptera larvae in the July samples. Note that the three ponds (nos. 15, 17, and 23) with vegetation and green sunfish form a tight cluster, and that they had three of the highest densities of damselflies. The following taxa, shared by all three ponds, contributed to their similarity and are obviously capable of coexisting with green sunfish: the damselflies Ischnura posita and Enallagma signatum; and the dragonflies Tetragoneuria cynosura, Perithemis tenera, Pachydiplax longipennis, and Erythemis simplicicollis.

Two ponds (nos. 28 and 63) with vegetation and other sunfish form another tight cluster that is quite distinct from the preceding in that it represents ponds that had much lower densities of Zygoptera. The third pond (no. 76) in that category also had low damselfly densities, but must have had a very different assemblage of dragonflies. Inspection of the presence/absence data reveals that difference is entirely due to omission: only four taxa (the damselfly Ischnura posita, and the dragonflies Plathemis lydia, Erythemis simplicicollis, and Libellula luctuosa) were recorded from pond no. 76, and all of those were found in either or both of ponds nos. 28 and 63; but an additional seven taxa (the damselflies Enallagma signatum and E. traviatum, and the dragonflies Tetragoneuria cynosura,

Table 2. Presence(+) or absence(-) of larval Odonata from selected ponds (see table 1) at Land Between The Lakes, based on sweep-net collections made in July and October 1986. Interrogatives (?) indicate that a taxon may be present in early instars but has not been identified with certainty.

Taxon Pond#	13	27	45	28	63	76	15	17	23	18	25	75	10	6	26	5	24	32
Gomphus ?exilis	–	+	–	+	+	–	–	–	–	–	–	–	–	–	–	+	–	–
AESHNIDAE	–	–	–	–	–	–	–	+	+	–	–	–	–	–	–	–	–	–
MACROMIIDAE	–	–	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	+
Tetragoneuria cynosura	–	+	+	+	+	–	+	+	+	–	–	–	–	–	–	+	+	+
Celithemis eponina	–	–	–	+	+	–	–	–	+	–	–	–	–	–	–	–	–	–
Erythemis simplicicollis	–	–	–	+	+	+	+	+	+	–	–	–	–	–	–	–	–	–
Ladona deplanata	–	+	–	–	–	–	–	–	–	–	+	–	–	–	–	–	+	–
Libellula luctuosa	–	?	–	?	+	+	–	?	?	–	?	–	–	–	–	–	?	–
Libellula vibrans	–	?	–	?	–	–	–	?	?	+	+	–	–	–	–	–	?	–
Pachydiplax longipennis	–	+	+	–	–	–	+	+	+	+	+	–	–	–	–	–	–	–
Perithemis tenera	–	+	–	–	–	–	+	+	+	–	+	–	+	+	+	+	–	+
Plathemis lydia	+	–	+	+	–	+	+	–	+	+	–	+	+	–	+	–	–	+
Sympetrum vicinum	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–
Tramea ?lacerata	–	–	–	+	+	–	–	–	–	–	–	+	–	–	–	–	–	–
Enallagma aspersum	–	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–
Enallagma signatum	–	+	–	+	+	–	+	+	+	–	–	–	+	–	–	+	–	+
Enallagma traviatum	–	+	–	+	+	–	–	–	–	–	–	–	–	–	–	–	–	–
Ischnura posita	–	+	+	+	+	+	+	+	+	+	–	+	+	–	–	–	+	+
Ischnura verticalis	–	+	+	–	–	–	+	+	–	–	+	–	+	–	–	–	–	–

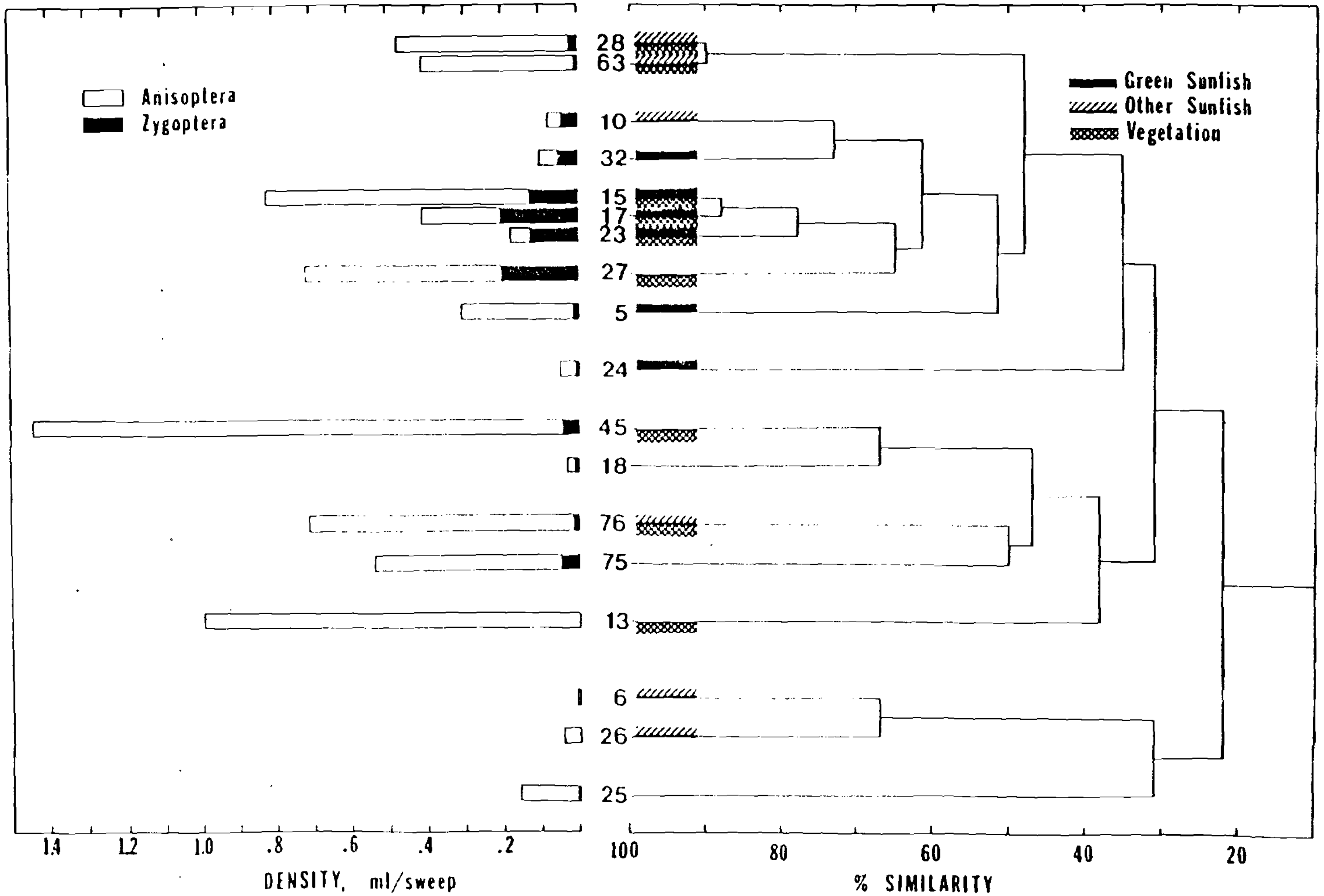

Figure 2. Results of a cluster analysis on similarity indices based on the presence or absence of 19 Odonata taxa in selected ponds at Land Between The Lakes (table 2). Numbers identify individual ponds, and shading patterns on the dendrogram indicate pond habitat categories (table 1). Bars to the left of each pond number show the mean density of larval Odonata in July 1986, and black areas indicate the proportion of that density comprised of damselflies.

Gomphus exilis, Macromiidae, Celithemis eponina, and Tramea lacerta) were shared by these last two ponds.

Other than the two sets noted above, the cluster analysis (figure 2) fails to group many sets of ponds that were assigned the same vegetation and fish assemblage classifications [i.e., "vegetated/no sunfish" (ponds nos. 13, 27, and 45); "non-vegetated/green sunfish" (ponds nos. 5, 24, and 32); "non-vegetated/other sunfish" (ponds nos. 6, 10, and 26); and "non-vegetated/no sunfish" (ponds nos. 18, 25, and 75)]. This failure suggests that such habitat characteristics have relatively little influence on the species composition of odonate assemblages; but we consider that conclusion to be premature. It is very likely that, in some of these cases, we have failed to classify the ponds correctly. For instance, three ponds (nos. 5, 10, and 32) that were classified "non-vegetated" but either "green sunfish" or "other sunfish" during our initial field trip in early July appear to cluster with most of the "vegetated/other sunfish" ponds (excepting pond no. 76) in figure 2. Inspection of field notes and photographs taken at each pond during the intensive sampling effort made later that month reveals that each of these ponds had some vegetation present that may have provided appropriate oviposition sites for damselflies.

Our efforts to categorize these ponds into "vegetated" and "non-vegetated" were clearly imperfect. Neither quantitative nor qualitative distinctions among "vegetated" ponds were included in the design of this study. Likewise our categorization of fish assemblages, based on one-effort seining of small fish, may have occasionally misclassified a pond. And that classification takes no account of the density of fish present, or the historical changes in fish assemblage composition during the recent past--both factors which might be expected to modify the influence of fish on odonate populations. Other variables, such as turbidity, may also have influenced both macrophyte densities and fish feeding behaviors in ways that may have interacted with their influence on odonate assemblages.

CONCLUSIONS

We conclude that this preliminary survey of the Odonata of selected ponds during one field season provides sufficient evidence to reject the "green sunfish hypothesis" in its original form (Johnson and Crowley 1980). But the data are not sufficient to suggest alternative hypotheses. Complete data sets for all macroinvertebrate taxa collected during our study have been deposited, along with reference specimens of all taxa, in the collections of the Center for Field Biology of Land Between The Lakes, at Austin Peay State University, Clarksville, Tennessee. We hope that those who pursue future field studies in LBL will find our preliminary results intriguing; and we hope that these results may eventually provide further insight into the factors responsible for determining aquatic littoral zone community structure.

ACKNOWLEDGMENTS

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Ticks and Tick-borne Diseases of the Tennessee Valley Region

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ABSTRACT

Ticks are important vectors of disease, and cause losses of millions of dollars annually to livestock, recreation, and tourism industries in the United States. At least 14 species of Ixodid ticks (Acari: Ixodidae) have been reported from the Tennessee Valley region. Of these, four are of economic or medical importance: the lone star tick (Amblyomma americanum), the Gulf Coast tick (Amblyomma maculatum), the American dog tick (Dermacentor variabilis), and the brown dog tick (Rhipicephalus sanguineus).

The lone star tick and American dog tick are the most commonly encountered species. The lone star tick is a major pest because of its long mouth parts, agressive behavior, and large numbers. The American dog tick is also a serious pest, and is the principal vector of Rocky Mountain spotted fever in the eastern United States.

The Gulf Coast tick and brown dog tick are less commonly encountered. The Gulf Coast tick is primarily distributed along the Gulf and Atlantic coasts where it is an important pest of cattle and man. This tick is periodically collected in the Tennessee Valley region, but does not appear to be established here. The brown dog tick is an important pest of domestic dogs, and is economically important because dogs often bring this tick indoors where it can reproduce in large numbers. It does not readily attach to man, but is a potential disease vector.

A Preliminary Report on the Aquatic Macroinvertebrates in Land Between The Lakes

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ABSTRACT

The goal of this study was to contribute to the knowledge of the biota of LBL by surveying the aquatic macroinvertebrates and cataloguing them according to their habitats. First-year objectives were (1) to identify collecting sites, and (2) to develop a computer-based information system for habitat characteristics and species distribution. Soil Conservation and Stabilization Service and LBL aerial photographs, LBL Forestry Department records, and LBL personnel provided background information on site locations. Due to drought and overgrowth it was necessary to field check all preliminary information. Of the more than 500 ponds and waterholes in LBL and the numerous streams, springs, and marshes, over 100 were visited. Preliminary data were collected on 70 ponds. A computer-based information system was developed to record site data and to identify long-term study sites. In general, ponds had mud or detritus bottoms, low oxygen, pH ranging from 5.0 to 7.8, little emergent vegetation, and grassy marginal vegetation. Preliminary identification has been made on 197 macroinvertebrates collected. Specimen data has been entered into a computerized data management system designed to match specimens with habitat characteristics. Among specimens collected are at least 18 Odonata first county records for Stewart County, Tennessee.

Breeding Bird Communities of the Forests of Land Between The Lakes

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ABSTRACT

During summer 1987, data were collected on bird and plant communities of eight forested tracts in Land Between The Lakes. This report presents findings based on data from seven of those tracts.

The seven tracts (18-30 ha, $\bar{x}$=23.4; none recently logged) were widely dispersed in LBL. All represented fairly mature second-growth stands, either embedded in or adjacent to other forested areas. Relative dominance values for the more important trees, calculated from pooled data for all seven tracts, were: *Quercus alba*, 39; *Carya* sp., 12; dead snags (several species), 9; *Q. velutina*, 8; *Q. prinus*, 8; *Q. stellata*, 5; *Fraxinus* sp., 2; *Nyssa sylvatica*, 2; *Fagus grandifolia*, 2. Mean values of other descriptive statistics, derived from the same data base, were: trees per ha, 529; basal area per ha, 12.4 m^2; canopy cover, 86 percent; canopy height, 23 m; ground cover, 19 percent; and shrub stems per ha, 1,903.

Bird populations were assessed from 10-30 June, using a fixed-radius point count technique. Each of four teams (one observer and one recorder per team) counted each tract twice, producing a data base representing eight ten-minute counts from each of 62 counting stations, for a total of 496 such counts. Of 61 bird species recorded, 24 occurred on all seven tracts, 15 on four to six, 9 on two to three, and 13 on only one. Forty species yielded 10 or more individual records and accounted for more than 99 percent of the total of 6,775 individual records. Twelve species occurred at least once within 25 m of the observer at half or more of the 62 counting stations. A relative index of abundance (RIA) was calculated for each bird species (RIA = mean number of individuals per 25 m radius point count X 100). Values of RIA ranged from 30 to less than 1. The 17 species with the highest RIA values, which collectively accounted for more than 80 percent of the 6,775 individual records were (RIA values follow names): *Molothrus ater*, 30.0; *Parus bicolor*, 26.8; *Cyanocitta cristata*, 26.4; *Sitta carolinensis*, 23.2; *Piranga olivacea*, 22.6; *Piranga rubra*, 15.3; *Empidonax virescens*, 14.5; *Melanerpes carolinus*, 14.3; *Polioptila caerulea*, 14.3; *Parus carolinensis*, 14.1; *Myiarchus crinitus*, 13.9; *Vireo olivaceus*, 12.3; *Picoides pubescens*, 11.5; *Contopus virens*, 8.3; *Hylocichla mustelina*, 7.3; *Cardinalis cardinalis*, 5.8; *Coccyzus americanus*, 4.4.