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

HELD AT BRANDON SPRING GROUP CAMP
LAND BETWEEN THE LAKES
MARCH 19 AND 20, 1999

Sponsored by:

The Center for Field Biology
Austin Peay State University, Clarksville, Tennessee

and

Center for Reservoir Research
Murray State University, Murray, Kentucky

and

Tennessee Valley Authority - Land Between The Lakes
Golden Pond, Kentucky

****

EDITED BY:

Steven W. Hamilton[1], Edward W. Chester[1], David S. White[2] and Mack T. Finley[1]
[1]The Center of Field Biology
[2]Center for Reservoir Research

Published by and available from:
The Center for Field Biology,
Austin Peay State University, Clarksville, Tennessee 37044

Price: $5.00

SUGGESTED CITATION

S.W. Hamilton, D. S. White, E. W. Chester and M. T. Finley. 1999. Proceedings of the Eighth Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Published
December, 1999

PREFACE

The Eighth Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys was held at Brandon Spring Group Camp in TVA's Land Between The Lakes on March 19 and 20, 1999. This biennial gathering of naturalists and field biologists was sponsored by the Center for Field Biology at Austin Peay State University, the Center for Reservoir Research at Murray State University, and Land Between The Lakes.

The symposium began Friday afternoon with welcoming comments from representatives of sponsoring institutions. Dr. Benjamin P. Stone, Director of the Center for Field Biology at Austin Peay State University, welcomed all participants. Additional comments were offered by Dr. David S. White, Director of the Hancock Biological Station at Murray State University.

There were three invited speakers that presented papers addressing the Symposium theme of "Habitat Restoration." The first speaker, Dr. Marjorie M. Holland, Biology Professor and Director of the University of Mississippi's Field Station at Oxford, Mississippi. Her presentations stressed the progress being made regarding wetlands protection and restoration throughout the mid-south. Excessive erosion and land development have seriously damaged extensive acreages of premium aquatic habitats and watersheds in the Mississippi area. Dr. Kenneth W. Cummins from the South Florida Water Management District, West Palm Beach, Florida, present an impressive overview of the Kissimmee River Restoration Project in the south Florida Everglades. He discussed the goals and objectives of restoring natural flow regime of natural stream channels of the Kissimmee River watershed. The final presentation Friday evening was given by Dr. William H. Martin, Professor of Biology at Eastern Kentucky University at Richmond, Kentucky. Dr. Martin discussed issues, values, and management needs required to preserve and enhance biodiversity in Kentucky's forests and other natural areas throughout the southeastern United States. He emphasized that preservation and protection were more practical and economically feasible when compared to restoration.

Three sessions of contributed papers were presented Saturday morning. Session I included 12 papers covering subjects concerning Aquatic Biology and Water Quality. This session was moderated by Dr. Steven Hamilton, APSU. Session II was moderated by Dr. Floyd Scott, APSU, and included 12 papers in the area of Zoology. Moderating the 16 papers in Session III in Botany, was Dr. Edward W. Chester, APSU. All contributors were invited to publish an abstract, short communication, or full manuscript in the 1999 proceedings. A total of 127 individuals representing 27 institutions registered at this symposium.

The style and format of these proceedings follow that established in previous proceedings of these symposia. Drs. White, Hamilton, and Finley organized and edited the Invited Papers; Dr. Hamilton edited abstracts and papers from Sessions I and II; and Dr. Chester edited abstracts and papers from Session III. Drs. Hamilton and Chester brought all these papers together into the final format.

ACKNOWLEDGMENTS

The editors thank Ms. Marilyn Griffy for her assistance in organizing and coordinating activities leading up to and throughout the symposium. We also recognize the participation of many APSU Center for Field Biology undergraduate and graduate research assistants for their help before and during this biennial event. Many abstracts and manuscripts were typed and corrected by Ms. Griffy, who also saw to many details of the proceedings organization. Ms. Laurina Lyle provided assistance with the proceedings cover and photographs. The help of these individuals and others forgotten was critical to the success of this symposium and completion of these proceedings. All complete manuscripts were reviewed fully. We appreciate the comments of all reviewers as this process greatly enhances the quality of these proceedings. While we (the editors) would wish this publication to be error free, most likely it is not and for this we assume responsibility.

SYMPOSIUM REGISTRANTS

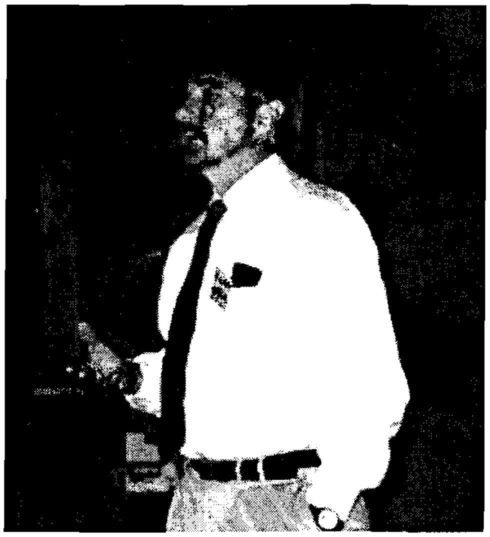
Following, in alphabetical order, is a list of those individuals who registered at the 1999 symposium. Institutional affiliation (when available), city (of the person's institution or home), and state are also given.

Christopher Adams, University of Kentucky, Lexington, KY; **Bill Atkinson**, Hopkinsville Community College, Hopkinsville, KY; **Kimberly Augenfeld**, University of Memphis, Memphis, TN; **Heather Bagwell**, Austin Peay State University, Clarksville, TN; **Claude Bailey**, TN Division of Natural Heritage, Harborsonville, TN; **Lisa Baker**, Austin Peay State University, Clarksville, TN; **Carol Baskauf**, Austin Peay State University, Clarksville, TN; **Carol Baskin**, University of Kentucky, Lexington, KY; **Jerry Baskin**, University of Kentucky, Lixington, KY; **Jennifer Bottom**, Murray State University, Murray, KY; **Tim Brown**, Austin Peay State University, Clarksville, TN; **Jocelyn Bryant**, Austin Peay State University, Clarksville, TN; **Willliam Bryant**, Thomas More College, Crestview Hills, KY; **Angelo Bufalino,** Austin Peay State University, Clarksville, TN; **Pam Bufalino**, Austin Peay State University, Clarksville, TN; **Ray Burkett**, Shelby State Community College, Memphis, TN; **Willodean Burton**, Austin Peay State University, Clarksville, TN; **John Butler**, Austin Peay State University, Clarksville, TN; **Edward Chester**, Austin Peay State University, Clarksville , TN; **Kevin Claridge**, University of Memphis, Memphis , TN; **Ron Clark**, Kentucky Wesleyan College, Calhoun, KY ; **Georgina Coffey**, Austin Peay State University, Clarksville, TN; **Chad Colburn**, Murray State University, Murray, KY; **Cheryl Crossett**, Union University, Jackson, TN; **Kenneth Cummins**, South Florida Water Management District, West Palm Beach, FL; **Don Dailey**, Austin Peay State University, Clarksville, TN; **Hal DeSelm**, UT-Knoxville, Knoxville, TN; **Wayne Drda**, Herpetological Investigations, St. Louis, MO; **Agnes Ellis**, Austin Peay State University, Clarksville, TN; **William Ellis**, Austin Peay State University, Clarksville, TN; **Craig Emerson**, Austin Peay State University, Clarksville, TN; **Mack Finley**, Austin Peay State University, Clarksville, TN; **Kevin Fitch**, ACS Conservation, Arnold AFB, TN; **Alex Flynt**, Austin Peay State University, Clarksville, TN; **Raymond Folsom**, Austin Peay State University, Clarksville, TN; **Tom Forsythe**, TVA, Abingdon, MO; **James Fralish**, Southern Illinois University, Carbondale, IL; **Scott Franklin**, University of Memphis, Memphis, TN; **Daniel French**, Austin Peay State University, Clarksville, TN; **Claire Fuller**, Murray State University, Murray, KY; **Steven Glickauf**, GA Dept. of Transportation, Atlanta, GA; **Sandra Gonzalez**, Austin Peay State University, Clarksville, TN; **Marilyn Griffy**, Austin Peay State University, Clarksville, TN; **Al Groeger**, Murray State University, Murray, KY; **Lidija Halda-Alija**, Murray State University, Murray, KY; **Steven Hamilton**, Austin Peay State University, Clarksville, TN; **Kristie Harris**, Murray State University, Murray, KY; **Mark Hatfield**, Murray State University, Murray, KY; **Mark Hawkins**, Austin Peay State University, Clarksville, TN; **Tracey Hawkins**, University of Kentucky, Jackson, KY ; **Michael Held**, Thomas More College, Crestview Hills, KY; **Susan Hendricks**, Murray State University, Murray, KY; **Amy Higdon**, Kentucky Wesleyan College, Owensboro, KY; **Timothy Hillard**, Kentucky Wesleyan College, Owensboro, KY; **Siti Nur Hidayati**, University of Kentucky, Lexington, KY; **Jennifer Hoffman**, TDA, Nashville, TN; **Marjorie Holland**, University of Mississippi, Oxford, MS; **Heather Hollis**, Austin Peay State University, Clarksville, TN; **Bob Holderby**, Austin Peay State University, Clarksville, TN; **Rebecca Houtman**, Austin Peay State University, Clarksville, TN; **Robert Hoyt**, Western Kentucky University, Bowling Green, KY; **Donna Hudgins**, Austin Peay State University, Clarksville, TN; **James Huggins**, Union University, Jackson, TN; **Teresa Keyes**, Murray State University, Murray, KY; **Rob Kingsolver**, Kentucky Wesleyan College, Owensboro, KY; **Nancy Kline**, Kentucky Wesleyan College, Owensboro, KY; **John Koons**, Jackson State Community College, Jackson, TN; **Jack Kovach**, Muskingum College, New Concord, OH; **John Lamb**, ACS Conservation, Arnold Air Force Base, TN; **Joann Lau**, Bellarmine College, Louisville, KY; **Jeff Lebkeucher**, Austin Peay State University, Clarksville, TN; **Xiaojie Li**, University of Kentucky, Lexington, KY; **Laurina Lyle**, Austin Peay State University, Clarksville, TN; **Clinton Major**, TN Division of Natural Heritage, Nashville, TN; **William Martin**, Eastern Kentucky University, Richmond, KY; **John Mateja**, Murray State University, Murray, KY;

Kim McCabe, Austin Peay State University, Clarksville, TN; **Amanda McIntyre**, Kentucky Wesleyan College, Owensboro, KY; **Michael McMahan**, Union University, Jackson, TN; **Mary McReynolds**, Austin Peay State University, Clarksville, TN; **Mary Lou McReynolds**, Austin Peay State University, Clarksville, TN; **Ashley Meyers**, Austin Peay State University, Clarksville, TN; **Nicole Mize**, Austin Peay State University, Clarksville, TN; **Sallie Noel**, Austin Peay State University, Clarksville, TN; **David Oetinger**, Kentucky Wesleyan College, Owensboro, KY; **Sunday Oladipupo**, Austin Peay State University, Clarksville, TN; **Michael Patterson**, Austin Peay State University, Clarksville, TN; **Brad Pendley**, Murray State University, Murray, KY; **Alva Powers**, Kentucky Wesleyan College, Owensboro, KY; **Adam Ray**, Austin Peay State University, Clarksville, TN; **Gary Rice**, Murray State University, Murray , KY; **Sharanda Robinson**, Austin Peay State University, Clarksville, TN; **David Robison**, Bellarmine College, Louisville, KY; **Ruben Rocha**, Austin Peay State University, Clarksville, TN; **Chuck Rozelle**, Austin Peay State University, Clarksville, TN; **John Rundle**, Murray State University, Murray, KY; **Joe Schiller**, Austin Peay State University, Clarksville, TN; **Stephanie Schmidt**, Austin Peay State University, Clarksville, TN; **Floyd Scott**, Austin Peay State University, Clarksville, TN; **Dinita Scurry**, Austin Peay State University, Clarksville, TN; **Heidi Semrau**, Austin Peay State University, Clarksville, TN; **Owen Sexton**, Washington University, Eureka, MO; **Paul Sikkel**, Murray State University, Murray, KY; **Brant Smith**, Austin Peay State University, Clarksville, TN; **Heather Smith**, Austin Peay State University, Clarksville, TN; **David Snyder**, Austin Peay State University, Clarksville, TN; **Kathleen Southard**, Austin Peay State University, Clarksville, TN; **Bill Spencer**, Murray State University, Murray, KY; **S. Joy Stephens**, Austin Peay State University, Novi, MI; **Ben Stone**, Austin Peay State University, Clarksville, TN; **Eneng Susilawati**, Murray State University, Murray, KY; **Scott Sutton**, Austin Peay State University, Clarksville, TN; **Cindy Taylor**, Austin Peay State University, Clarksville, TN; **Christina Therrell**, Austin Peay State University, Clarksville, TN; **Jeffrey Walck**, Ohio State University, Columbus, OH; **Clare Weickert**, Southern Illinois University, Carbondale, IL; **Lane West**, Austin Peay State University, Clarksville, TN; **Mary West**, Hopkinsville Community College, Hopkinsville, KY; **Beverly Whaley**, Austin Peay State University, Clarksville, TN; **David White**, Murray State University, Murray, KY; **Joe Whittaker**, Southern Illinois University, Carbondale, IL; **Scott Williamson**, Austin Peay State University, Clarksville, TN; **Wayne Wofford**, Union University, Jackson, TN; **Peder Yurista**, Murray State University, Murray, KY; **Ed Zimmerer**, Murray State University, Murrray, KY; **Gene Zirkle**, Fort Campbell Military Reserv., Clarksville, TN; **Patty Zirkle**, Northwest High School, Clarksville, TN.

SYMPOSIUM PARTICIPANTS

Invited Speakers



Dr. Kenneth W. Cummins

Dr. Marjorie M. Holland

Dr. William H. Martin

Session I: Aquatic Biology and Water Quality - (from left) M. McReynolds, R.D. Hoyt, S. Hendricks, P. Yurista, E. Susilawati, W. Spencer, S.W. Hamilton, C. Harris, J. Bottom, J.G. Lebkuecher, R.A. Ray, and C. Therrell.

Session II: Zoology - (from left) C.A. Rozelle, J.W. Lamb, G.A. Zirkle, C.C. Weickert, M. Hattfield, B.T. Smith, J.C. Whittaker, R.D. Burkett, and E.J. Zimmerer.

Session III: Botany - (from left) J.M. Lau, C.C. Baskin, Xiaojie Li,, W.S. Bryant, J.M. Baskin, E.W. Chester, C. Adams, J. Schibig, S. Glickauf, H.R. DeSelms, S.N. Hidayati, J.S. Fralish, and J.L. Walck.

TABLE OF CONTENTS

Page

CONTRIBUTED PAPERS - SESSION II: ZOOLOGY

CONTRIBUTED PAPERS - SESSION III: BOTANY

INVITED PAPERS

HABITAT RESTORATION

Friday, March 19, 1999

Moderator:

David S. White
Murray State University

Editors:

David S. White
Murray State University

Mack T. Finley
Austin Peay State University

Steven W. Hamilton
Austin Peay State University

EVALUATION OF THE RESTORATION OF THE KISSIMMEE RIVER IN SOUTH FLORIDA

KENNETH CUMMINS[1], MARGARET WILZBACH[1], RICHARD MERRITT[2], AND JAMES BROCK[3]

[1]South Florida Water Management District, Ecosystem Restoration Department
Tarpon Bay Environmental Laboratory, Sanibel, FL
[2]Michigan State University, Department of Entomology, East Lansing, MI
[3]Rapid Creek Research, Inc., Boise, ID.

INTRODUCTION

Within the five Water Management Districts in the state of Florida, each having jurisdiction over water regulation within their boundaries, water supply and flood control are managed largely through a series of conveyances, structures, and reservoirs. The South Florida Water Management District (SFWMD) boundaries conform to the historical watershed of the Everglades plus some separate east and west coast estuary drainage basins that have been artificially joined to the system by the U. S. Army Corps of Engineers (Corps). In the South Florida District, water distribution is highly regulated. As in many areas of the United States, the water is apportioned between agricultural, urban, and environmental needs and major disputes between these users often arise. It has only been within the last decade that environmental needs were given an equal seat at the bargaining table when water distribution issues are resolved. In fact, in the overall water plan for South Florida, management of Everglades's water supplies is the dominant environmental consideration. The major water management mechanism is regulation of releases from Lake Okeechobee in south central Florida. The primary water supply for Lake Okeechobee comes from the Kissimmee River at its north end (Fig. 1). In addition to supplying water to the Everglades and the lower east coast, the lake supplies the east and west coast estuaries. This is the result of the connection by the Corps of Lake Okeechobee to the estuaries through canals that joined with the Caloosahatchee River on the west coast and the St. Lucie River on the east coast.

Coupled with the hydrologic restoration efforts that are specifically directed at the Everglades, there are projects to rehabilitate sections of the Kissimmee River in central South Florida (Fig. 1). Major efforts have been mounted to establish base line, that is pre-restoration, conditions so as to allow continued evaluation of the success of the rehabilitation efforts (*e.g.*, Toth 1993, 1996, Toth *et al.* 1995, and papers in Dahm 1995). If restoration is defined as returning a system to pre-settlement conditions, then the projects are more properly referred to as rehabilitation, that is the return of the system back to some intermediate, presumably improved, condition between the present and the historical state. The continued evaluation of the ecological parameters that are identified as critical is viewed as providing the data necessary to make "mid-course corrections" in the restoration project as dictated by an adaptive management strategy. As in the case of many restoration projects, it is difficult to identify specific courses of action that would be called into play to bring about this adaptive management scenario. At any rate, the best management strategy usually involves the least possible intervention into ecosystem structure and function and maximum reliance on natural processes. The Kissimmee River restoration will involve back filling of the channelized river using the existing spoil levee material resulting in the re-connection of the main channel with the associated

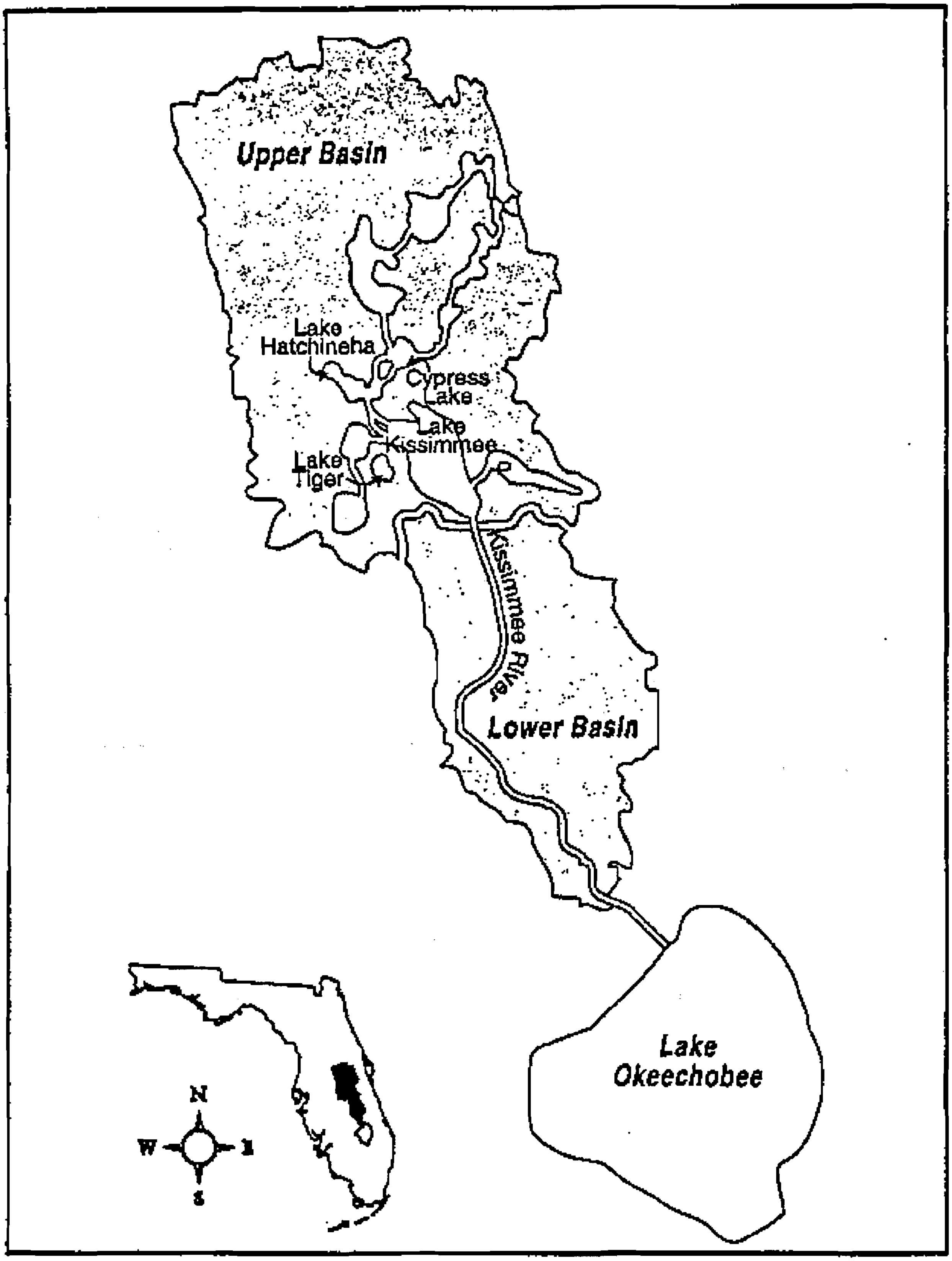


Figure 1. The Kissimmee River Basin in south central Florida.

historical flood plain and its remnant wetlands and braided channels. In addition, the regulated hydrologic regime will be adjusted to better reflect normal historical annual flow patterns. That is, more water released in the wet season and less water released in the dry season, rather than the reversed pattern that now exists (Fig. 2).

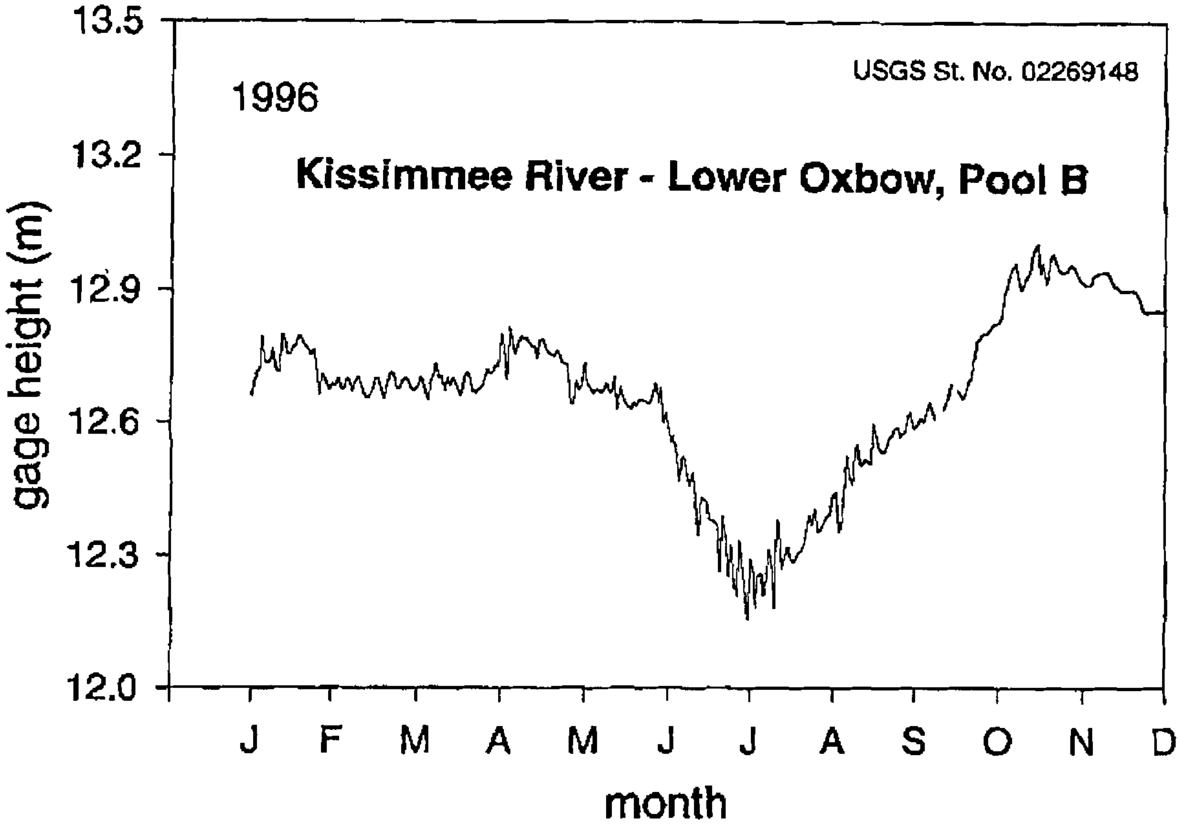


Figure 2. Example of the annual hydrograph for the lower remnant channel of Pool B showing low flows in the wet season (May-October) and high flows in the dry season (November-April).

The work reported here has been directed toward developing conceptual models of ecosystem structure and function for partially restored remnant channels (oxbows) of the Kissimmee River. A central focus of this work has been on invertebrates inhabiting component plant bed types in the riparian marsh (defined as the littoral zone plus the accompanying broad leaf marsh) that form the fringe of these remnant channels and the habitat conditions in these beds. Invertebrates are clustered in functional groups and used as surrogates for ecosystem attributes, such as the balance between autotrophy and heterotrophy (Merritt *et al.* 1996, 1999). Maintaining the appropriate condition of these ecosystem attributes is viewed as the key to ecosystem health (integrity) and sustainability.

THE KISSIMMEE RIVER STUDY SITE

The Kissimmee River that historically flowed about 161 km (100 mi.) through the 1200 sq. km (1,600 sq. mi.) Lower Basin (Fig. 1) from its headwaters in the Kissimmee Lakes area was a broad, meandering, 1.5 to 3 km wide floodplain system. USGS records indicate that historically over 90% of the floodplain was inundated over 50% of the time (see papers in Dahm 1995). The channelization resulted in the loss of approximately 14,000 hectares (35,000 acres) of riparian marsh (Koebel 1995). Undoubtedly many plant and animal species were lost or reduced to relict populations (Toth *et al.* 1995).

The Kissimmee River in its present configuration is a channelized canal (C-38) divided into a series of five pools (impoundments) separated by lock and dam structures that were constructed by the Corps from 1962 through 1971 (Fig. 1, Fig. 3). In the mid-1980s, a series of three weirs was constructed to augment the flow through three remnant channels along Pool B (Fig. 3). These partially restored remnant channels, with their increased circulation under high flow conditions, represent the best example of some of the characteristics that would be expected in the rehabilitated channel system (papers in Dahm 1995, Toth 1996).

All the aquatic plant bed, macroinvertebrate diversity, density, functional group designation, and drift studies, and fish sampling were conducted within a 1000 meter reach of the lower (furthest down river) remnant meander channel of Pool B (Fig. 3). The riparian marsh along this section of river is dominated by the littoral plants *Nuphar luteum* (spatterdock) and *Polygonum densiflorum* (smartweed) and the broadleaf marsh plants *Pontederia cordata* (pickerelweed), *Sagittaria lancifolia* (arrowhead), and *Panicum hemitomum* (maidencane). Floating plants, the native *Pistia stratiotes* (water lettuce) and the exotic *Eichornia crassipes* (water hyacinth) and *Salvinia minima* (common salvinia fern), are variously found interspersed in open spaces in the riparian marsh.

MANAGEMENT GOALS

The management goals for the Kissimmee River restoration are to reconnect the approximately middle third of the channelized river with its floodplain and to instigate a more natural flow regime through changes in the present release schedule. The geomorphic alteration will be accomplished by backfilling the existing river with the original fill material along the canal. The inundation of the floodplain and more natural flow patterns is expected to dramatically increase habitat suitability for game fishes, such as the largemouth bass, and for wading birds.

The partnership between the SFWMD and COE has taken an adaptive management strategy. If recovery of plant, invertebrate, fish, and bird populations does not proceed as hypothesized (e.g., Dahm 1995), as compared to levels measured prior to initiation of the physical channel and flow alterations, procedural changes will be explored. Although the concept of alternative strategies or "fine tuning" the restoration has been agreed to, specific plans of action will await data indicting how the habitat restoration is not meeting expectations.

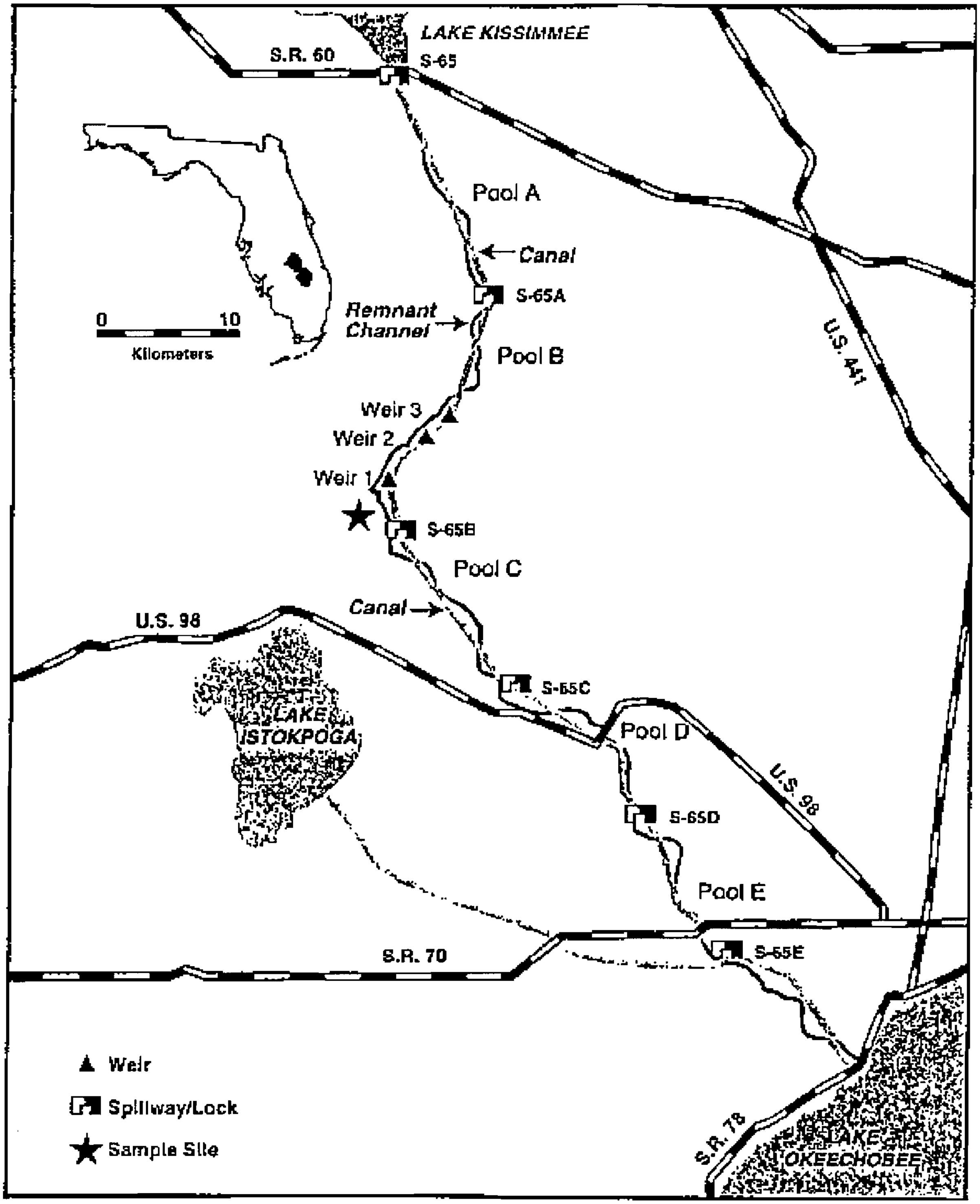


Figure 3. Map of study section of Kissimmee River, Pool B (after Merritt *et al.* 1996).

METHODS

The methods employed to develop the conceptual models presented here involved invertebrate sampling, in the plant beds and in the drift, open and closed system measurements of community metabolism in riparian marsh plant beds, and fish collections by electro-fishing along the lower remnant channel of Pool B.

It is widely held that one of the very best integrative measures of aquatic ecosystem condition is community metabolism (*e.g.*, Vannote *et al.* 1980). The balance between autotrophy and heterotrophy determines the pathway of the major energy transfers in a given system, such as the Kissimmee River riparian marshes. This balance is expressed as the 24 hour P to R ratio, that is the ratio of total gross primary production (P) to total community respiration (R). Littoral plant bed community metabolism studies were conducted in specific spatterdock and smartweed beds that were selected based on the mono-specific nature and size of the stands. Metabolism was measured by following changes in dissolved oxygen using two methods: open system or closed re-circulating chamber measures. The open system measures were made using YSI™ 600 series sondes positioned on PVC rods driven into the sediments in the plant beds and connected to data loggers to record ambient dissolved oxygen over 24 hour periods several cm under the water surface, at mid-depth, and several cm off the bottom. Water depth in these beds was between 0.75 and 1.25 m. Changes in water depth due to boat wakes were monitored with pressure transducers. The 20 liter closed re-circulating chambers (*e.g.*, Dodds and Brock 1998) were arranged in 4 chamber pods that were positioned on the deck of a 40 hp outboard motor-powered pontoon boat that could be moved to the selected plant bed where the measurements were to be made. The deck holding the chambers could be lowered into the water to a desired depth. The submerged portions of plants and their attached periphyton were enclosed in chambers and dissolved oxygen measured over 24-hour periods. Recirculation within the chambers was maintained with axial impellers. Super-saturation and complete oxygen depletion were avoided by opening and flushing the chambers with ambient water when needed. When ambient river water was too high in oxygen, nitrogen gas was bubbled into a head box to create lower oxygen water that was then used to purge the chambers. The re-circulating chambers could also be fitted on to stainless steel bottoms with a flanged opening to the sediment surface. This allowed the plants and roots to remain in tact and for the exchange of subsurface water with the chamber water.

Two types of invertebrate sampling were conducted: 1) plant beds, open sediments, and large woody debris were sampled with a D-frame dip net having an 0.80 mm mesh net; and 2) drift onto and off of the floodplain was sampled with 0.25 mm mesh drift nets. The D-frame net was used by disturbing the upper several cm of sediments and drawing the net along the bottom, up along plant stems, or along the surface of large woody debris for 45 seconds. In sampling the rooted aquatic plants, the net was moved vigorously front to back and side to side during the timed period.

Invertebrate samples from the plant beds were sorted by taxa (generic level in most cases) and categorized according to functional feeding groups (FFG) as given in Merritt *et al.* (1996, 1999) and Merritt and Cummins (1996). The FFG categories are as follows:

Shredders -Herbivore (feed on live macrophyte tissue -vascular plants or macroalgae);
Shredders - Detritivore (feed on coarse particulate organic matter detritus -CPOM);
Scrapers (feed on periphyton);
Plant Piercers (imbibe cell fluids of macroalgae);
Filtering Collectors (filter fine particulate organics -FPOM- from the water column);
Gathering Collectors (feed on depositional FPOM);
Predators (capture live prey which they engulf or pierce and withdraw fluids).

Biomass of the invertebrates sorted to FFGs and measured to length were calculated using INVERTCALC a software program (Cummins and Wilzbach, unpublished) that uses 33 length-mass regressions developed for specific invertebrate taxonomic groupings (see also Smock 1980). As developed in Merritt *et al.* (1996, 1999), various ratios of FFGs, and other functional groups, can be used as surrogates for different aquatic ecosystem attributes. For example, the autotrophic index, that is P/R (autotrophy/heterotrophy), can be predicted by the ratio of the live plant-consuming invertebrates as a proportion of the detrital-consuming invertebrates (Merritt *et al.* 1996, 1999). Table 1 summarizes data from the Kissimmee River, lower remnant channel of Pool B, for the P/R surrogate. P/R ratios have been measured directly as ≥ 1 for *Nuphar* beds and < 1 for *Polygonum* beds in the riparian marsh of that reach of river.

Table 1. The autotrophic/heterotrophic ecosystem attribute (P/R) estimated by macroinvertebrate functional feeding group analysis in *Nuphar* and *Polygonum* plant beds in the lower remnant channel of Pool B of the Kissimmee River. (Table modified from Merritt *et al.* 1996, 1999).

Ecosystem Attribute	FFG Ratio for Estimating Attribute	Predicted Ratio for Attribute	FFG Ratios for *Nuphar* Beds		FGG Ratios for *Polygonum* Beds	
			Number	Biomass	Number	Biomass
P/R (Autotrophy to Heterotrophy Ratio)	Macrophyte Shredders + Scrappers *as a proportion of* CPOM Shredders + Total Collectors	Autotrophic System Ratio > 0.75	Fall 0.42	1.16	Fall 0.39	0.33
			Spring 0.51	0.17	Spring 2.00	0.55

The drift nets used to sample invertebrates moving on to and off of the floodplain (riparian marsh) were deployed in pairs with the openings facing in opposite directions relative to the edge of the channel (Fig. 4). Drift net pairs were positioned at six sampling sites along the remnant channel in locations previously observed to be sites of significant floodplain exchange flows that occur with changing water levels (*i.e.*, on to the floodplain during the rising limb and off of the floodplain during the falling limb of the hydrograph). Sampling was conducted during the wet season (Jan. 27-28 and Feb. 5-6, 1997). Triplicate 0.25 mm mesh drift nets, each approximately 1 m in length with a mouth opening of 0.06 m^2, were located in the open channel above and below the floodplain sampling stations. Six paired drift nets of the same type but with a mouth opening of 0.15 m^2 were positioned at the selected sampling locations at the edge of the floodplain. Sampling was from dusk to dawn on each sampling date and the current velocity at the mouth of each net was measured with a Marsh McBirney™ digital flow meter at the time of pick up.

Largemouth bass (*Micropterus salmoides*)) and bluegill (*Lepomis macrochirus*) were collected for gut analyses with a boat-based electro-shocker. Fish were collected on each drift sampling date from the general area of drift sampling immediately after retrieval of the drift nets (early morning). Fish diets were characterized by frequency of occurrence and percent composition (Bowen 1983).

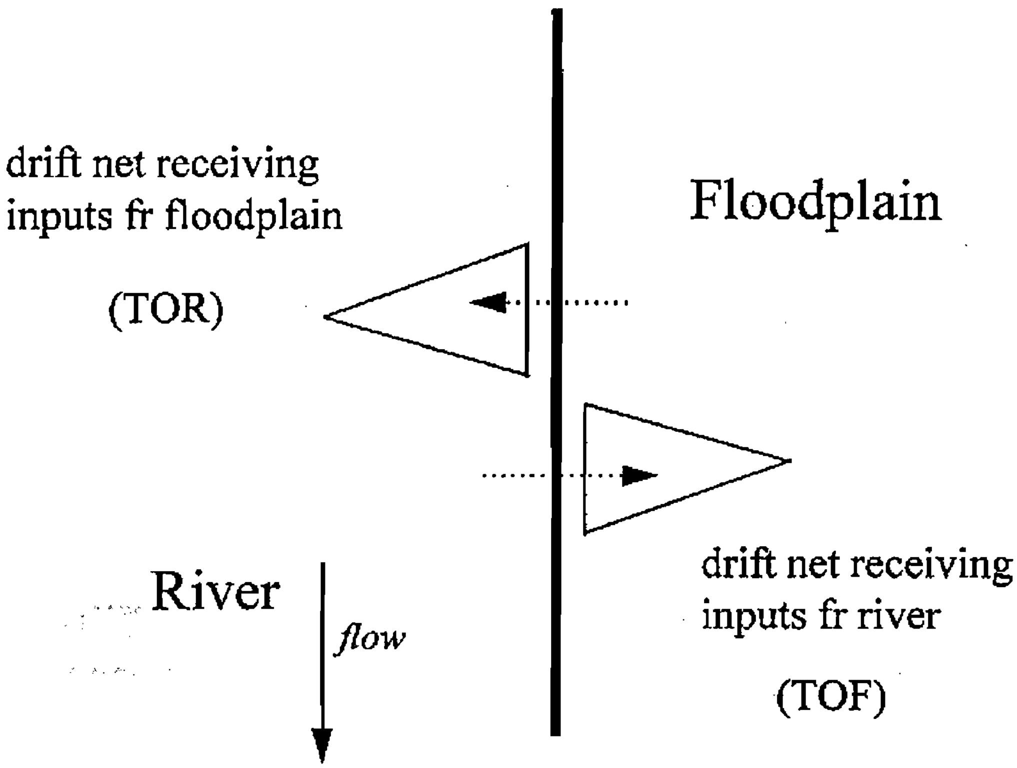


Figure 4. Drift net positioning for invertebrate movement studies.

CONCEPTUAL MODELS

The conceptual models presented here were developed after analysis of the plant metabolism, invertebrate distribution, abundance, community functional organization, and drift, and fish data. Given all the potential sources and sinks for dissolved oxygen in the riparian marsh littoral plant beds (Fig. 5), the most significant ones were identified. The two dominant sources of DO are re-aeration at the water surface and photosynthetic oxygen production by periphytic algae on submerged plant stems, leaves, and adventitious roots. The primary DO sink in the system was clearly microbial respiration associated with decaying plant litter in and on the sediments. Measurements using chamber bottoms open to the sediments that allowed exchange between chamber water and ground water revealed that gain from oxygen-depleted ground water or loss of oxygenated chamber water to subsurface reservoirs acted as a DO sink. However, when measured in littoral plant beds in a remnant channel of Pool C, the maximum effect was less than 10% over 24 hours. Thus, P (gross primary production), R (total community respiration) and re-aeration (RA) were the main components built into the conceptual model of the two dominant plant bed types in the Kissimmee River riparian marsh. The importance of net primary production in generating DO is seen clearly in a six day continuous measure of dissolved oxygen and PAR light available (Fig. 6). The increase in temperature over the period decreased the DO slightly (due to reduced solubility), but the general pattern of light driving photosynthetic DO generation remained the same over the record.

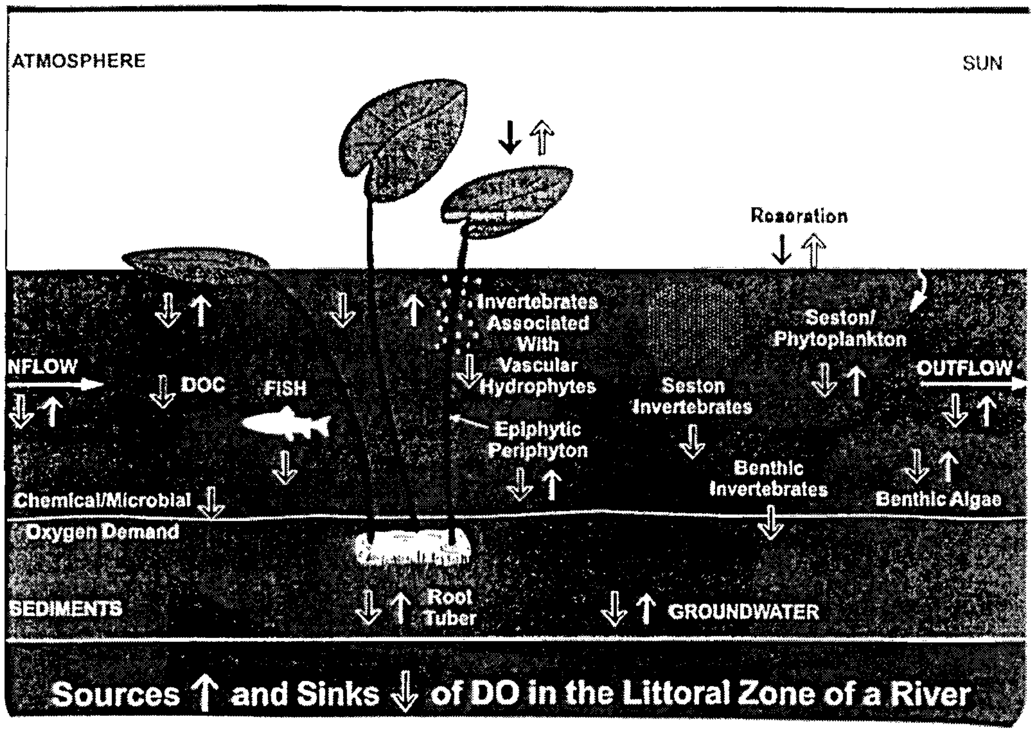


Figure 5. Potential sources and sinks of dissolved oxygen in riparian marsh littoral zone plant beds in the Kissimmee River.

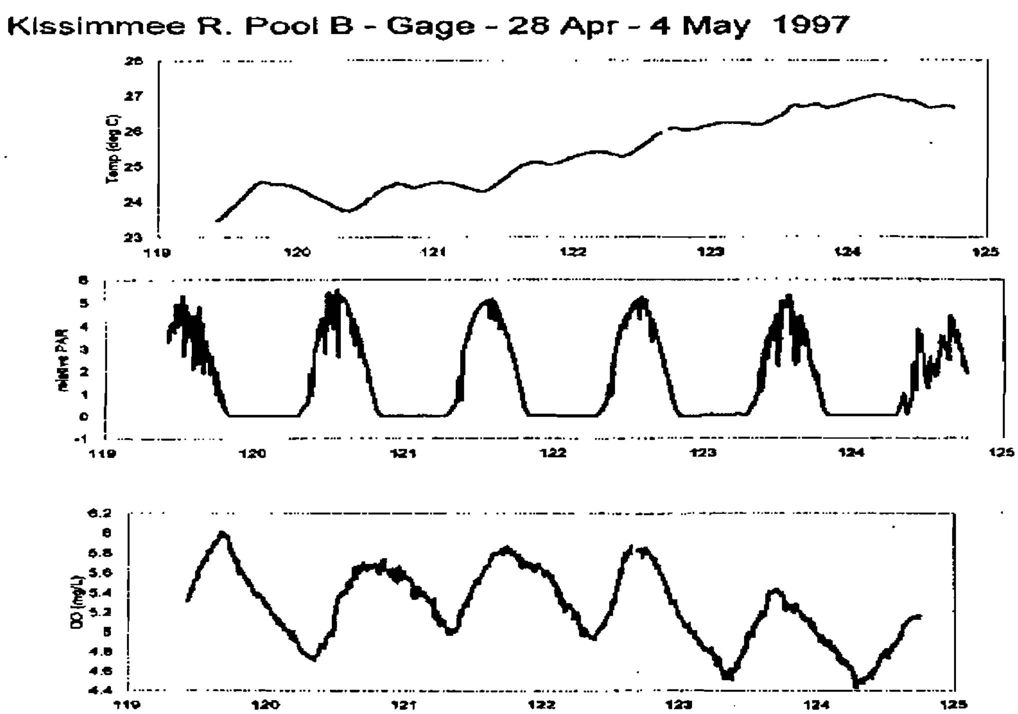


Figure 6. Six day record of temperature, light, and DO at mid-depth in the open channel of Pool B.

The stem densities and percent foliar coverage at the surface differs significantly between the two plant types. The mean stem density of *Nuphar* was measured as 15 and 46 for *Polygonum*. The effect of cover on light penetration into the bed, for example to reach the periphyton on the plant stems, was correspondingly different between the two. Meter square photos of dense and sparse beds of *Nuphar* and *Polygonum* are shown in Fig. 7 and the differences in light attenuation in median stem density beds of the two species as compared to the open channel are given in Fig.8. Light penetrates into the *Nuphar* beds essentially the same as in the open channel while penetration of PAR is 10 to 20 % less in the *Polygonum* beds. Although, as shown in Fig. 8, the PAR transmission into *Nuphar* beds is the same as into the open channel water, the photosynthetically derived DO is slightly greater in the beds than in the open water. This difference in periphytic DO production is significantly greater in *Nuphar* than in *Polygonum* beds, differing by between 1 and 2 mg/l (Fig. 9). Because DO often reaches critical levels for game fish such as centrarchids, this difference in availability could be quite significant for fish survival.

A conceptual model also was developed to capture the primary patterns of movement of invertebrates and fish on to and off of the floodplain (riparian marsh) based on directional drift net collections and the analysis of the digestive tracts of fish taken in each of the areas where drift nets had been deployed (Fig. 10). The accidental or passive drifters, such as copepods, were found in increasing numbers in the drift when flows increased between January and February. The pattern of increased drift was the same in the main channel, where median flows increased from 6.1 cm/s in January to 19.8 cm/s in February, and onto (0.05 cm/s to 0.3 cm/s) and off of (0.9 cm/s to 3.3 cm/s) the floodplain. In contrast, the behavioral or active drifter *Hyalella* (amphipod) showed increased transport in the main channel, but was able to migrate against the flow gradients on to and off of the floodplain (Fig. 11). The conceptual model (Fig.10) emphasizes the coupling processes that link those centered primarily on the floodplain with those taking place largely in the main channel. A comparison of relative abundance of invertebrate taxa in the drift (lower curve) with those recovered from the digestive tracts of centrarchids, show the much greater dependence of bluegill on drift than largemouth bass (Fig. 12).

An additional component of the model of invertebrate drift on to and off of the floodplain could be the influence of disturbance caused by boat wakes which could dislodge animals increasing passive (accidental) drift (Fig. 10). An example of the potential effect of changes in water level can be seen in a three day pattern of sudden changes measured at a fixed point in a *Nuphar* plant bed in the lower remnant channel of Pool B in May (Fig. 13). These sudden changes in depth of up to over 3 cm could easily dislodge and/or move non-active drifters. The boat wake trace reflects well known weekend fishing activity patterns in the Kissimmee River remnant channels. It is interesting to speculate that if the Kissimmee River restoration is successful at increasing habitats favorable for sport fishing, boating would be expected to increase markedly and this could significantly increase invertebrate drift exchange between the channel and floodplain.

Invertebrate functional feeding group(FFG) analysis predicts that in the Kissimmee River remnant channels of Pool B, the *Nuphar* beds are autotrophic in the fall but in the spring and in both seasons in *Polygonum* beds conditions are heterotrophic (Table 1). The expected invertebrate surrogate P/R ratio calculated on a biomass basis because it normalizes for size differences. Numerical ratios usually agree with those based on biomass, providing the calculations are made when most populations are dominated by median or greater sized (age) individuals. For example, large numbers of small autotrophically based invertebrates were encountered in the Kissimmee River remnant channels in the spring in *Nuphar* beds (Table 1). The expected FFG ratio of >0.75 for the autotrophic P/R >1 surrogate is derived from the lotic literature (*e.g.*, Cummins *et al.* 1981) and measurements made directly by the authors in other studies.

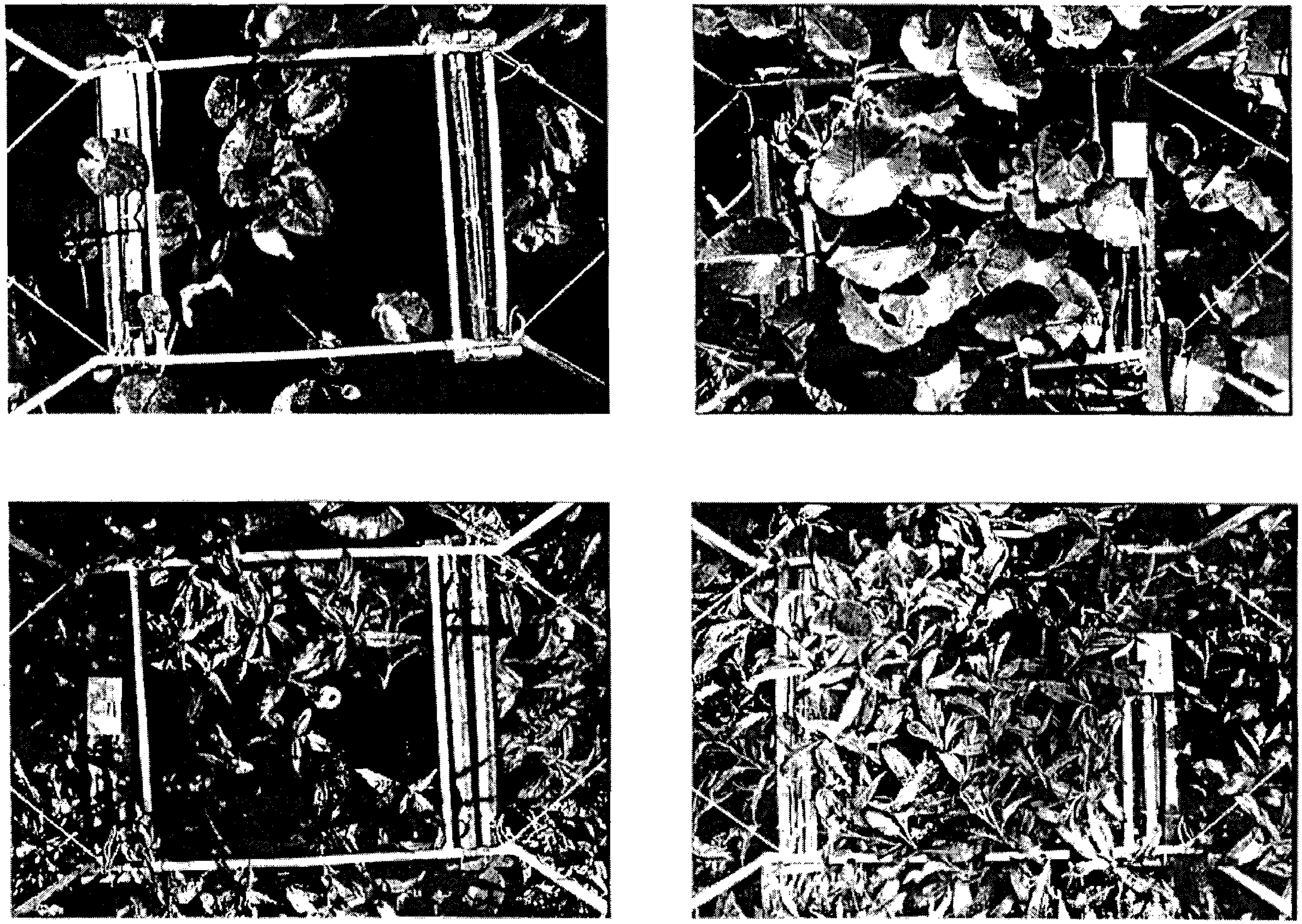


Figure 7. Sparse and dense (left to right) cover examples for *Nuphar* (above) and *Polygonum* (below) in the remnant channel of Pool B.

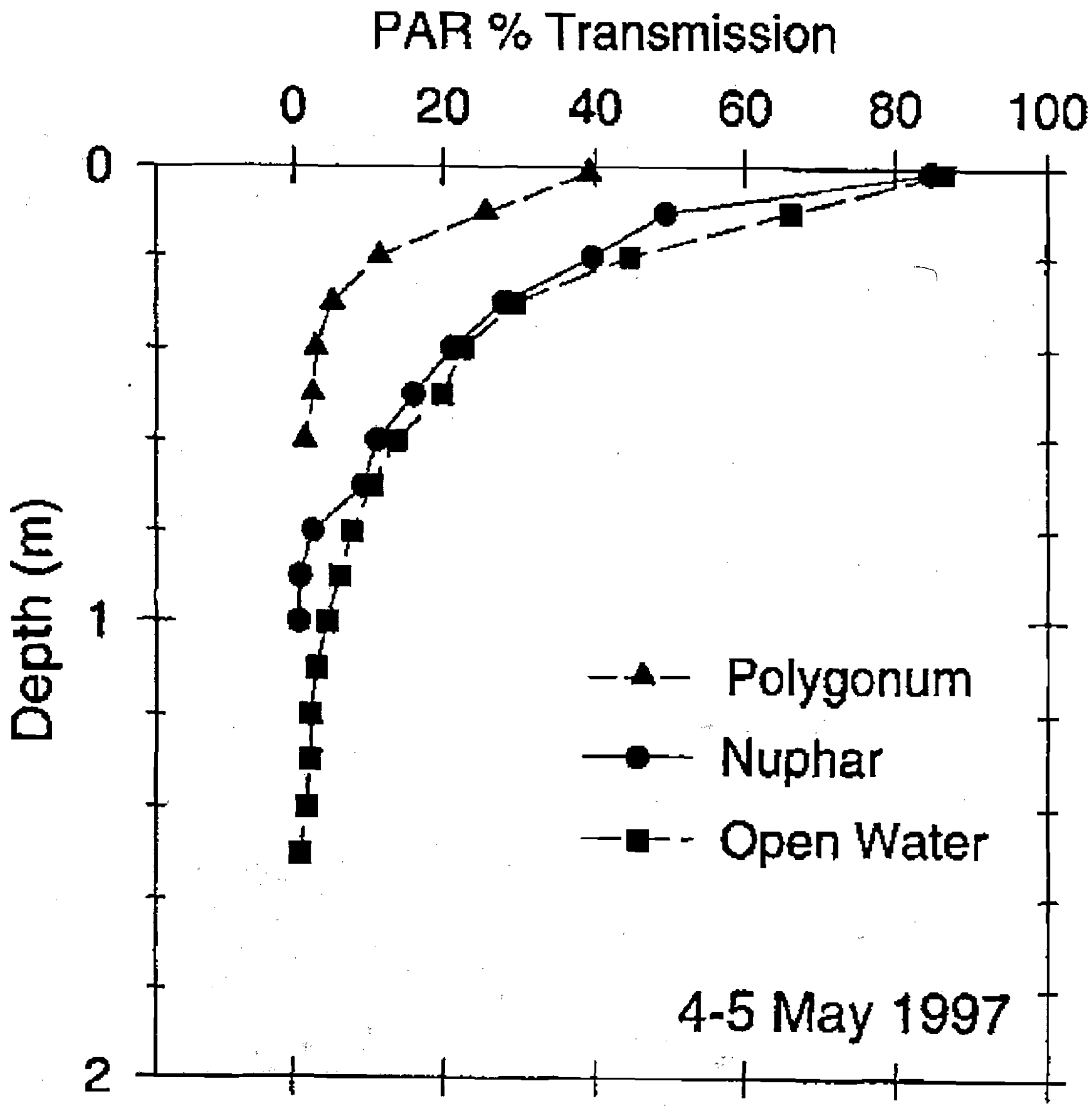


Figure 8. Comparison of PAR transmission into *Nuphar* and *Polygonum* beds and the open channel in Pool B.

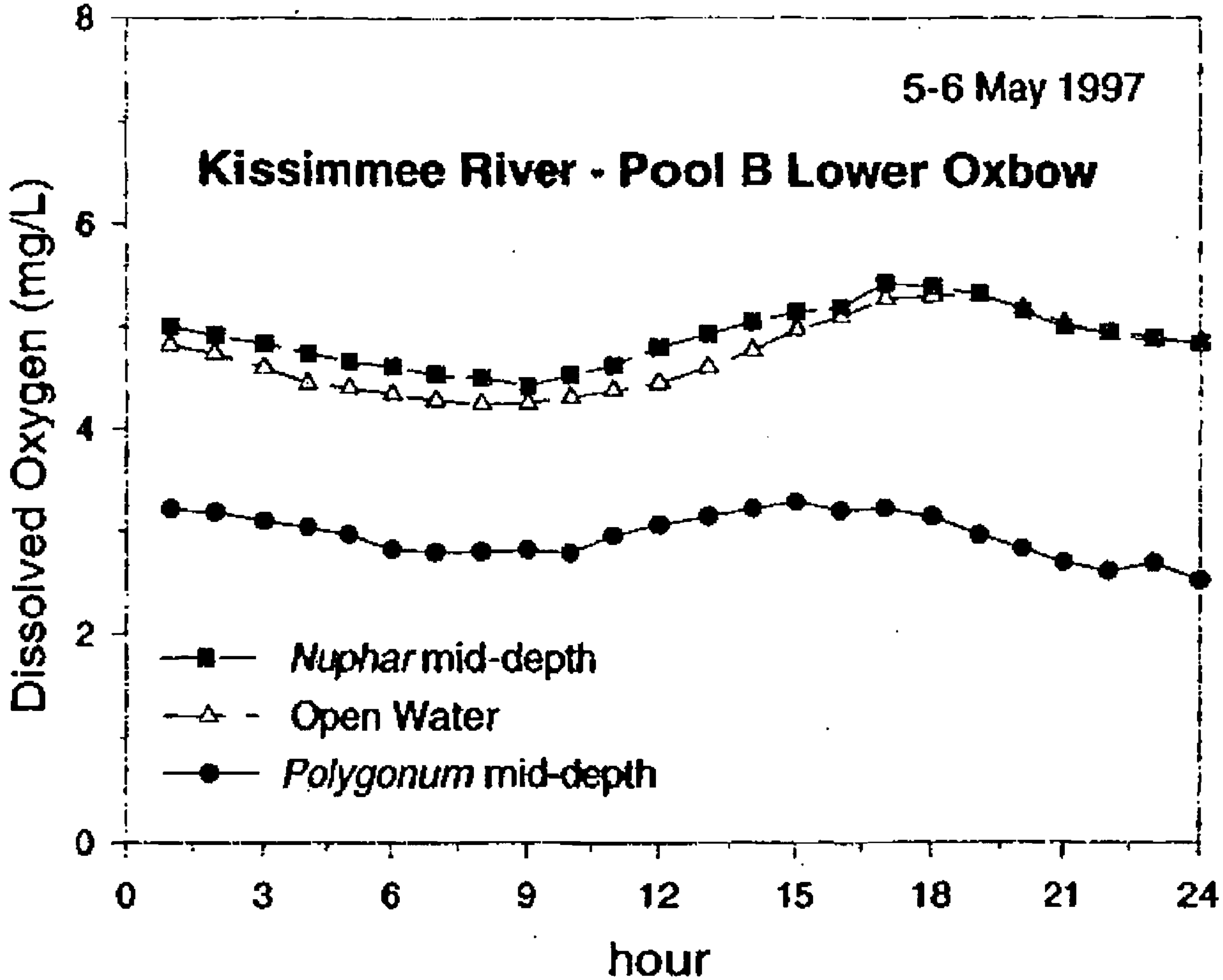


Figure 9. Comparison of 24 hour DO levels in *Nuphar* and *Polygonum* beds and the open channel in Pool B.

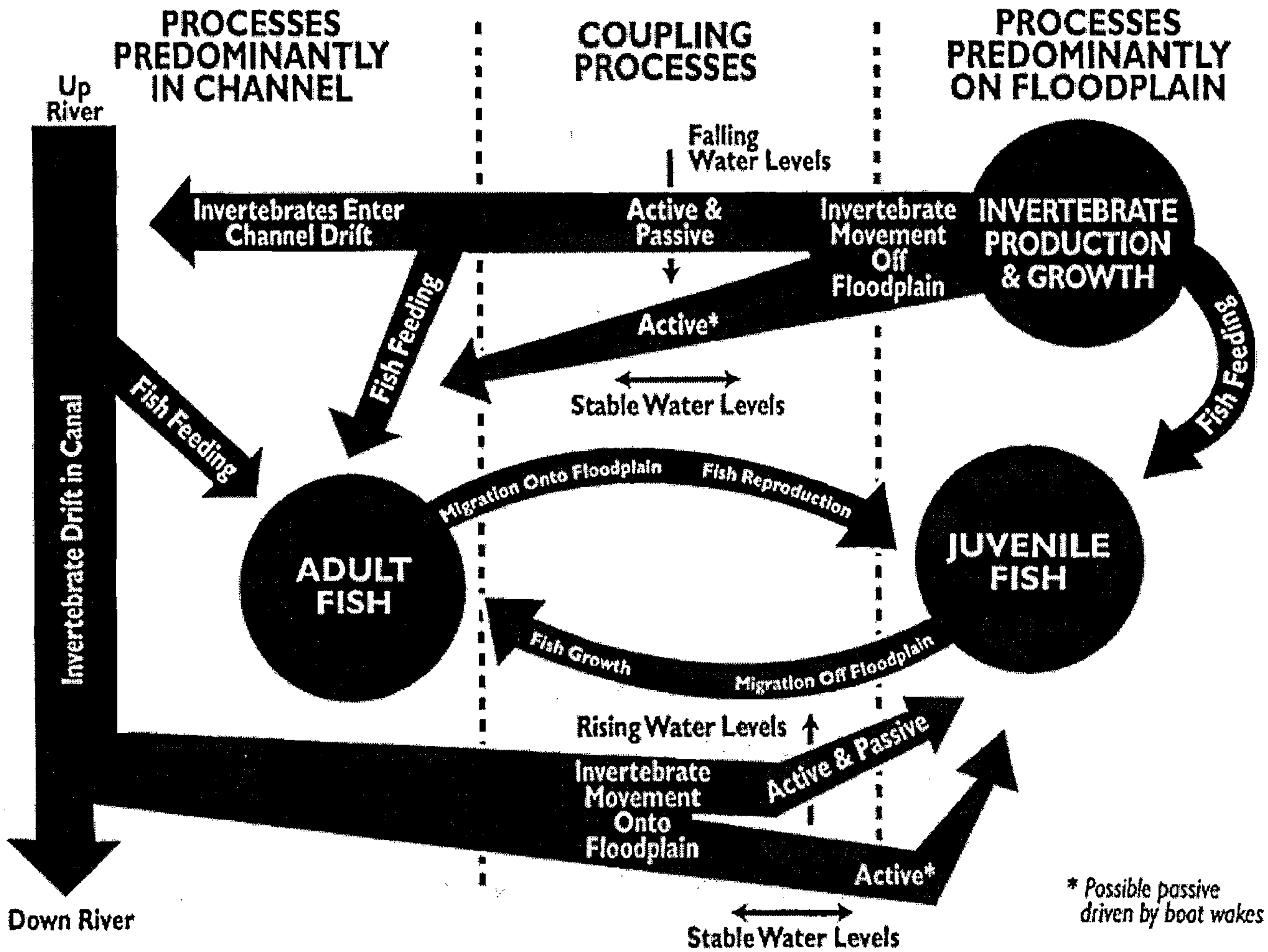


Figure 10. Conceptual model of invertebrate drift (active and passive) and fish feeding across the interface between the open channel and the floodplain (riparian marsh).

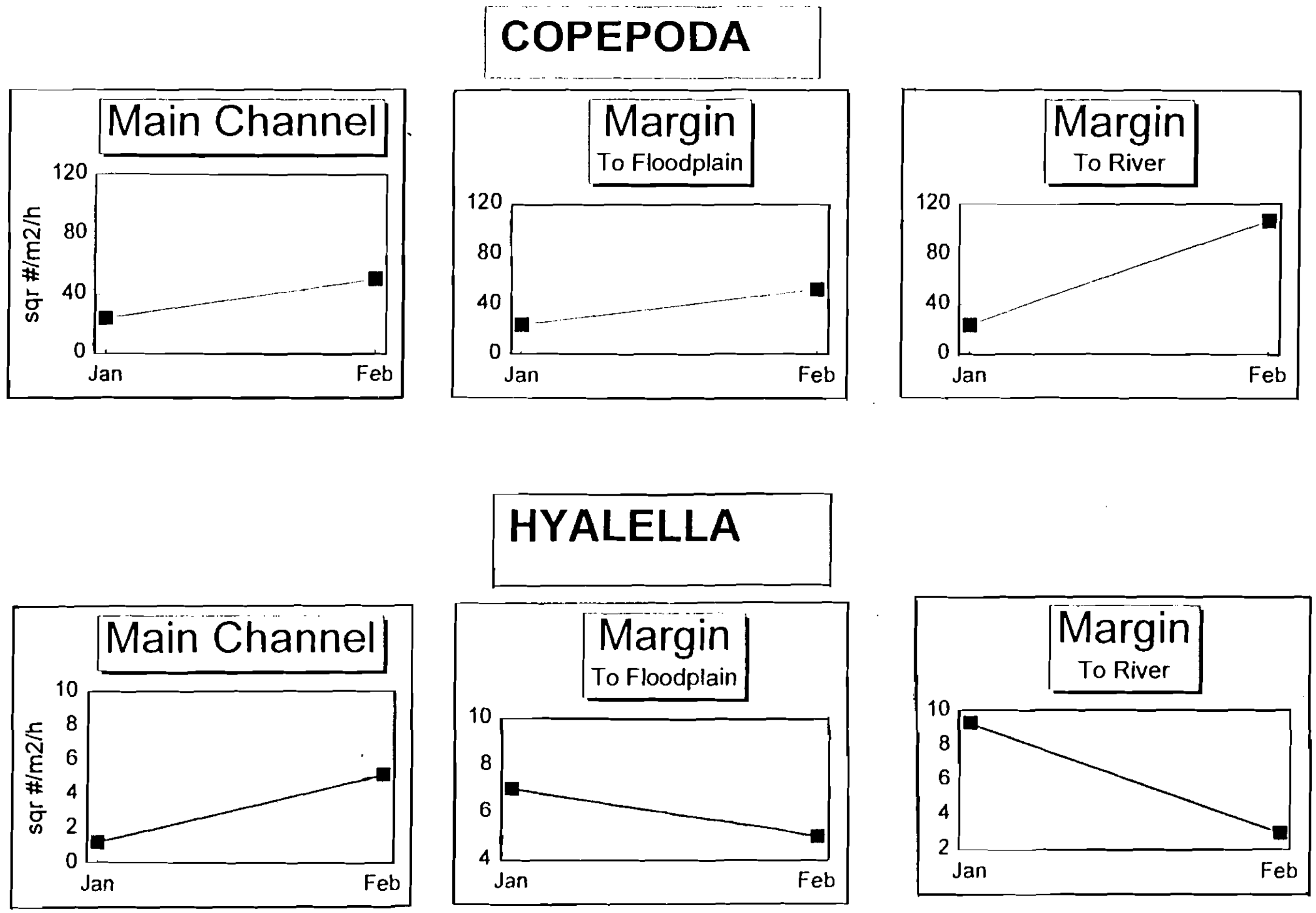


Figure 11. Comparison of movement in the main channel and on to and off of the floodplain between the passive drifting copepods and active drifting amphipods. Flows were three times higher in February than in January.

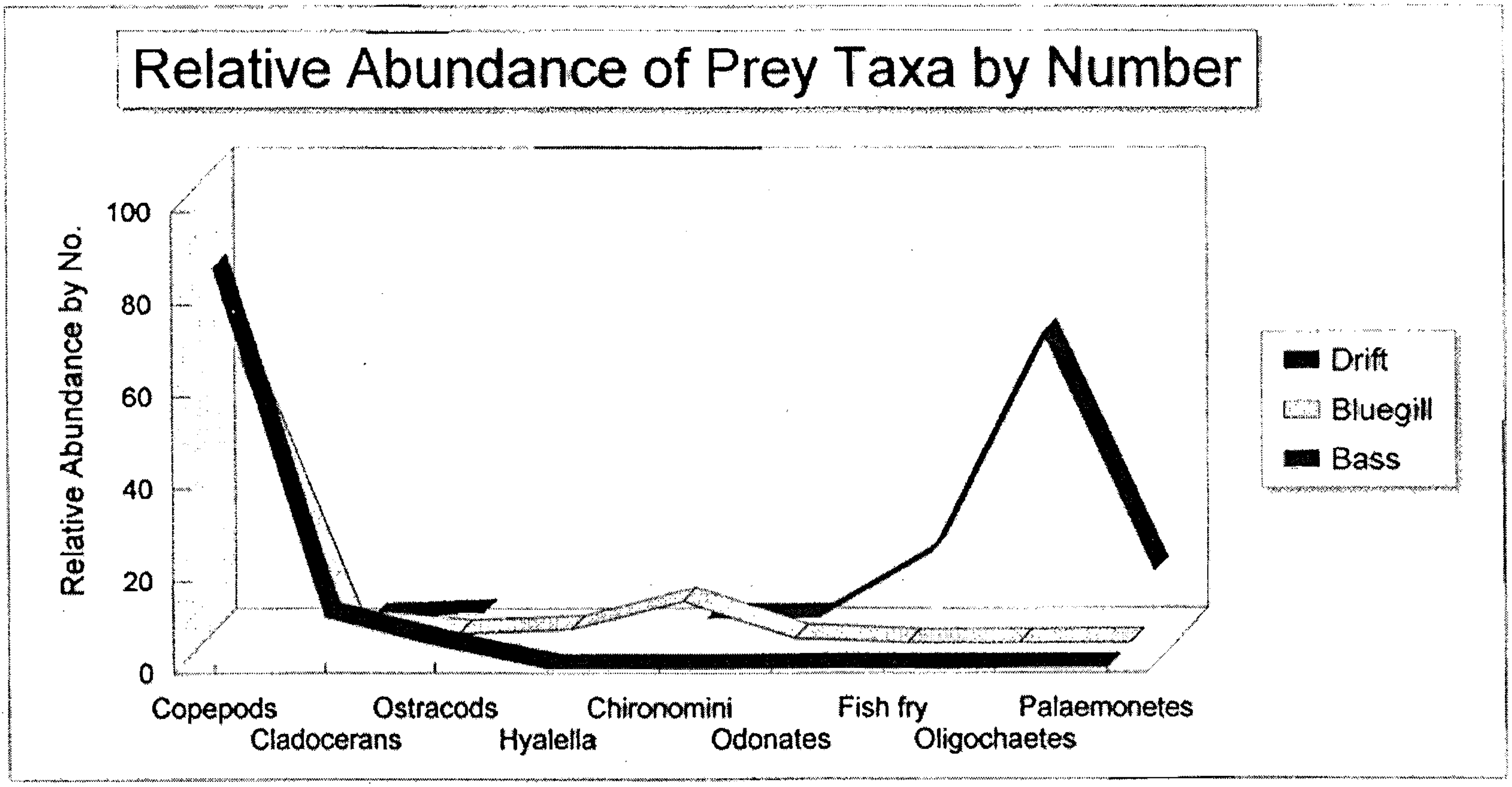


Figure 12. Comparison of the relative abundance and biomass of invertebrate taxa recovered from the drift (lower curve) with those found in bluegill (middle curve) and largemouth bass (upper curve) stomachs.

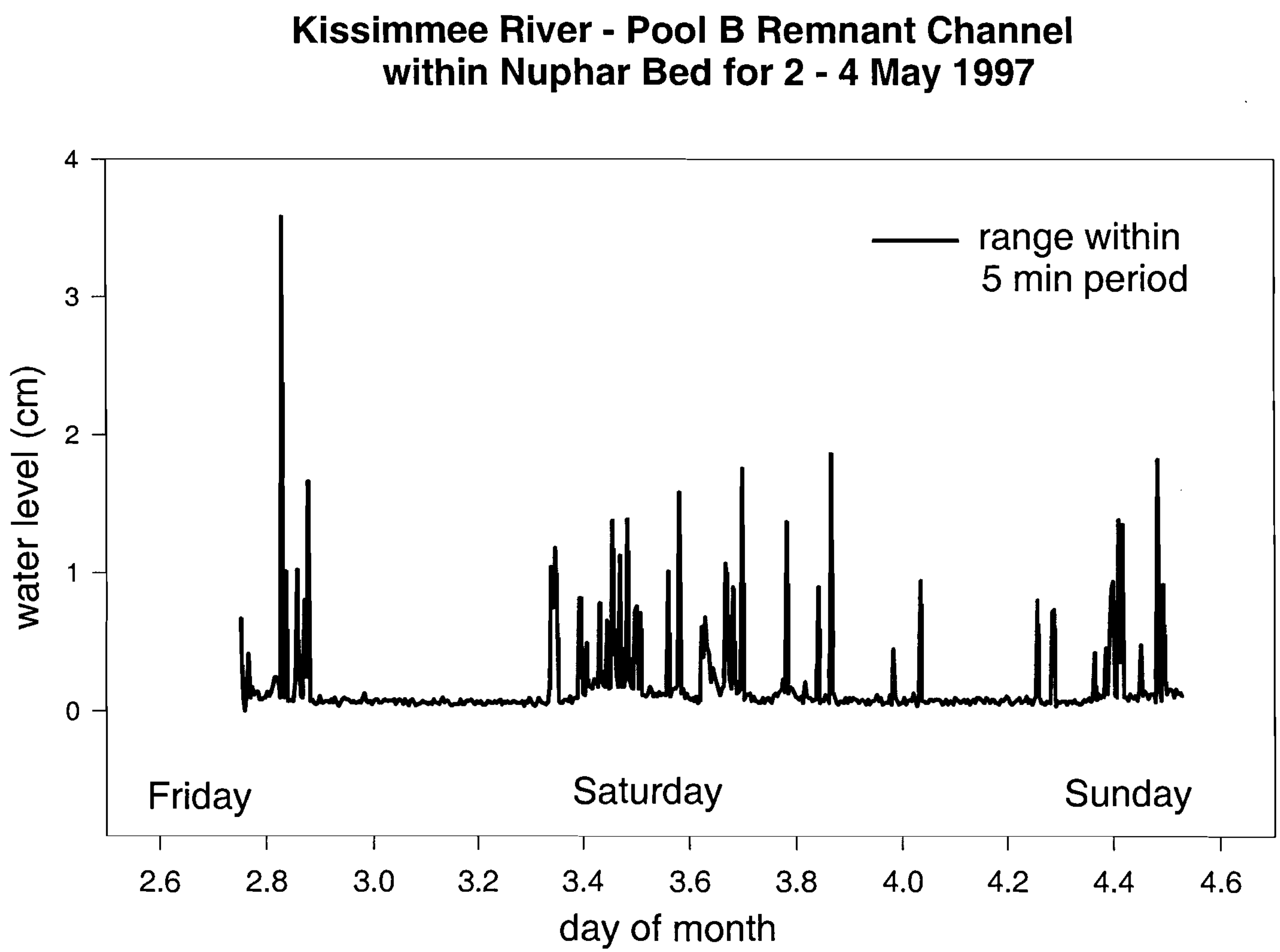


Figure 13. Sudden changes in water column depth produced by boat wakes over a three day period in a *Nuphar* bed in the lower remnant channel of Pool B of the Kissimmee River.

The facultative scraper (*Hyallela azteca*) and shredder (*Palaemonetes paludosus*) in the remnant channels of Pool B have been proposed as keystone species on the basis of their abundance in the two plant bed types and importance in fish digestive tracts (Merritt *et al.* 1999). *Hyallela*, as a facultative periphytic algal scraper, that is more abundant in the open *Nuphar* beds while *Palaemonetes*, the facultative detrital shredder, is more abundant in the dense *Polygonum* beds (Table 2). A conceptual model has been developed (modified from Merritt *et al.* 1999) that summarizes the relationships between plant bed types, autotrophy and heterotrophy, keystone invertebrate species, the links to wading birds and game fish, and the drivers that might manipulated in an adaptive management strategy to shift the balance between the two basic pathways (Fig. 14). Because the large game fish the largemouth bass utilizes the open stem habitats (*e.g.*, *Nuphar*) for cover but depends on *Palaemonetes* which are more abundant in dense, closed stem habitats (*e.g.*, *Polygonum*) edges between the two bed types may be the critical habitat feature. This suggests that, as much as possible, the management strategy should be to use the drivers to favor a larger number of smaller beds of juxtaposed *Nuphar* and *Polygonum* than larger beds of the two. As part of the adaptive management strategy, it would be advantageous to follow the development of new plant bed areas with quarterly areal photography and adjust flow regimes and/or use selective cutting to influence the configuration of the beds as they develop.

Table 2. The relationship between two proposed keystone invertebrate species and the two dominant plant bed types of the riparian marsh of the lower remnant channel of Pool B of the Kissimmee river. *Hyallela azteca* is a facultative scraper that feeds on periphyton primarily on plant stems and *Palaemonetes paludosus* is a facultative CPOM shredder feeding primarily on aquatic plant leaf litter. (modified from Merritt *et al.* 1999)

Plant Type	Keystone	Total Number	Total Biomass	Mean	Mean
Nuphar	*Hyallela*	247	202.3	49.4	14.8
	Palaemonetes	26	48.6	5.2	9.7
Polygonum	*Palaemonetes*	101	709.8	20.2	141.9
	Hyallela	53	74.1	10.6	4.1

CONCLUSIONS

The Kissimmee River restoration (rehabilitation), the largest project of its kind ever attempted, depends on the physical alterations achieved by back filling of the canal and modifications in the regulation of seasonal flows in the river (*e.g.*, Toth 1993, 1996). Modification of flow regimes will be achieved by changes in the releases from the control structure at the outlet of Lake Kissimmee, at the head of the Kissimmee River (Fig 1). The evaluation of the success of the rehabilitation endeavor, in which success is measured as the spread and/or recovery of designated ecosystem components, will be focused largely on specific populations of organisms. Particular importance is afforded aquatic and semi-aquatic plants, water birds, and game fish (*e.g.*, Dahm 1995). Additional attention has been directed at general ecosystem attributes, such as the balance between autotrophy and heterotrophy, as reported in this paper. Because the overall outcome of the restoration (rehabilitation) may well depend on the balance between these two pathways (*e.g.*, Fig 14), the drivers that control the development of the alternatives will need to be watched closely, and manipulated, when possible, to achieve the apportionment sought by the restoration managers. This sort of manipulation, continually focused to achieve the desired ecosystem structure and function, is part and parcel of the adaptive management process.

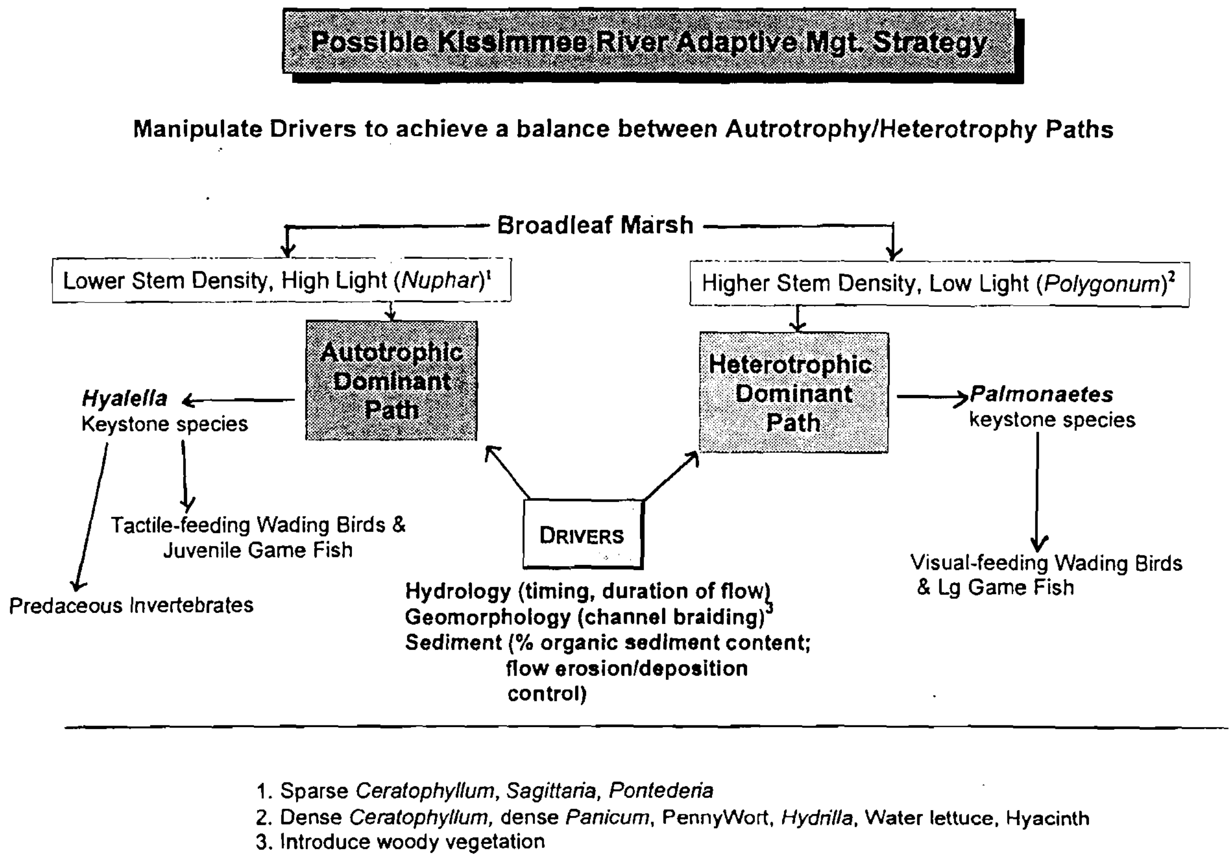


Figure 14. A conceptual model linking proposed keystone invertebrate species with higher trophic levels as part of autotrophic and heterotrophic dominated pathways and showing some drivers that potentially influence which pathway will dominate.

LITERATURE CITED

Bowen, S.H. 1983. Quantitative description of diet. Pp 325-336 *in:* Fisheries techniques (L.A. Neilsen and D.L. Johnson, eds.). American Fisheries Society, Bethesda, MD.

Cummins, K.W., M.J. Klug, G.M. Ward, G.L. Spengler, R.W. Speaker, R.W. Ovink, D.C. Mahan, and R.C. Petersen. 1981. Trends in particulate organic matter fluxes, community processes, and macroinvertebrate functional groups along a Great Lakes drainage basin river continuum. *Verh. Internat. Verein. Limnol.* 21:841-849.

Dahm, C.N. (ed.). 1995. *Restoration Ecol.* 3(3):145-238. (*Entire issue devoted to the Kissimmee River restoration*).

Dodds, W.K. and J. Brock. 1998. A portable flow chamber for *in situ* determination of benthic metabolism. *Freshwat. Biol.* 39:49-59.

Koebel, J.W., Jr. 1995. An historical perspective on the Kissimmee River restoration project. *Restoration Ecol.* 3:149-159.

Merritt, R.W. and K.W. Cummins (eds.). 1996. An introduction to the aquatic insects of North America. Kendall/Hunt, Dubuque, IA.

Merritt, R.W., J.R. Wallace, M.J. Higgins, M.K. Alexander, M.B. Berg, W.T. Morgan, K.W. Cummins, and B. VandenEeden. 1996. Procedures for the functional analysis of invertebrate communities of the Kissimmee River-floodplain ecosystem. *Fl. Scient.* 59:216-274.

Merritt, R.W., M.J. Higgins, K.W. Cummins, and B. VandenEeden. 1999. The Kissimmee River-Riparian marsh ecosystem, Florida: seasonal differences in invertebrate functional feeding group relationships. Pp 55-79 *in:* Invertebrates in freshwater wetlands of North America: ecology and management (D.P. Batzer, R.B. Rader, and S.A. Wissinger, eds.). John Wiley & Sons, Inc., New York, NY.

Smock, L.A. 1980. Relationships between body size and biomass of aquatic insects. *Freshwat. Biol.* 10:375-383.

Toth, L.A. 1993. The ecological basis of the Kissimmee River restoration plan. *Fl. Scient.* 56: 25-51.

Toth, L.A. 1996. Restoring the hydrogeomorphology of the channelized Kissimmee River. Pp. 369-383 *in:* River channel restoration: guiding principles for sustainable projects (A. Brookes, and F.D. Shields, Jr., eds.), John Wiley & Sons, New York, NY.

Toth, L.A., D.A. Arrington, M.A. Brady, and D.A. Muszick. 1995. Conceptual evaluation of factors potentially affecting restoration of habitat structure within the channelized Kissimmee River ecosystem. *Restoration Ecol.* 3:160-180.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. *Can. J. Fish. Aquat. Sci.*37:130-137.

STATUS OF RESTORATION OF FRESHWATER WETLAND HABITATS: VIEWS FROM THE MID-SOUTH

MARJORIE M. HOLLAND[1] AND CHARLES M. COOPER[2]

[1]Department of Biology, The University of Mississippi, University, MS 38677
[2]USDA-Agricultural Research Service National Sedimentation Laboratory, Oxford, MS 38655

INTRODUCTION

In the early 1990s, The Ecological Society of America proposed The Sustainable Biosphere Initiative (SBI) in response to calls from the scientific community and policy makers to set overarching priorities for ecological research. The response resulted in development of a framework for acquisition, dissemination, and utilization of ecological knowledge (Lubchenco *et al.* 1991). The SBI focuses on the necessary role of ecological science in wise management of resources for maintenance of life support systems (Lubchenco *et al.* 1991). The SBI proposed research in three priority areas: global change, biological diversity, and sustainable ecological systems. After a successful launching of the broad SBI, the Freshwater Imperative (FWI) Research Agenda (Naiman *et al.* 1995) was envisioned as a more focused initiative concentrating on freshwater issues. The FWI agenda proposes establishment of long-term programs for freshwater research relating directly to improved understanding of wetland characteristics and watersheds of which they are a part. Current research agendas such as SBI (Lubchenco *et al.* 1991), FWI (Naiman *et al.* 1995), and the agenda developed by the Organization of Biological Field Stations (Lohr *et al.* 1995) have set priorities establishing long-term programs for freshwater research relating directly to improving watershed management and sustainability. With widespread manipulation and alteration of watershed dynamics, watershed data acquisition is essential. This paper provides an overview of current research efforts to rejuvenate freshwater wetland habitats in the Mid-South region of the USA.

Two research needs articulated in the SBI report which form the basis of current work described here are (1) to determine patterns and indicators of ecological responses to stress, leading to technologies necessary to assess the status of ecological systems, to forecast and assess stress, and to monitor the recovery of damaged ecological systems, and (2) to accelerate the basic science of restoring damaged and degraded ecological systems, by developing, testing, and applying principles of restoration ecology. Of particular interest has been resiliency or ability of a system to respond to stress (Holland 1996), or the ability of a system to return to its pre-perturbation condition. The overall integrating focus for research described here has been the response of components of freshwater wetlands (water quantity and quality, vascular plants, and soils) to various types of natural or anthropogenic stress.

While the notion of ecosystem *resilience* has just been mentioned, two other words that begin with "*re*" need definition. According to a recent committee convened by the National Academy of Sciences (1992) *rehabilitation* is "used primarily to indicate improvements of a visual nature to a natural resource; putting back into good condition or working order." *Restoration*, on the other hand, is defined by the same committee (National Academy of Sciences 1992) as the "return of an ecosystem to a close approximation of its condition prior to disturbance." We suggest that when the resilience of a system is understood, then similar degraded systems can more easily be rehabilitated or restored.

CHARACTERISTICS OF THE MID-SOUTH

The USA Mid-South region encompasses those States bordering the lower Mississippi River and presents numerous opportunities for addressing questions related to freshwater habitats, ranging from the response to stress of various systems to conservation biology to economic development issues. Since we are based in Oxford, Mississippi, our focus is on case studies with which we have become directly involved throughout the Mid-South region. Streams flowing through Oxford empty into the Yazoo-Tallahatchie River system, and then into the Mississippi River (Fig. 1). Thus, our examples come primarily from the Yazoo River drainage. The Yazoo Basin is representative of degraded watershed streams in hill lands that drain into the Mississippi River from Iowa to Mississippi. Many of the structural and non-structural measures described here are applicable to stream problems along both USA coasts as well as on other continents.

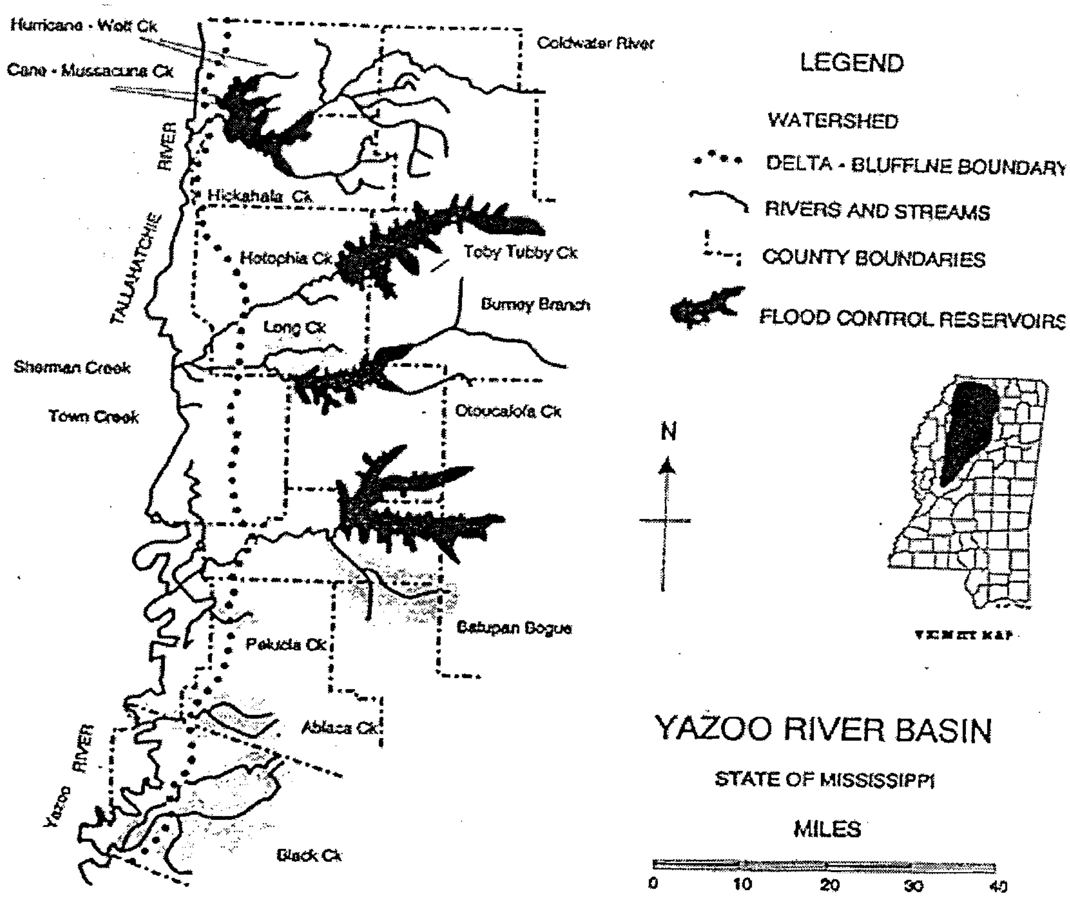


Figure 1. Map showing locations of the Demonstration Erosion Control Project watershed.

Physical characteristics

Undoubtedly the best source of information about pre-settlement and early settlement conditions throughout northern Mississippi is gained from writings of Dr. E. N. Lowe, an employee of the Mississippi State Geological Survey in the early 20th century, who was not only a perceptive geologist, but a good botanist as well (Lowe 1910, 1921). The foothills of the Yazoo Basin (Fig. 1) in Mississippi have a loess cap covering unconsolidated gravels and clays, but no rock formations are apparent. These layers overtop sand; thus, permanent bed controls are non-existent (Cooper *et al.* 1996). The upper Yazoo Basin lies within the Gulf Coastal Plain (Fig. 1) Physiographic Province. Average annual precipitation is on the order of 127 cm, mostly from intense thunderstorms (Watson *et al.* 1997).

Historical background of erosion problems

The erosional history of the Yazoo Basin in northwestern Mississippi is representative of similar small stream valleys draining into the Lower Mississippi River. Erosional history of these streams can be divided into four time periods: (a) early history to 1910; (b) the Drainage District period to 1939; (c) federal involvement from 1940 to 1984; and (d) the time of implementation of the Demonstration Erosion Control project from 1985 to present (Watson *et al.* 1997). Throughout the 1800s with the removal of the Native Americans to lands west of the Mississippi River, a period of aggressive expansion of agricultural development began. The net result of this period of massive land use change, from virgin forest with very little cultivation to aggressive cultivation of hills, was erosion of soil from cultivated hills into the floodplain and channels of the valleys. Clearing and farming of the region brought massive erosion, gully formation and sedimentation problems. Loess soils rapidly eroded from hilltops and side slopes and filled valleys with over a meter of new sediment. With increasing upland erosion, silt and debris accumulation restricted channel capacity. Thus, between 1919 and 1924, laws were enacted to create 95 swamp land districts and drainage districts (Watson *et al.* 1997). However, these laws had no provisions for coordination between districts, fostering no concern for how the districts affected one another, and resulting in increasing mismanagement of resources.

As a result of the landscape erosion, Congress declared the area a national disaster and passed the Flood Control Act of 1954 (P.L. 534). This program established a massive flood prevention program and stabilized much of the local landscape but did little to reverse channel erosion processes. Channel incision from several causes (lowering of local river levels, channelization of downstream portions of streams, knickpoints, and excessive stream energy) was followed in many streams by explosive channel widening (Cooper *et al.* 1996). By the mid-1950s, watershed planning was underway by the USDA Soil Conservation Service (SCS). The SCS planning efforts were an improvement over the earlier district planning efforts in that SCS urged that planning was made on a total watershed basis without restriction by county boundaries, and effective upland soil conservation practices were designed to reduce sediment supply (Watson *et al.* 1997). Continuing flooding, erosion, and sedimentation problems in the Yazoo Basin required a truly joint coordinated approach toward their solution; thus, legislation was enacted in 1984 establishing the Demonstration Erosion Control Project (DEC). This was a milestone in cooperative effort between the U.S. Army Corps of Engineers, the USDA/ NRCS, and the USDA- Agricultural Research Service National Sedimentation Laboratory. Legislation authorized these agencies to work collaboratively on a program to demonstrate, on a watershed system basis, methods of reducing flooding, erosion, and sedimentation in several watersheds of the foothills area in the Yazoo Basin (USDA Soil Conservation Service 1989).

By 1985, the Demonstration Erosion Control (DEC) project was in place. The DEC project provides for development of a system for control of sediment, erosion, and flooding in the hill areas of the Yazoo Basin, Mississippi, and long-term monitoring of the performance of constructed facilities, overall system response of channel rehabilitation measured in sediment yield reduction, and monitoring of habitat enhancement. Since all team members are very much aware of the finite financial resource base available to DEC, decisions on allocation of human and financial resources must be based on evidence of the most critical erosion problems. Perhaps most importantly, each of the groups involved in the DEC project have become collaborative participants in a feedback loop which offer suggestions based on sound science to continuously evaluate and improve the project (Watson *et al.* 1997).

EXAMPLES OF EFFORTS TO RESTORE FRESHWATER WETLAND HABITATS

In the next few paragraphs, we have chosen to present overviews of examples of Oxford-based efforts to understand, maintain, or restore freshwater wetland habitats. These efforts may be separated into two general categories: (A) efforts designed to prevent or minimize habitat degradation, and (B) efforts designed to determine attributes of functional systems. The goal for each example is to provide sound scientific knowledge for solving current environmental problems.

Efforts to prevent or minimize habitat degradation

The Demonstration Erosion Control Project.

One example of a large-scale effort designed to prevent or minimize habitat degradation is the Demonstration Erosion Control Project. Of all the projects we describe, this project has the longest history, thus we will discuss it first. Successes from the DEC project have been described in numerous places (Cooper *et al.* 1989, 1996; Cooper and Knight 1990; Knight and Cooper 1995; Knight *et al.* 1997; Shields *et al.* 1995a, 1995b; Wang *et al.* 1997), thus our treatment here is not exhaustive.

In order to achieve the goals of DEC, several control techniques have been utilized. Useful erosion control techniques include: (a) grade control structures, (b) bank stabilization, and (c) drop pipes. Grade control structures prevent habitat loss by halting the progress of head-cuts in incised stream channels. Bank stabilization measures have reduced sediment production, and observations indicate that the structures themselves produce excellent habitat for macroinvertebrates and fish. Drop pipes prevent the development and expansion of gullies along incised stream channels. Over 2,000 L-shaped drop pipes have been placed throughout the DEC project, wherever land runoff will enter a stream: such placement forces water to pool upstream of the pipe. These structures have been found to be especially useful in creating suitable vertebrate habitat. For example, studies of the effectiveness of drop pipes have found 100 species of vertebrates living in pools created behind drop pipes, while in one month of sampling, 5,000 individual amphibians were captured in traps behind drop pipes (Knight and Cooper 1995, Knight *et al.* 1997).

Two examples of streams included in the DEC project will illustrate the points made earlier. Goodwin Creek is part of the Long Creek Basin southeast of Batesville, Mississippi (Fig. 1), in Panola County, and demonstrates successful habitat creation. Prior to habitat modification, the shallow stream [average depth = 20 cm] was isolated from its floodplain, lacked large woody debris, was carbon-starved, and species diversity was low. Further creek incision was causing extended bank failure. After a series of weirs were installed, colonization by macrophytes proceeded, weir-associated pools were consistently deeper, and species diversity increased. Restoration tactics utilized at Goodwin Creek were deemed successful by DEC collaborators and are being used currently in other DEC streams.

Several studies in other parts of the country have shown that riparian vegetation can be successful in reducing nutrient concentrations in the water column downstream from their source (Correll 1991, Lowrance *et al.* 1984, Peterjohn and Correll 1984). Toby Tubby Creek, another stream component of the DEC project, drains from Oxford into Sardis Reservoir (Fig. 1). Ongoing studies indicate that high nutrient spikes from the City of Oxford are trapped or processed by the natural system with an extensive riparian zone and frequent stream/floodplain interaction. Preliminary data showed filtered ortho-P reductions of 36 percent in 1997 and 37 percent in 1998. Nitrate-nitrogen was reduced 50 percent and 55 percent during the same years. Periodic meetings of the restoration team allow for regular review and assessment of various techniques, which afford timely modifications of design and sampling, and effective integration of new information.

Use of constructed wetlands for wastewater treatment.

A second technique employed to prevent or minimize habitat degradation is the construction of wetlands for wastewater treatment. The use of wetlands for wastewater treatment was stimulated by a number of studies in the early 1970s that demonstrated the ability of natural wetlands to remove suspended sediments and nutrients, particularly nitrogen and phosphorus, from domestic wastewater (Mitsch and Gosselink 1993). Two constructed wetlands in northern Mississippi constructed wetlands are worth noting. One is at a dairy farm on the Coldwater River in Hernando (Fig. 1), while the second is at the Center for Water and Wetland Resources at The University of Mississippi Field Station (Fig. 2). Work at the Hernando dairy farm began in 1990 with the use of constructed wetlands adjacent to heavy livestock runoff areas to process on-farm animal waste (Cooper *et al.* 1998). Total waste production from an average of 80 Holstein cattle was estimated at 10,336 liters per day. Prior to the start of the project, a large 42 m x 52 m settling lagoon was connected to three parallel wetland cells. The initial plantings of *Scirpus validus* (bulrush) have now been replaced by luxuriant mixed species cultures. A variety of parameters have been measured since the start of the project: for example, total phosphorus removal averaged 53.2%, while ammonia nitrogen reduction by the wetland system averaged 81.6% (Cooper *et al.* 1998). Thus, the Hernando dairy farm is viewed as a welcomed success story.

The second constructed wetland examples are located at The University of Mississippi Field Station (UMFS) in northern Mississippi approximately 18 kilometers northeast of the Oxford campus at the headwaters of the Little Tallahatchie River watershed (Fig. 2). UMFS covers 246 hectares with over 200 experimental ponds and mesocosms, most of which are fed from gravitational flow of the numerous springs and seeps at the Station (Knight 1996); the Center for Water and Wetland Resources (CWWR) is being established on site at UMFS. The wastewater treatment facility servicing the CWWR will consist of six constructed wetlands. The upper two raceways [wetland cells] are each 3.1 meters wide and consist of a rock filter system in which a plastic liner and limestone rock have been installed (Davis 1998). The lower two pairs of raceways are bentonite-lined, and will be planted with various wetland plants known to assimilate wastewater effectively. Criteria established for the plants to be transplanted into the wastewater wetlands include: native herbaceous perennial vegetation present at UMFS with the ability to retain nutrients in wastewater that are also aesthetically pleasing (Davis 1998).

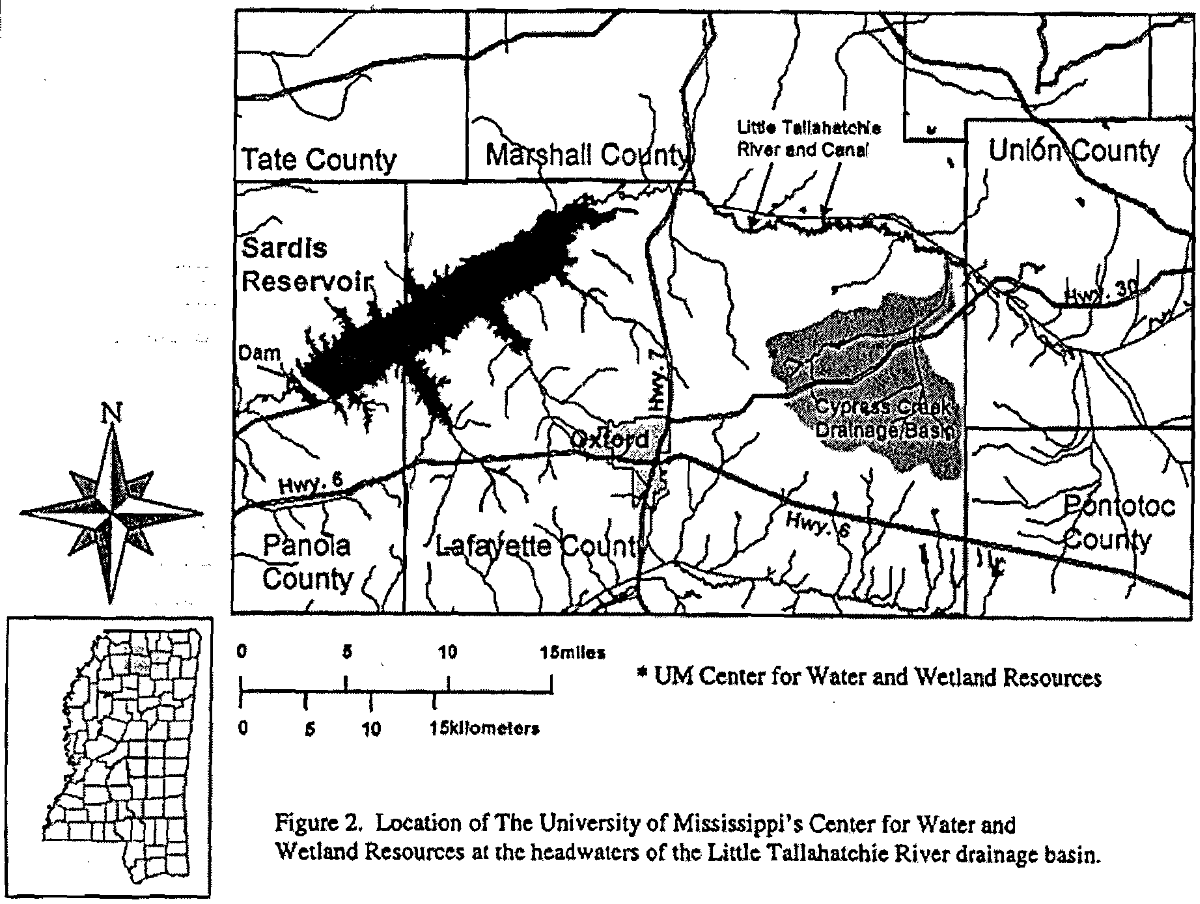


Figure 2. Location of The University of Mississippi's Center for Water and Wetland Resources at the headwaters of the Little Tallahatchie River drainage basin.

Surveys of vascular plant aboveground biomass were conducted from June 1997 through May 1998 to determine optimal species for consideration in the CWWR constructed wetland cells. Species identified as having maximum aboveground biomass during the summer growing season were *Juncus effusus* L. (softrush), *Polygonum sagittatum* L. (tearthumb), and *Leersia oryzoides* (L.) Swartz. (rice cut grass). Observations of vascular plant community composition have provided data for a recommendation list of a diverse plant community including native ferns, sedges, grasses, rushes, and forbs that can survive in a system subjected to the fluctuating effluent concentrations, insect or vertebrate invasions, and changes in hydrology that could be experienced in the UMFS wastewater treatment system (Davis and Holland 1998).

Another wastewater constructed wetland study conducted at the UMFS examined the fate of different pesticides following simulated cropland runoff and rainfall events (Moore 1999). Water, sediment, and plant samples were collected weekly for the duration of each experiment (chlorpyrifos, 84 days; atrazine and metolachlor, 35 days). According to results from this research, downstream or receiving system impacts could be mitigated by using constructed wetlands as "buffers" for agricultural pesticide runoff (Moore 1999). In fact, this study provided practical answers to questions relating to performance of constructed wetlands within agricultural watersheds.

Efforts to determine attributes of functional systems

Assessment of ecological integrity: need for a soil perturbation index.

As has been mentioned earlier, the SBI report (Lubchenco *et al.* 1991) articulated a need to determine patterns of ecological responses to stress as well as to monitor the recovery of damaged ecological systems. In northern Mississippi, efforts to understand attributes of functional systems have attempted to answer key questions, including (1) how to measure 'success' of a restoration project and (2) how to know when a system is sustainable. Truly functional wetland systems are thought to exhibit ecological integrity, so studies have been underway to examine the composition of wetland soils in younger versus more mature forested wetlands (Smith 1997, Balducci 1998, Maul *et al.* 1999) as one component of wetland ecological integrity.

Baseline information about ecosystem resilience is needed (Brinson and Rheinhardt 1996) to better use reference wetlands to develop standards against which impacts to wetlands are evaluated. Reference wetlands are defined as sites within a specified geographic region that are chosen to encompass the known variation of a group of wetlands, including both those subjected to natural disturbance as well as those that have been altered by human activity (Brinson and Rheinhardt 1996). Thus, studies of wetland soils have included mature forested wetlands as an indication of what characteristics local intact forested wetlands would be expected to exhibit (Smith 1997, Balducci 1998, Maul *et al.* 1999). These studies proposed development of a biogeochemical indicator to provide a systematic approach that includes both the organisms and physical aspects of an ecosystem. The index combines values from soil organic matter, total organic carbon, total Kjeldahl nitrogen, and total phosphorus to produce a Soil Perturbation Index (Maul *et al.* 1999).

Using the biogeochemical parameters mentioned above, the Soil Perturbation Index (Fig. 3) compares uncut mature wetlands to wetlands of earlier successional stages (Maul *et al.* 1999). In this index (model), zero percent change is the mean value of the biogeochemical parameters for the uncut wetlands and is considered the biogeochemical reference because it has zero perturbation. This perturbation index displays wetlands demonstrating the lowest biogeochemical functions as deviating most from the biogeochemical reference. Using the model developed, biogeochemical functions decrease after harvesting, reaching a low point at approximately 8 to 9 years after human alteration, and a predicting that it would take 16-17 years for all soil parameters measured to return to pre-harvest conditions (Smith 1997, Maul *et al.* 1999). These results seemed so promising that tests of a Soil Perturbation Index have now been completed for several other wetland systems within the Yazoo-Tallahatchie River system (Balducci 1998, Maul and Holland 1999). Perhaps with further refinement, the Soil Perturbation Index will give us one way to measure success of a wetland restoration project.

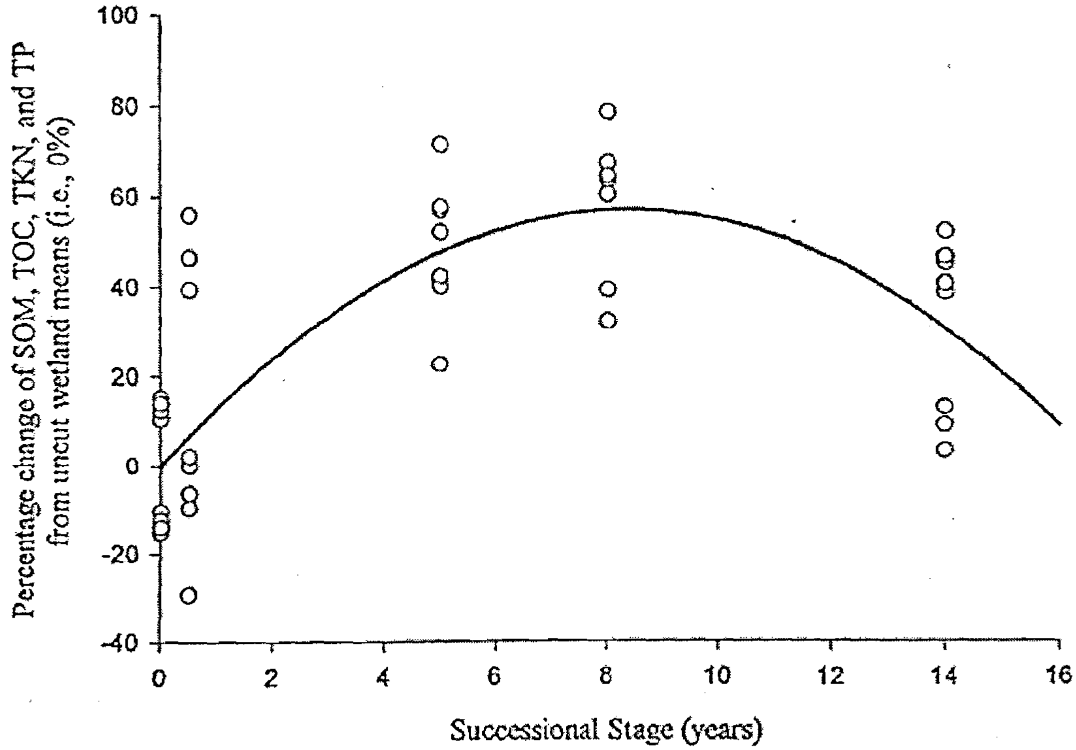


Figure 3. The Soil Perturbation Index shows percent change from a biogeochemical reference determined from uncut wetlands (0 years). This Soil Perturbation Index shows a change in biogeochemical function that is greatest 8-9 years after timber harvesting. This index predicts that it would take 16-17 years for soil organic matter (SOM), total organic carbon (TOC), total Kjeldahl nitrogen (TKN), and total phosphorus (TP) to return to pre-harvest conditions (from Smith 1997).

Proposal for rehabilitation of the Little Tallahatchie River.

In response to the catastrophic 1927 flooding of the lower Mississippi River the federal government mandated the implementation, by the United States Army Corps of Engineers (COE) of a comprehensive flood control program for the region. Among the resultant projects in northern Mississippi are Sardis Dam and Reservoir (Fig. 1), and the channelization of the Little Tallahatchie River, the reservoir's major tributary (Fig. 2). Since the mid-1990's the citizens living near the Little Tallahatchie River (LTR) have been asking the COE to rehabilitate the original meandering stream which was bypassed by the channelization. The impetus for the COE to conduct a river rehabilitation project on the LTR was derived from various business, civic, and community groups in and around Oxford, MS, Lafayette and Marshall Counties. The range of perspectives (academic, economic, recreational) coalesce around a concern with how land use decisions and policies may affect the northern Mississippi region and adjacent states, which collectively comprise an important recreational area (Charlier 1996).

In response to public concern over management practices imposed on a publicly owned resource area, the COE has completed preliminary investigations and moved on to the project planning phase of stream restoration of the lower reaches of the LTR. Currently, the COE rehabilitation project is in the Ecosystem Restoration Report stage. At the end of the COE assessment in late 1999, actual work to begin rehabilitation of the LTR will begin.

Pre-rehabilitation research on existing overstory and sapling species of the LTR floodplain has been completed (Pigott 1998, Pigott and Holland 1998). Between April and October 1997, composition of all woody vascular plants occurring along eight belt transects extending through a 16-km study area was recorded (Pigott 1998). Based on Lowe's (1921) observations, we had expected to find *Acer saccharinum* L. (silver maple), *Platanus occidentalis* L. (sycamore), *Populus deltoides* Battr. Ex Marsh.(eastern cottonwood), *Salix nigra* Marsh. (black willow), and *Taxodium distichum* (L.) L.C. Rich (bald cypress) along the LTR. In fact, the most dominant overstory and sapling species observed within the transects were bald cypress, silver maple, and sycamore (Pigott 1998). However, neither cottonwood nor black willow, the early floodplain colonizers, were encountered in the 1997 survey (Pigott and Holland 1998). Such pre-rehabilitation information will certainly provide valuable baseline data for comparisons of pre- and post-rehabilitation conditions within the LTR floodplain.

THOUGHTS FOR FUTURE RESTORATIONS OF FRESHWATER WETLAND HABITATS

In effectively restoring freshwater wetland habitats, several needs have been identified. First, the availability of "reference" (or mature) wetlands is critical in order to make reasonable comparisons between degraded and fully functional wetlands. Second, there is a need for sound background information in order to document changes implemented through restoration of habitats. If no information is available on a particular site, then access to reference wetlands becomes more critical. Third, there is a need to view each wetland as a part of a larger watershed (or drainage basin); characteristics upstream and downstream of the project site should be examined in order to better model and ultimately predict what impact future manipulations might have. Fourth, there is a need to review regularly whatever data are gathered through monitoring programs to assess progress and to modify the sampling regime as appropriate. Thus, as with the DEC project, a comprehensive assessment can be updated regularly of new developments, and necessary adjustments can be made in a timely fashion.

ACKNOWLEDGMENTS

For thoughtful discussions of various aspects of materials and ideas presented here, we thank the following: Jill A. Balducci, Elizabeth R. Blood, Billy Ross Brown, Sara A. Davis, Gerald P. Inmon, Jonathan D. Maul, Rebecca Lynn Smith Maul, Alfred T. Mikell, Matthew T. Moore, Kevin R. Pigott, Paul Rodrigue, F. Douglas Shields, Jr., and Sam Testa, III. For funding of components of the work described here, we thank: the U.S. Department of Agriculture Natural Resources Conservation Service Wetland Science Institute and the participants of the Demonstration Erosion Control Project – the USDA Agricultural Research Service National Sedimentation Laboratory, the U.S. Army Corps of Engineers, and the Mississippi Natural Resources Conservation Service. For helpful reviews of the manuscript, the authors thank Mack Finley and Steven Hamilton.

LITERATURE CITED

Balducci, J.A. 1998. Ecological integrity of wetland soils: testing of a perturbation index in northern Mississippi wetlands. Masters Thesis, Department of Biology, The University of Mississippi, Oxford, MS.

Brinson, M.M. and R. Rheinhardt. 1996. The role of reference wetlands in functional assessment and mitigation. *Ecological Applications* 6:69-76.

Charlier, T. 1996. Advocates going to great depths to help little river meander again. The Commercial Appeal. Memphis, TN. 22 April 1996.

Cooper, C.M., F.D. Hudson, and K. Bray. 1996. The Demonstration Erosion Control (DEC) project in the Yazoo Basin. In the 6th Federal Interagency Sedimentation Conference. (March 10-14, 1996). Vol. 2, pages 43-45. Sponsored by the subcommittee on Sedimentation Interagency Advisory Committee on Water Data (Las Vegas, Nevada).

Cooper, C.M. and S.S. Knight. 1990. Water quality cycles in two hill land streams subjected to natural, municipal and non-point agricultural stresses in the Yazoo Basin of Mississippi (1985-1987). *Verh. Intl. Verein. Limn.* 24:1654-1663.

Cooper, C. M., S.S. Knight, and L.L McDowell. 1989. Pre-project water quality of two watershed streams in DEC Project in Yazoo Basin in Mississippi. March 1989. (U.S. Dept. of Commerce) PB 89-198-81, 32 pp. (NTIS Technical Research Report).

Cooper, C.M., S.S. Knight, and S. Testa, III. 1998. A constructed wetland system for treating agricultural waste. *Verh. Internat. Verein. Limnol.* 26:1321-1327.

Correll, D.L. 1991. Human impact on the functioning of landscape boundaries. Pp. 90-109 in: Ecotones: the role of landscape boundaries in the management and restoration of changing environments (M.M. Holland, P.G. Risser, and R.J. Naiman, eds.). Chapman and Hall, New York.

Davis, S.A. 1998. Vegetation and substrate types for wastewater treatment wetlands. Masters Thesis, Department of Biology, The University of Mississippi, Oxford, MS.

Davis, S.A. and M.M. Holland. 1998. Vascular plant species native to northern Mississippi for use in constructed wetlands for wastewater treatment. Pp. 10-19 in: Proceedings of the 1998 Mississippi Water Resources Conference. (B.J. Daniel, ed.). Raymond, MS.

Holland, M.M. 1996. Ensuring sustainability of natural resources: focus on institutional arrangements. *Can. J. Fish. Aquat. Sci.* 53:432-439.

Knight, L.A. 1996. A history and general description of The University of Mississippi Biological Field Station. The University of Mississippi Biological Field Station, Publication No. 2, Oxford, MS.

Knight, S.S. and C.M. Cooper. 1995. Preliminary water quality analysis of drop pipe inlet basins in the DEC Project. Proceedings of the Sixth Fed. Interagency Sedimentation Conf. Vol 2, pp. P24-P27.

Knight, S.S., C.M. Cooper, and P.C. Smiley, Jr. 1997. Water quality of drop pipe inlet basins in the DEC project. Pp. 1035-1040 in: Management of landscapes disturbed by channel incision. (S.Y. Wang, E.J. Langendoen, and F.D. Shields, Jr., eds.). The University of Mississippi School of Engineering, Center for Computational Hydrosciences and Engineering, University, MS.

Lohr, S. A., P.G. Conners, J.A. Stanford, and J.S. Clegg. 1995. A new horizon for Biological Field Stations and Marine Laboratories. Rocky Mountain Biological Laboratory Miscellaneous Publication Number 3:1-36. Crested Butte, CO.

Lowe, E.N. 1910. Our waste lands: a preliminary study of erosion in Mississippi. Miss. Geol. Survey, Jackson, MS.

Lowe, E.N. 1921. Plants of Mississippi: a list of plants and ferns. Mississippi State Geological Survey, Bulletin No. 17:1-293.

Lowrance, R., R. Todd, J. Fail, Jr., R. Leonard, and L. Asmussen. 1984. Riparian forests as nutrient filters in agricultural watersheds. *Bioscience* 34:374-377.

Lubchenco, J., A.M. Olson, L.B. Brubaker, S.R. Carpenter, M.M. Holland, S.P. Hubbell, S.A. Levin, J.A. MacMahon, P.A. Matson, J.M. Melillo, H.A. Mooney, C.H. Peterson, H.R. Pulliam, L.A. Real, P.J. Regal, and P.G. Risser. 1991. The sustainable biosphere initiative: an ecological research agenda. *Ecology* 72:371-412.

Maul, R. Smith and M.M. Holland. 1999. Application of the soil perturbation index to evaluate created and restored wetlands. Final Report to the USDA Natural Resources Conservation Service Wetland Science Institute. Oxford, MS.

Maul, R.Smith, M.M. Holland, A.T. Mikell, and C.M. Cooper. 1999. Resilience of forested wetlands located in the southeastern United States: demonstration of a soil perturbation index. *Wetlands* 19:288-295.

Mitsch, W.J. and J.G. Gosselink. 1993. Wetlands. Van Nostrand Reinhold Company, Inc. New York.

Moore, M.T. 1999. Fate of chlorpyrifos, atrazine, and metolachlor from non-point sources in wetland mesocosms. Dissertation, Department of Biology, The University of Mississippi, University, MS.

Naiman, R.J., J. J. Magnuson, D.M. McKnight, and J.A. Stanford. 1995. The freshwater imperative: a research agenda. Island Press, Covelo, CA.

National Academy of Sciences. 1992. Restoration of aquatic ecosystems. National Research Council. Committee of restoration of aquatic ecosystems – science, technology, and public policy. National Academy Press, Washington, D.C.

Peterjohn, W.T. and D.L. Correll. 1984. Nutrient dynamics in an agricultural watershed: observations on the role of a riparian forest. *Ecology* 65:1466-1475.

Pigott, K.R. 1998. Current woody vegetative community structure and composition in a sixteen kilometer stretch of the Little Tallahatchie River. Masters Thesis, Department of Biology, The University of Mississippi. University, MS.

Pigott, K.R. and M.M. Holland. 1998. Current woody vegetative community structure and composition in a sixteen kilometer stretch of the Little Tallahatchie River influenced by the Sardis Reservoir. Pp. 64-78 in: Proceedings of the 1998 Mississippi Water Resources Conference, April 6-7, 1998, Raymond, MS, USA.

Shields, F.D., Jr., S.S. Knight, and C.M. Cooper. 1995a. Rehabilitation of watersheds with incising channels. *Water Resources Bulletin* 31:971-982.

Shields, F.D., Jr., S.S. Knight, and C.M. Cooper. 1995b. Experiment in stream restoration. *Journal of Hydraulic Engineering* 121:494-502.

Smith, R.L. 1997. The resilience of bottomland hardwood wetland soils following timber harvest. Masters Thesis, Department of Biology, The University of Mississippi, University, MS.

U.S. Department of Agriculture Soil Conservation Service. 1989. Status report on the Yazoo Basin Demonstration Erosion Control Project. Soil Conservation Service. Fort Worth, TX.

Wang, S.Y., E. Langendoen, and F.D. Shields, Jr., editors. 1997. Management of landscapes disturbed by channel incision, stabilization, rehabilitation, and restoration. University of Mississippi, University, MS.

Watson, C.C., N.K. Raphelt, and D.S. Biedenharn. 1997. Historical background of erosion problems in the Yazoo Basin. Pp. 115-119 in: Proceedings of the conference on management of landscapes disturbed by channel incision. (Wang, S.S.Y., E.J. Langendoen, and F.D. Shields, Jr., eds).

CONTRIBUTED PAPERS

SESSION I: AQUATIC BIOLOGY AND WATER QUALITY

Saturday, March 20, 1999

Moderator and Editor:

Steven Hamilton
Austin Peay State University

SURVEY OF LARVAL AND ADULT CADDISFLIES (INSECTA: TRICHOPTERA) OF THE DRAKE'S CREEK DRAINAGE, KENTUCKY

MICHAEL C. BEISER[1], ROBERT D. HOYT[2], AND STUART E. NEFF[3]

[1]Mississippi Office of Pollution Control, Pearl, MS 39208
[2]Department of Biology, Western Kentucky University, Bowling Green, KY 42101
[3]Department of Biology, Temple University, Philadelphia, PA 19122

ABSTRACT. **Larval caddisflies were sampled from three streams in the Drake's Creek drainage in south-central Kentucky from 1 November 1982 to 15 October 1983. A total of 1665 larvae representing four families, eight genera, and seven species was collected. The family Hydropsychidae was the most diverse and abundant taxonomic group. *Cheumatopsyche* and *Hydropsyche* species represented one-half of all larval specimens collected. *Neophylax concinnus*, family Uenoidae, was the most abundant species taken. Almost two-thirds of all larvae collected were from the West Fork. The greatest number of taxa occurred at the most downstream collecting sites. Larval densities were greatest during the spring and summer. *Hydropsyche scalaris* represented a new species record for Kentucky. Adult caddisflies were collected from the same areas as larvae from 1 July to 15 October. A total of 865 adults representing eight families, 14 genera, and 31 species were collected. Ninety-five percent of all adults belonged to the families Hydropsychidae and Leptoceridae. *Cheumatopsyche campyla* was the most common species. The greatest number of individuals and taxa of adult caddisflies were taken along the Trammel Fork. Most adults were late summer emergents, 1 August to 1 September, and had extended emergent periods. Microhabitat availability appeared to be the major feature responsible for the distribution and abundance of observed taxa. Twenty-one adult caddisflies represented locality records for Warren County, Kentucky.**

INTRODUCTION

Faunal surveys of the Trichoptera of Kentucky are limited to only a few of the major drainage systems (Haag and Hill 1983, Floyd and Schuster 1990). Ross (1944) compiled records of 46 species for the state. Resh (1975) provided the most extensive listing of the distribution of the order within the state, but these records were largely from the Salt, Cumberland, Kentucky, and Big Sandy River systems in central and eastern Kentucky. The Green River system in southwestern and west-central Kentucky is virtually unknown with respect to caddisflies (Resh 1975).

Resh (1975) listed 175 species of caddisflies in Kentucky, but none from Allen and Simpson counties, and only two, *Cheumatopsyche oxa* Ross and *Hydropsyche depravata* Hagen, from Warren County in south-central Kentucky. Later surveys in Rowan County (Picazo and DeMoss 1980), Boyd and Henderson counties (Haag and Hill 1983), Rockcastle and Jackson counties (Thoeny and Batch 1983), Breathitt, Clark, McCreary, Menifee, Powell, and Whitley counties (Phillippi and Schuster 1987), Pulaski County (Floyd and Schuster 1990, Floyd 1992), the mainstem Kentucky River (Houp and Schuster 1997), and various locations sampled by the Kentucky Division of Water (Houp, in press) have added numerous species records from the state, and have provided additional insights into the distribution of caddisflies of Kentucky.

Based upon a search of the literature, Laudermilk (1995) compiled a list of Kentucky Trichoptera that totaled 200 species. New species descriptions by Schuster (1997) from Kentucky and West Virginia, by Houp *et al.* (1998) from LaRue and Marion Counties, Kentucky, and 19 additional species records reported by Houp (in press) have increased this total to 220.

The objectives of this study were to examine the spatial and temporal distribution and relative abundance patterns of larval caddisflies in three streams in the Drake's Creek drainage, one that is influenced by municipal and industrial waste inputs, one that drains a predominantly agricultural area, and another that receives much of its influent from hypogean inflows. An additional goal was to conduct a preliminary investigation of the adult trichopteran fauna of the drainage.

STUDY AREA

The Drake's Creek drainage includes three major streams, the West Fork, Middle Fork, and Trammel Fork, each having its source in northern Tennessee (Fig. 1). The West Fork is a fourth order stream and flows through central Simpson County, Kentucky, receiving some hypogean inflow and municipal and industrial wastes from the city of Franklin. It merges with the Middle Fork, a fifth order stream, near Drake, Kentucky, in central Warren County, 37.2 km from its confluence with the Barren River near Bowling Green, Kentucky.

The Middle Fork drains areas in extreme eastern Simpson County, western Allen County, and southeastern Warren County. Much of the watershed area is used for agricultural purposes. The karstic nature of leached substrata is obvious.

The Trammel Fork is a fifth order stream that drains central and western Allen County, receiving much of its input from hypogean inflows resulting from the mature karst development of the region. It merges with the combined West and Middle Forks in Warren County, 27.5 km from its confluence with the Barren River.

Seven sampling stations were selected throughout the drainage (Fig. 1). All stations were riffle areas of approximately 50 m^2, with substrates ranging from pebble to cobble size stones in a bed of gravel.

Three sampling stations, WF1, WF2, WF3, were located on the West Fork; Station 1 in Simpson County at Creek Kilometer 31.7, 6.5 km upstream from the Franklin city sewage treatment plant effluent; Station 2 in Simpson County at Kilometer 57.2, 19 km downstream from the Franklin sewage treatment plant; and Station 3 in Warren County at Kilometer 72, 1.75 km upstream from the confluence of the West and Middle Forks.

Two sampling stations, MF1, MF2, were on the Middle Fork; Station 1 in Allen County at Creek Kilometer 20.7; and Station 2 in Warren County at Kilometer 36.4, 3.45 km above the confluence of the West and Middle Forks.

Two sampling stations, TF1, TF2, were on the Trammel Fork; Station 1 in Allen County at Creek Kilometer 32.2; and Station 2 in Warren County at Kilometer 43.7, 0.3 km upstream from the confluence of the Trammel Fork with the combined West and Middle Forks.

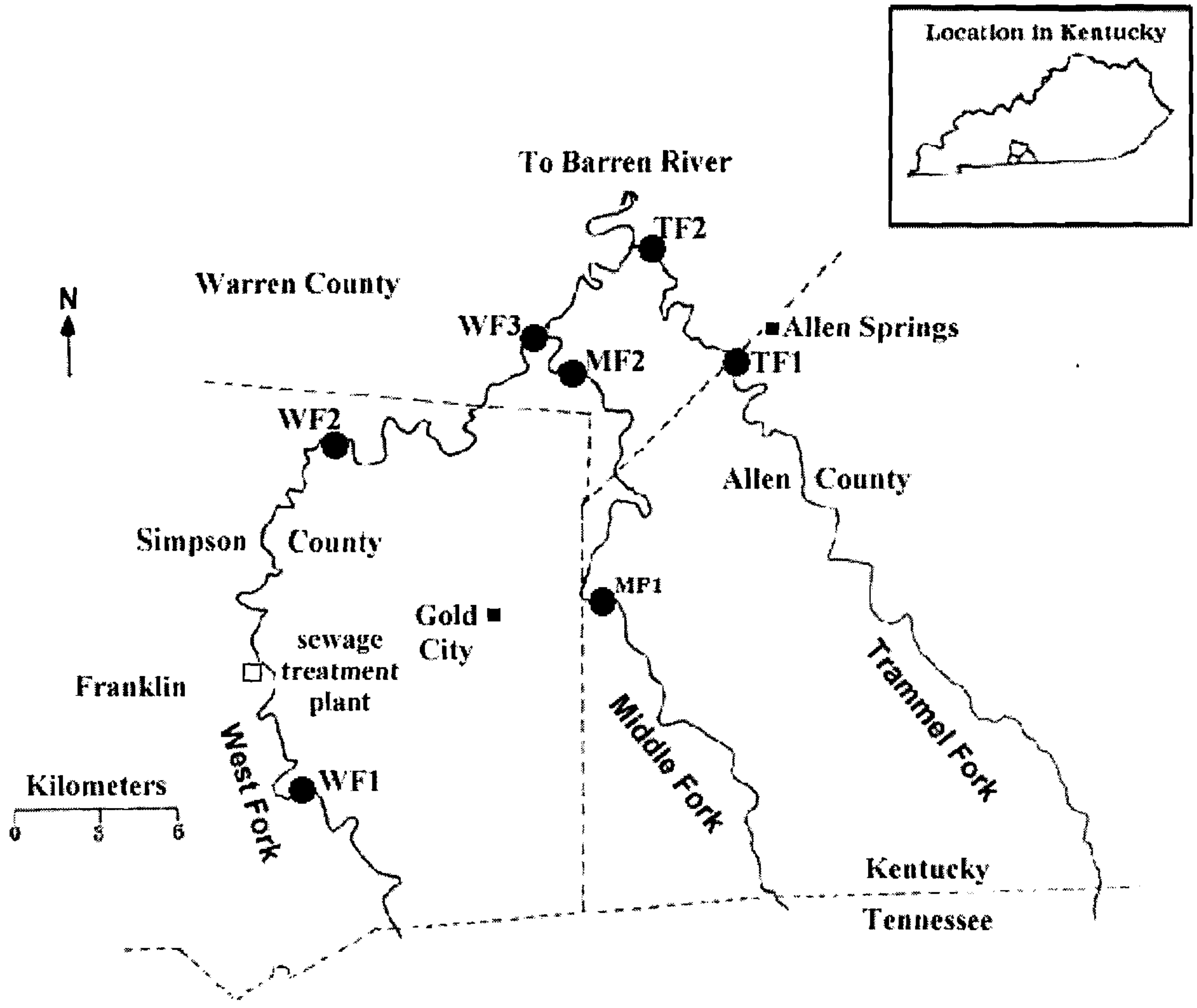


Figure 1. Map of Drake's Creek drainage showing its location in Kentucky and collecting stations.

MATERIALS AND METHODS

Collections of larvae were made semimonthly at all stations except TF1 which was sampled monthly. Collections were made for twelve months from 1 November 1982 to 15 October 1983 on the first and fifteenth day of each month. A Surber sampler (0.09 m^2) was used to obtain samples from riffle areas; two samples being taken at each station per collection. In sampling, all stones within the sample area were examined by hand and all larvae and cases removed. Underlying gravel was disturbed to a depth of 3-10 cm to recover any burrowing forms. Kick samples using a 0.5 mm mesh seine were also taken monthly, examined in the field, and any forms not collected with the Surber sampler were added to the collection.

Specimens were placed in Kahle's fluid for two weeks for fixation of soft tissues (Wiggins 1996). Specimens were then placed in 70 percent ethanol for permanent storage. Keys by Morse and Holzenthal (1996), Pennak (1978), Ross (1944), Schuster and Etnier (1978), Schefter and Wiggins (1986), and Wiggins (1996) were used to identify larval specimens to the most specific taxon possible.

From 1 July to 15 October, a black light apparatus similar to that described by Schuster and Etnier (1978) was used to capture night flying adults in an attempt to corroborate larval identifications and to capture adult representatives not being collected as larvae. All adult males were identified to species, but females were not identified beyond the genus level unless species identification was certain. Specimens were prepared for identification following the method of Ross (1944). Keys by Betten (1934), Blickle (1979), Flint *et al.* (1979), Gordon (1974), Morse (1975), and Ross (1944) were used. Nomenclature of *Hydropsyche* followed the recommendations of Schefter *et al.* (1986).

Stream flow in centimeters per second, temperature in degrees centigrade, and water depth in centimeters were recorded at each sample site using a General Oceanic digital flowmeter, degree centigrade thermometer, and meter stick, respectively. The mean and range for each parameter are shown in Table 1.

Table 1. Means and ranges (in parentheses) of temperature in degrees centigrade, stream flow in centimeters per second, and depth of sample site in centimeters for each collecting station in the Drake's Creek drainage for the time periods 1 November to 15 October 1982 and 1 May to 15 October 1983. WF = West Fork stations, MF = Middle Fork stations, TF = Trammel Fork stations.

1 November - 15 October	WF1	WF2	WF3	MF1	MF2	TF1	TF2
Temperature	14.6 (6-24)	14.1 (6-22)	14.9 (7-24)	14.6 (4-26)	15.3 (5-27)	14.5 (5-30)	15.0 (5.5-30)
Stream Flow	48.3 (13-91)	60.5 (17-107)	58.1 (17-121)	28.0 (2-64)	79.7 (18-152)	76.7 (11-128)	47.8 (8-131)
Sample Depth	26.2 (10-48)	30.6 (10-68)	37.3 (14-68)	27.5 (13-48)	28.4 (11-61)	36.4 (16-75)	38.6 (14-102)
1 May - 15 October	**WF1**	**WF2**	**WF3**	**MF1**	**MF2**	**TF1**	**TF2**
Temperature	19.3 (13-24)	18.5 (15-22)	19.2 (15-23)	20.4 (15-26)	21.1 (14-27)	20.1 (12-28)	20.6 (11-26)
Stream Flow	40.0 (15-90)	50.0 (17-77)	55.0 (17-95)	16.0 (2-48)	71.0 (18-142)	84.0 (33-128)	41.0 (8-105)
Sample Depth	22.0 (10-48)	25.0 (13-65)	25.0 (13-65)	26.5 (12-48)	25.0 (11-61)	28.0 (16-47)	32.0 (22-55)

RESULTS

Larvae

A total of 1665 larvae representing five families, seven genera, and seven recognizable species was collected (Table 2). Families represented were Brachycentridae, Hydropsychidae, Limnephilidae, Rhyacophilidae, and Uenoidae.

Table 2. Distribution and abundance of larval caddisflies from the West Fork (WF), Middle Fork (MF), and Trammel Fork (TF) of the Drake's Creek drainage, Allen, Simpson, Warren Counties, Kentucky, 1 November 1982 - 15 October 1983.

Taxon	Station						
	WF1	WF2	WF3	MF1	MF2	TF1	TF2
Ryacophilidae							
Rhyacophila fenestra	0	3	2	2	4	0	0
Hydropsychidae							
Cheumatopsyche sp.	24	145	119	62	190	35	33
Hydropsyche cuanis	0	1	0	0	0	0	0
Hydropsyche depravata	5	20	49	0	2	2	1
Hydropsyche frisoni	0	1	8	0	13	1	2
Hydropsyche scalaris	0	0	3	0	11	0	1
Hydropsyche cheilonis	0	0	38	8	27	1	1
Hydropsyche sp.	0	18	7	1	0	3	2
Limnephilidae							
Pycnopsyche sp.	0	0	0	0	1	0	1
Brachycentridae							
Brachycentrus sp.	0	0	0	0	0	0	1
Micrasema sp.	0	0	0	0	1	0	0
Uenoidae							
Neophylax concinnus	581	0	2	9	3	47	174
Totals	610 36.7%	188 11.3%	228 13.7%	82 4.9%	252 15.1%	89 5.3%	216 13.0%

Numerical Abundance.

Hydropsychidae was the most diverse and abundant taxonomic group represented by five species referable to two genera, *Cheumatopsyche,* and *Hydropsyche*, and included 834 specimens (Table 2). *Cheumatopsyche* was the most abundant hydropsychid taxon with 608 individuals. Identification of *Cheumatopsyche* was not possible beyond the genus level. Key characters were sufficiently developed in all except 31 *Hydropsyche* specimens to allow species determination. *Hydropsyche depravata* was the most abundant species while *Hydropsyche scalaris* Hagen, *H. frisoni* Ross, *H. cuanis* Ross, and *H. cheilonis* Ross occurred in limited numbers (Table 2).

Brachycentridae was the least abundant family observed with two genera, *Brachycentrus* and *Micrasema*, each represented by only one specimen. The family Rhyacophilidae was also poorly represented with 11 specimens of one species, *Rhyacophila fenestra* Ross (Table 2). Limnephilidae was represented by one genus, *Pycnopsyche,* and it was not abundant in the larval collections. The most abundant species collected in the study was the uenoid *Neophylax concinnus* (MacLachlan) which was represented by 816 individuals (Table 2).

Spatial Distribution.

Sixty-two percent of all larval caddisflies were taken on the West Fork (Table 2). Approximately equal numbers were observed in the Middle and Trammel forks.

The greatest number of taxa was observed at the most downstream station on all streams, nine of twelve taxa at MF2 and TF2 and eight at WF3 (Table 2). Station WF1, the uppermost station in the entire drainage, had only three taxa but included *Neophylax concinnus*, the most abundant taxon in the study (Table 2).

Because of the large numbers of *N. concinnus* at WF1, that station had the greatest percent representation of larvae with lesser but recognizable peaks at the most downstream stations of each stream. *Neophylax concinnus* was concentrated at the uppermost station on the West Fork and the two Trammel Fork stations (Table 2).

Cheumatopsyche was broadly distributed throughout the drainage, occurring at all seven sampling stations, and was the first or second most abundant taxon at each site (Table 2).

Like *Cheumatopsyche*, *Hydropsyche* specimens occurred at all sampling sites, being in greatest abundance at the downstream stations (Table 2). *Hydropsyche depravata* was the most abundant and widely distributed *Hydropsyche* species (Table 2). *Hydropsyche scalaris* occurred most commonly at the lower Middle Fork station (MF2), an area where fewer *H. depravata* were found (Table 2). *Hydropsyche frisoni* and *H. cuanis* were less numerous and not broadly distributed. Like *H. frisoni, H. cheilonis* occurred most at downstream stations (Table 2).

Seasonal Occurrence.

Caddisfly larvae were equally abundant during the spring and summer seasons and less so during the fall and winter (Table 3). Of the most abundant species observed, *Cheumatopsyche* and *Hydropsyche cheilonis* exhibited similar seasonal patterns being most abundant in the fall and gradually declining through each successive season (Table 3). *Hydropsyche depravata* was most abundant in the summer and fall while *Neophylax concinnus* was most abundant in spring and summer.

Table 3. Seasonal occurrence of larval caddisfly species in the Drake's Creek drainage, Allen, Simpson, Warren Counties, Kentucky, 1 November 1982 - 15 October 1983.

	Season			
Taxon	Fall	Winter	Spring	Summer
Ryacophila fenestra	0	0	11	0
Cheumatopsyche spp.	226	172	117	93
Hydropsyche cheilonis	23	22	18	12
Hydropsyche depravata	48	1	5	25
Hydropsyche frisoni	5	0	12	8
Hydropsyche sp.	0	0	15	16
Neophylax concinnus	27	5	390	394
Others	4	2	7	7
Totals	333 20.5%	202 12.7%	575 33.6%	555 33.2%

Adults

Light trap collections produced a total of 865 adult caddisflies representing eight families, 14 genera, 31 species (Table 4). The families represented were Glossosomatidae, Leptoceridae, Limnephilidae, Hydropsychidae, Hydroptilidae, Philopotamidae, Phryganeidae, and Polycentropodidae.

Numerical Abundance.

Ninety-five percent of adult caddisflies collected belonged to the Hydropsychidae and the Leptoceridae (Table 4). The family Hydropsychidae included two genera and eight species (Table 4). *Cheumatopsyche campyla* was the most frequently collected species (42.5% of all hydropsychids and 28% of total specimens). The Leptoceridae included five genera and 13 species. The leptocerid genus *Ceraclea* was the most diverse represented by five species while *Nectopsyche exquisita* (Walker) was the most abundant representative (Table 4).

Table 4. Distribution and abundance of adult caddisflies from the West Fork (WF), Middle Fork (MF), and Trammel Fork (TF) of the Drake's Creek drainage, Allen, Simpson, Warren Counties, Kentucky, 15 July - 15 October 1983. Family percent of total in parentheses next to the family name. (F = female, M = male)

	Station						
Taxon	WF1	WF2	WF3	MF1	MF2	TF1	TF2
Glossosomatidae (<1%)							
Glossosoma intermedium	1 M	-	-	-	-	-	-
**Protoptila maculata*	-	-	-	-	-	-	1 F
**Protoptila palina*	-	-	-	-	-	-	1 F
Philopotamidae (<1%)							
Chimarra obscura	-	-	-	-	1 M	-	-
Polycentropodidae (<1%)							
**Neureclipsis crepuscularis*	2 F	-	2 F	-	-	-	-
Hydropsychidae (65.8%)							
Cheumatopsyche campyla	34 M,	60 M,	24 M,	-	3 M,	14 M,	4 M,
	2 F	13 F	8 F	-	2 F	54 F	24 F
Cheumatopsyche oxa	-	9 M	1 M	-	-	-	-
	-	-	-	-	-	9 F	-
Hydropsyche cheilonis	-	-	-	-	-	1 M	1 M
	-	-	1 F	-	-	-	-
Hydropsyche depravata	37 M,	2 M,	6 M,	-	6 M,	-	-
	14 F	8 F	3 F	3 F	6 F	3 F	7 F
Hydropsyche orris	19 M	1 M,	6 M	-	8 M,	6 M	82 M,
	-	4 F	-	-	2 F	-	3 F
Hydropsyche scalaris	-	-	-	-	-	-	2 M
Hydropsyche simulans	-	-	-	-	-	-	1 M
Hydropsyche slossonae	-	-	-	-	-	1M	-
	-	-	-	-	-	-	-
Hydroptilidae (1%)							
**Hydroptila angusta*	-	-	1 F	-	-	-	-
**Hydroptila virgata*	-	-	-	-	-	-	1 F
**Hydroptila waskesia*	-	-	-	-	-	1 F	-
Phryganeidae (<1%)							
**Phryganea sayi*	-	-	-	-	2 F	-	-
Limnephilidae (2.8%)							
Pycnopsyche indiana	5 M	5 M	7 M,	1 M	1 M	-	4 M
	-	-	1 F	-	-	-	-

Table 4. Continued:

Taxon	WF1	WF2	WF3	MF1	MF2	TF1	TF2
	Station						
Leptoceridae (29%)							
Ceraclea ancylus	7 M	-	-	-	-	1 M	1 M
Ceraclea maculata	-	-	-	-	-	3 M	3 M
Ceraclea protonepha	3 M	-	-	-	-	-	-
Ceraclea resurgens	-	-	-	-	-	1 M	-
Ceraclea transversa	4 M,	-	-	-	-	10 M,	-
	1 F	-	-	-	-	1 F	-
Mystacides sepulchralis	2 M	1 M	1 M	-	-	-	-
Nectopsyche exquisita	1 M	-	-	1 M	-	6 M,	11 M
	-	-	-	-	-	69 F	5 F
Nectopsyche pavida	-	-	-	-	-	-	8 M,
	1 F	-	-	-	-	-	1 F
Oecetis cinerescens	25 M	-	-	-	5 M	8 M,	2 M,
	-	-	-	-	-	1 F	2 F
Oecetis inconspicua	-	3 M	1 M	-	3 M,	10 M,	11 M
	-	-	1 F	-	1 F	4 F	-
**Oecetis persimilis*	-	1 F	-	-	-	-	-
Triaenodes ignitus	1 M	-	-	-	-	6 M	-
Triaenodes tardus	2 F	2 F	-	-	-	-	-
Unidentified forms	-	-	-	-	1 M	-	-
	9 F	1 F	11 F	2 F	20 F	40 F	19 F
Totals	170	110	74	7	61	249	194
	19.7%	12.7%	8.5%	0.8%	7.1%	28.8%	22.4%

* Indicates species represented by female specimens only.

Spatial Distribution.

Slightly more adult caddisflies were collected along the Trammel Fork (51.2%) than the West Fork (42%) (Table 4). The Trammel Fork stations also had the greatest taxa richness, 19 and 20, versus 9-13 in the West Fork (Table 4). The Middle Fork had the fewest numbers of both specimens and taxa.

Cheumatopsyche campyla was collected near every station except the lower-most Middle Fork and *Hydropsyche depravata* was taken at all collecting stations (Table 4). *Hydropsyche orris*, like *Cheumatopsyche campyla,* was taken at all stations except the lower Middle Fork station. All specimens of the genus *Ceraclea* were collected at the upper-most West Fork station and the two Trammel Fork stations (Table 4). However, the most abundant representatives, *Nectopsyche exquisita* and *Oecetis cinerescens* (Hagen), occurred mostly at the Trammel Fork stations (Table 4).

Seasonal Occurrence.

Over the four-month period that adults were collected, most (75%) were taken from 1 August to 1 September (Table 5). *Cheumatopsyche campyla, Hydropsyche orris*, and *Nectopsyche exquisita* were the dominant species during this period (Table 5). *Hydropsyche depravata* gradually increased in abundance during the late summer reaching its peak of abundance on 15 September (Table 5). *Pycnopsyche indiana* was unlike other caddisflies in appearing only during a short time frame in October (Table 5).

Table 5. Number and date of occurrence of adult caddisflies from the Drake's Creek drainage, Allen, Simpson, Warren Counties, Kentucky, 15 July - 15 October 1983.

Taxon	15Jul	1Aug	15Aug	1Sept	15Sept	1Oct	15Oct
Cheumatopsyche campyla	10	23	82	94	29	4	0
Cheumatopsyche oxa	2	0	14	0	3	0	0
Cheumatopsyche sp.	0	3	23	5	0	0	0
Hydropsyche depravata	11	8	19	18	38	1	0
Hydropsyche orris	20	15	35	55	6	0	0
Hydropsyche sp.	2	11	13	16	1	1	0
Pycnopsyche indiana	0	0	0	0	0	12	12
Nectopsyche exquisita	2	15	1	75	0	0	0
Oecetis cinerescens	25	15	1	2	0	0	0
Oecetis inconspicua	2	4	22	5	1	0	0
Others	24	25	25	28	5	1	1
Totals	98 11.3%	119 13.8%	235 27.1%	298 34.5%	83 9.6%	19 2.2%	13 1.5%

DISCUSSION

Larvae

The widespread distribution of *Cheumatopsyche* and *Hydropsyche* larvae throughout the Drake's Creek drainage is typical of the two genera and has also been reported by Robak (1962), Gordon and Wallace (1975), and Wiggins and Mackay (1978). Wiggins and Mackay (1978) referred to the species in these genera as "generalists" and Robak (1962) characterized them as tolerant of a wide variety of environmental conditions.

At the species level, Gordon and Wallace (1975) showed that *Hydropsyche* larvae partition themselves on the basis of specific environmental conditions within a drainage. In our study, this was evidenced by *H. depravata* being collected nearly exclusively in the West Fork while *H. cheilonis, H. frisoni, and H. scalaris* were collected in greatest abundance at the lower-most stations on the West and Middle Fork. Schuster and Etnier (1978) reported *H. depravata* to typically occur on medium-sized rocks in riffle areas of small, warm water streams that have high amounts of organic material. While less has been reported locally on *H. frisoni* and *H. scalaris, H. cheilonis* appears to be quite tolerant of high levels of suspended organic materials (Schuster and Etnier 1978).

Cummins (1975), Wiggins and Mackay (1978), and Vannote *et al.* (1980) stated that aquatic macroinvertebrate communities tend to become collector dominated with increasing distance from stream origins. Among all functional feeding groups, collectors form the major group in large streams (Cummins 1975). Based on caddisflies alone, the pattern of increasing numbers of collectors (*Cheumatopsyche* and *Hydropsyche*) downstream in the West Fork and Middle Fork was consistent with the above view of a stream continuum. The collection of fewer larval members of the above-mentioned genera at the Trammel Fork stations coupled with the presence of adult representatives suggested a larval presence in the Trammel Fork in areas other than those sampled.

In the West Fork, *Neophylax concinnus*, a scraper, was collected almost exclusively at an upstream station that was shaded by a complete canopy of riparian vegetation. By contrast, at the lower-most Trammel Fork station scrapers (*N. concinnus*) outnumbered collectors (*Cheumatopsyche*). This represented an exception to Vannote *et al.* (1980) who reported that collectors dominate mid-size streams of Order 4-6. However, this observation might suggest a shift of benthic communities in the stream continuum in streams receiving heavy hypogean inflows.

No physical feature of the water at any station supported a strong correlation for organism presence or abundance. The presence of *Neophylax concinnus* in such large numbers above the municipal sewage effluent at Franklin, Kentucky suggests it has little or no survivability downstream due to increased stream organic load, although this conjecture could not be proven. The influence of hypogean water inflows at West Fork Station 2, Middle Fork 1, and Trammel Fork 1 was reflected in the depressed water temperatures at those stations in the summer as well as during the entire study. Explanations for the spatial and temporal abundance of the caddisflies observed probably related to microhabitat availability as much as any environmental variable.

Seasonal peaks of larval occurrence gave some evidence of life cycle periodicity. *Cheumatopsyche* larval dominance in the fall and winter suggested a spring and mostly summer emergence, typical of this normally multivoltine species group. Adult data observed in this study and reported by Resh (1975) and Houp and Schuster (1997) corroborated this conclusion. Although no adult *Neophylax concinnus* were taken in the light trap sampling, the great number of larvae taken in the spring and summer, coupled with the appearance of pupae in mid-October, suggested an autumn emergence for the species. Floyd and Schuster (1990) reported the collection of two species from this genus in the mid- to late October collections.

Hydropsyche scalaris represented a new species records for Kentucky. This species is one of the most widespread members of the genus (Schuster and Etnier 1978), its presence in Kentucky representing the approximate center of its known range.

Adults

Although the entire emergence season was not included in our study and light trapping is biased in sampling adult caddisflies, *i.e.*, some are not attracted to light; mating behavior, temperature, and wind conditions influence collecting success (Resh *et al.* 1975); and females predominate in light trap collections (Resh *et al.* 1975, Haag and Hill 1983, Houp and Schuster 1997), it was felt, none-the-less, that a preliminary investigation into the adult caddisfly fauna would be beneficial.

Because larval sampling was confined to stream riffles, little correlation was expected between larval and adult species occurrences. *Cheumatopsyche* spp. specimens, *Hydropsyche cheilonis,* and *Pycnopsyche* sp. were congruent representatives. The greater number of adult taxa observed in our light trap collections was attributed to their emergence from adjacent, unsampled pool habitats. Adult representatives of *Pycnopsyche, Protoptila, Mystacides, Nectopsyche,* and *Triaenodes* that occurred in our light samples supported this supposition since Wiggins (1996) reported these genera to occupy the slower portions of streams as larvae.

Crichton (1960) considered adult caddisflies to be either summer or autumn species. Most of the species in our study coincided with Crichton's definition of summer forms, occurring in greatest numbers from August into early September. A similar conclusion was drawn by Houp and Schuster (1997) for Kentucky River caddisflies. The occurrence of *Pycnopsyche indiana* during a short period in the fall was similar to the observation of Houp and Schuster (1997) for *P. lepida* (Hagen) in the Kentucky River.

The thirty-one species of adult caddisflies taken in this study included 21 locality records for Warren County and represented the first report of caddisflies from Allen and Simpson Counties. The total number of species observed in our study was typical of stream/drainage studies in Kentucky. Picazo and DeMoss (1980) reported finding 5 taxa, Haag and Hill (1983) 40 species, Floyd and Schuster (1990) 79 species, and Houp and Schuster (1997) 50 species. In our study caution was reserved for those taxa represented by only one specimen, especially if it was female, or if the taxon was represented by only females. This included specifically the members of the families Polycentropodidae, Hydroptilidae, and Phryganeidae. Future studies in the drainage should reconcile this caution or verify the proposed identifications.

The reporting of *Hydropsyche scalaris* in this study brings the total number of species reported from Kentucky to 221. This is greater than the 153 and 219 species reported from Arkansas (Bowles and Mathis 1989) and Ohio (Huryn and Foote 1983, Usis and Foote 1989), respectively, but less than the 239 reported from Virginia (Parker and Voshell 1981) and the 298 species reported by Etnier and Schuster (1979) from Tennessee. Many areas of the state have been largely overlooked by collectors. Additional collections from these areas are needed before the distribution of the order within Kentucky will be completely understood and will likely yield new distributional records.

ACKNOWLEDGMENTS

The authors express their gratitude to all those individuals who aided in the verification of the identities of caddisfly larvae. These include specifically Dr. Eric P. McElravy, Ms. Pat Schefter and Dr. Richard N. Vineyard, Dr. Guenter Schuster, Dr. Charles Covell, and Dr. Vincent Resh. Special thanks are extended to Dr. Steven Hamilton for reviewing an early copy of the manuscript. This study was funded in part by a grant from the Graduate Student Research Fund at Western Kentucky University.

LITERATURE CITED

Betten, C. 1934. The caddisflies or Trichoptera of New York state. *New York State Mus. Bull.* 291:1-576.

Blickle, R.L. 1979. Hydroptilidae (Trichoptera) of America north of Mexico. *New Hampshire Agr. Exp. Bull.* 509:1-97.

Bowles, D.E., and M.L. Mathis. 1989. Caddisflies (Insecta:Trichoptera) of mountainous regions of Arkansas, with new records for the order. *J. Kansas Entomol. Soc.* 62:234-244.

Crichton, M.I. 1960. A study of captures of Trichoptera in a light trap near Reading, Berkshire. *Trans. R. Entomol. Soc. Lond.* 112:319-344.

Cummins, K.W. 1975. The ecology of running waters - theory and practice. Pp. 277-293 *in:* International Joint Commission, International Reference Group on Great Lakes Pollution from Land Use Activities, Proceedings of the Sandusky River Basin Symposium, Tiffin, OH.

Etnier, D.A., and G.A. Schuster. 1979. An annotated list of Trichoptera (caddisflies) of Tennessee. *J. Tennessee Acad. Sci.* 54:15-22.

Flint, O.S., Jr., J.R. Voshell, and C.R. Parker. 1979. The *Hydropsyche scalaris* group in Virginia, with the description of two new species (Trichoptera:Hydropsychidae). *Proc. Biol. Soc. Wash.* 92(4):837-862.

Floyd, M.A. 1992. New microcaddisfly (Trichoptera: Hydroptilidae) record for Kentucky. *Trans. Kentucky Acad. Sci.* 53:50.

Floyd, M.A., and G.A. Schuster. 1990. The caddisflies (Insecta:Trichoptera) of the Buck Creek system, Pulaski County, Kentucky. *Trans. Kentucky Acad. Sci.* 51:127-134.

Gordon, A.E. 1974. A synopsis and phylogenetic outline of the nearctic members of *Cheumatopsyche*. *Proc. Acad. Nat. Sci. Philadelphia* 126:117-160.

Gordon, A.E., and J.B. Wallace. 1975. Distribution of the family Hydropsychidae (Trichoptera) in the Savannah River Basin of North Carolina, South Carolina, and Georgia. *Hydrobiologica* 46:405-423.

Haag, K.H., and D.R. Hill. 1983. Additions to the distributional list of Kentucky Trichoptera: Big Sandy River (Boyd County); Pond Creek and Scenic Lake (Henderson County). *Trans. Kentucky Acad. Sci.* 44:21-23.

Houp, R.E. (In Press). New caddisfly (Trichoptera) records from Kentucky with implications of water quality. *Trans. Kentucky Acad. Sci.*

Houp, R.E., K.H. Houp, and S.C. Harris. 1998. Two new species of microcaddisflies (Trichoptera:Hydroptilidae) from Kentucky. *Entomol. News* 109:99-102.

Houp, R.E., and G.A. Schuster. 1997. Caddisflies (Insecta: Trichoptera) of the mainstem of the Kentucky River, Kentucky. *Trans. Kentucky Acad. Sci.* 58:67-73.

Huryn, A.D., and B.A. Foote. 1983. An annotated list of the caddisflies (Trichoptera) of Ohio. *Proc. Entomol. Soc. Wash.* 85:783-796.

Laudermilk, E. 1995. The caddisflies (Trichoptera) of Kentucky (unpublished list). Kentucky Nature Preserves, 801 Schenkel Lane, Frankfort, KY 40601.

Morse, J.C. 1975. A phylogeny and revision of the caddisfly genus *Ceraclea* (Trichoptera, Leptoceridae). *Contrib. Am. Entomol. Inst.* 11:1-97.

Morse, J.C., and R.W. Holzenthal. 1996. Trichoptera genera. Pp. 350-398 in: An introduction to the aquatic insects of North America (R.W. Merritt and K.W. Cummins, eds.). Kendall-Hunt Publ. Co., Dubuque, Iowa.

Parker, C.R., and J.R. Voshell, Jr. 1981. A preliminary checklist of the caddisflies (Trichoptera) of Virginia. J. Georgia Entomol. Soc. 16:1-7.

Pennak, R. W. 1978. Freshwater invertebrates of the United States. John Wiley & Sons, New York.

Phillippi, M.A., and G.A. Schuster. 1987. New records of caddisflies (Trichoptera) from Kentucky. *Entomol. News* 98:113-116.

Picazo, E.D., and G.L. DeMoss. 1980. The aquatic insects, exclusive of Diptera, of Hays Branch, Rowan County, Kentucky. *Trans. Kentucky Acad. Sci.* 41:99-104.

Resh, V.H. 1975. A distributional study of the caddisflies of Kentucky. *Trans. Kentucky Acad. Sci.* 36:6-16.

Resh, V.H., K.H. Haag, and S.E. Neff. 1975. Community structure and diversity of caddisfly adults from the Salt River, Kentucky. *Environ. Entomol.* 4:241-253.

Robak, S.S. 1962. Environmental requirements of Trichoptera. Pp. 118-126, In: Third seminar in biological problems in water pollution (C.M. Tarzwell, ed.). U.S.P.H.S. Publ. 999-WP25.

Ross, H.H. 1944. The caddisflies, or Trichoptera, of Illinois. *Bull. Illinois Nat. Hist. Surv.* 23:1-326.

Schefter, P.W., and G.B. Wiggins. 1986. A systematic study of the nearctic larvae of the *Hydropsyche morosa group* (Trichoptera: Hydropsychidae). Royal Ontario Museum, Life Sciences Miscellaneous Publications.

Schefter, P.W., G.B. Wiggins, and J.D. Unzicker. 1986. A proposal for assignment of *Ceratopsyche* as a subgenus of Hydropsyche, with new synonyms and a new species (Trichoptera: Hydropsychidae). *J. N. Am. Benthol. Soc.* 5:67-84.

Schuster, G.A. 1997. Description of a new species of terrestrial limnephilid caddisfly (Trichoptera) from Kentucky and West Virginia (USA). Pp.417-424 in : Proc. 8th Intl. Symp. on Trichoptera (R.W. Holzenthal and O.S. Flint, Jr., eds.), Ohio Biological Survey, Columbus, Ohio.

Schuster, G.A., and D.A. Etnier. 1978. A manual for the identification of the larvae of the caddisfly genera *Hydropsyche* Pictet and *Hydropsyche* Ulmer (Hydropsychidae). U.S. E.P.A. Publication No. 611/4-78-060.

Thoeny, W.T., and D.L. Batch. 1983. New species records of caddisflies (Trichoptera: Hydropsychidae) in Kentucky. *Trans. Kentucky Acad. Sci.* 44:74-75.

Usis, J.D., and B.A. Foote. 1989. New records of caddisflies (Trichoptera) from Ohio, with particular reference to Stillfork Swamp, Carroll County. *Entomol. News* 100:83-85.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. *Can. J. Fish. Aquat. Sci.* 37:130-137.

Wiggins, G.B. 1996. Larvae of the North American caddisfly genera (Trichoptera). University of Toronto Press, Toronto, Ontario.

Wiggins, G.B., and R.K. Mackay. 1978. Some relationships between systematics and trophic ecology in nearctic aquatic insects, with special reference to Trichoptera. *Ecology* 59:1211-1220.

CHARACTERISTICS OF PHOTOAUTOTROPHIC PERIPHYTON AND UNIALGAL CULTURES GROWN *IN SITU* WITHIN THE SULPHUR FORK CREEK WATERSHED

JEFFERSON G. LEBKUECHER AND REBECCA A. HOUTMAN

Department of Biology and The Center for Field Biology,
Austin Peay State University,Clarksville, Tennessee 37044

ABSTRACT. Effects of water quality in the Sulphur Fork Creek watershed and Buzzard Creek of Robertson County, Tennessee on growth and physiological status of a pollution-intolerant algae, periphyton primary production, and periphyton photoautotrophic-heterotrophic biomass ratios were evaluated during the spring, summer, and fall of 1998. Overall, Buzzard Creek had low photoautotrophic periphyton production and low periphyton heterotrophic to photoautotrophic biomass ratios relative to stream sites within the Sulphur Fork Creek Watershed, especially the west fork of upper Miller Creek. Photosystem-II concentration, photosystem-II photochemical efficiency, and reproduction rate determinations following *in situ* growth of the pollution-intolerant alga *Selenastrum capricornutum* support conclusions from the periphyton characteristics data which indicate poor water quality within the Sulphur Fork Creek Watershed, especially in the west fork of upper Miller Creek.

INTRODUCTION

Metabolism and diversity in small streams are affected by changes in water quality that alter photoautotrophic components of the trophic base (Lebkuecher *et al.* 1998). Autochthonous primary production is the major contributor to the trophic base of small streams, especially in those with decreased detritus input due to removal of riparian flora (Vannote *et al.* 1980, Lamberti and Steinman 1997). Because algae are the most important photoautotrophic components of small lotic systems (Dodds 1991, Lambert and Steinman 1997), changes in water quality that affect photoautotrophic periphyton production in streams with little canopy cover may severely affect whole-stream ecological relationships.

The Sulphur Fork Creek watershed of Robertson County, Tennessee is targeted by the U.S. Natural Resource Conservation Service for implementation of best management practices to improve water quality. Assessments of aquatic primary production were determined at selected sites within the Sulphur Fork Creek watershed as an indicator of water quality and to provide baseline data to evaluate the impact of planned best management practices to improve water quality. This research is a supplement to other bio-monitoring studies being conducted in the watershed by The Center for Field Biology at Austin Peay State University.

The Sulphur Fork Creek watershed is located in the Western Pennyroyal Plain subsection of the Pennyroyal Karst ecoregion (Baskin *et al.* 1997). This subsection is characterized geologically by limestone, chert, shale, siltstone, sandstone, and dolomite. Soils are of the Pembroke, Crider, and Baxter series, forming a thin, loess mantle over limestone (Miller 1974). Vegetation is characterized as western mesophytic forest consisting largely of *Quercus* and *Carya* species (Braun 1950). No single climax forest type occurs. Instead, a mosaic of types are present which are largely determined by edaphic factors and the diverse topography (Chester and Ellis 1989). The Sulphur Fork Creek watershed drains approximately 120,000 acres of the southern half of Robertson County and consists largely of highly erodible farmland planted with tobacco using conventional tillage, numerous livestock operations, and suburban developments (Mack T. Finley, Austin Peay State University, personal communication).

Study of photoautotrophic production yields valuable information on the effects of water quality on the trophic relations of aquatic ecosystems (McIntire and Colby 1978, Naiman 1983). Nonpoint source pollution (i.e., pollutants entering water bodies from diffuse sources) is the most significant pollution problem in the watershed (M. T. Finley, APSU, personal communication). Because different pollutants enter streams during different times and affect periphyton production and physiological status in different ways, photoautotrophic periphyton production, autotrophic indexes, and the physiological status of the pollution-sensitive algae, *Selenastrum capricornutum*, grown *in situ* were evaluated during May, July, and September of 1998.

MATERIALS AND METHODS

Sampling site locations

The lower Buzzard Creek sampling site is located approximately 6.4 km from Highway 41/11, off Buzzard Creek Road, 100 m upstream of its confluence with Little Buzzard Creek. The upper Calebs Creek site is located 7.2 km northeast of I-24, off Highway 49, between Coopertown and Glover Crossroad. The lower Miller Creek site is located 9.6 km northeast of I-24, approximately 0.4 km downstream of the Carr Road bridge. The upper Miller Creek site is on the west fork of upper Miller Creek along Henry Gower Road, 0.8 km from the intersection with Sandy Springs Road.

Periphyton sampling

Periphyton was sampled between May 19 and 27, 1998, between July 1 and 9, 1998, and between September 4 and 12, 1998 in lower Buzzard Creek, lower Miller Creek, upper Miller Creek, and upper Calebs Creek. Periphyton sampling methods followed the recommendations of Morin and Cattaneo (1992). The sampling procedures were designed to provide the most consistent environmental conditions at all sites, a prerequisite to comparing aquatic primary productivity among different sites (Naiman 1983). Commercial periphytometers holding acid-washed slides, placed parallel to flow, were submerged 5 cm below the stream surface. The periphytometers were placed in areas of similar flow (Table 1) and sunlight exposure (full exposure during the photoperiod, maximum 2000 μmol photons$\cdot m^{-2} \cdot s^{-1}$). For all assays described below, periphyton was removed with a razor blade from both sides of the slides from each site.

Periphyton ash-free dry weight

Ash-free dry weight was determined following the methods of Clesceri *et al.* (1989). Periphyton from both sides of 12 slides from each site were scraped into preweighed, prefired, crucibles. Periphyton from three slides were combined to give four replicates. The periphyton was dried at 105°C for 24 h, cooled at 2% relative humidity, and weighed to the nearest 0.1 mg. The dried periphyton was ashed at 550°C for 2 h. Ash-free dry weight was determined following re-wetting the ash with deionized water to reintroduce water of hydration, drying at 105°C for 24 h, and cooling at 2% relative humidity.

Table 1. Characteristics of sampling sites in the Sulphur Fork Creek watershed and lower Buzzard Creek.

Characteristic	Lower Buzzard	Lower Miller	Upper Miller	Upper Calebs
Width (m)	6.7	14.4	3.9	2.4
Average Depth (m)	0.32	0.56	0.38	0.20
Flow at mid-stream($m \cdot s^{-1}$)	0.22	0.22	0.25	0.17
Discharge ($m^3 \cdot s^{-1}$)	0.29	0.99	0.12	0.04

Chlorophyll *a* concentration

Chlorophyll *a* concentration was determined following the methods of Arnon (1949). Chlorophyll (chl) was extracted by grinding periphyton from four slides (1 slide per replicate) from each site with a mortar and pestle for 3 minutes in 80% acetone buffered with 2.5 mM NaPhosphate buffer, pH 7.8 at 25°C. The homogenate was filtered through Whatman no. 1 filter-paper circles. Optical density was determined at 663 nm and chl *a* concentrations calculated (Arnon 1949). Photoautotrophic periphyton biomass was calculated from the chl *a* concentrations using the equations of Clesceri *et al.* (1989).

Autotrophic Index

The heterotrophic nature of the periphyton community was evaluated by determining the autotrophic index (AI) and was calculated using the following equation (Crossey and La Point 1988):

$$AI = \frac{\text{Ash-free wt of organic matter (mg/m}^2\text{)}}{\text{chlorophyll } a \text{ (mg/m}^2\text{)}}$$

In situ sensitive algal assay

Selenastrum capricornutum, a pollution-sensitive green alga and a standard assay organism (Bartsch 1971, Shubert 1984), was used to perform *in situ* growth assays (Koltz *et al.* 1975, Shubert 1984). Anexic *Selenastrum capricornutum* (University of Texas Culture Collection, Austin Texas) was cultured in 25 ml of Bold's nutrient media with 0.15 $g \cdot L^{-1}$ penicillin for 3 d at 200 μmol photons$\cdot m^{-2} \cdot d^{-1}$ and 25^{o}C to obtain cells in the exponential growth phase. *Selenastrum capricornutum* (2 X 10^5 cells) were suspended in 6 ml of one-twentieth strength nutrient solution in 16 clear, 1.5 nm-porous membrane bags which allow rapid passage of stream nutrients (Spectrum, Laguna Hills, CA., Spectra/Por Biotech membranes, molecular weight cut off = 3,500 daltons, 10-mm diameter, 10-cm length). The algae-containing bags were suspended 5 cm below the surface parallel to flow between bars of a metal frame attached to the periphytometers at each site. Cells were harvested after 4 d of *in situ* exposure in July from three bags per site. To increase the chance of obtaining significant results, the assays performed in September were evaluated using four bags per site and after 6 d of *in situ* exposure. Cells were counted using a hemocytometer. Three replicate counts were used to obtain the mean number of cells in each bag to calculate the number of population doublings per day.

Physiological status following the *in situ* assay

The physiological status of *Selenastrum capricornutum* grown *in situ* was evaluated using chl *a* fluorescence transients measured with a Plant Efficiency Analyzer (PEA; Hansatech Limited, Kings Lynn, Norfolk, England). Cells suspended in stream water (0.4 ml) were placed inside the fluorescence chamber for 3 min to oxidize primary electron acceptors prior to fluorescence induction. Fluorescence transients were measured during a 2-s flash of red light (2000 μmol photons$\cdot m^{-2} \cdot s^{-1}$) provided by an array of six light-emitting diodes (peak at 650 nm). The fluorescence signals were detected using a PIN-photodiode after passing through a long filter (50% transmission at 720 nm). Origin fluorescence yield (F_O), an indicator of the efficiency of photosystem II light-harvesting pigment complexes (Walker 1990, Lebkuecher and Eickmeier 1991) was calculated by determining the line of best fit through the data points from the first 4-12 μs of fluorescence induction (Walker 1990). Relative concentration of photosystem II was determined as the variable fluorescence yield (F_V), obtained by subtracting F_O from the maximum fluorescence yield (F_M) (Guenther *et al.* 1990, Strasser *et al.* 1995, Lebkuecher 1997, 1998). The quantum efficiency of photosystem II was determined as F_V/F_M (Kitajima and Butler 1975).

Determination of site abiotic characteristics

Stream depth (D) at each site was determined at 1-m horizontal intervals across the stream and averaged. Stream velocity (v) was determined with a Gurley, model 1100 flow meter (Gurley Instruments, Troy, New York) at 0.4 of the vertical distance between the streambed and the water surface at 1-m horizontal intervals and averaged. Discharge (Q) was calculated using the following equation (Gordon *et al.* 1992):

$$Q = \text{width}_1 D_1 v_1 + \text{width}_2 D_2 v_2 + \ldots + \text{width}_n D_n v_n$$

Statistical Methods

Statistical analyses followed the recommendations of Sokal and Rohlf (1981) and Day and Quinn (1989). The experimental design employed a model I analysis of variance with equal replication (Zar 1984). Means are determined to be significantly different if they were dissimilar at the experimentwise error rate of alpha = 0.05 probability level using the Tukey-Kramer Honestly Significant Difference Test (Sokal and Rohlf 1981). This conservative test was necessary because the number of the degrees of freedom were greater than the number of comparisons.

RESULTS AND DISCUSSION

Primary production is the rate at which inorganic carbon is assimilated into organic form and can be measured as the rate of photoautotrophic biomass accumulation (Lamberti and Steinman, 1997). Approximately 1.5% of the dry weight of algae is chl *a*, and the rate of chl *a* accumulation per unit area is widely used to determine aquatic primary production (Keithan and Lowe 1985, Lamberti and Steinman 1997). Aquatic primary production is largely dependent on water quality and is most often increased by decreased water quality resulting from nutrient loading (Baxter 1977; Lebkuecher *et al.* 1996). Streams pick up dissolved and particulate pollutants from agricultural, silvicultural, and urban sources. This nonpoint source pollution is the major contributor to poor water quality in West Tennessee (Finley *et al.* 1992, Hupp 1992). The negative effect of nonpoint source pollution on water quality is indicated by the high values of primary production, as determined by mg chl $a/m^2 \cdot d$ (Keithan and Lowe 1985), in upper and lower Miller Creek relative to undisturbed Buzzard Creek, the reference stream, and upper Calebs Creek during May 1998 (Table 2).

Primary production was greatest in upper Miller Creek during the May sampling, indicative of heavy nutrient loading (Baxter 1977). Primary production during the May sampling was similar at the study sites in lower Buzzard Creek and upper Caleb Creek. However, it is important to note that the lower Buzzard Creek site is in a lower reach of the stream relative to the study site at the upper reach of Calebs Creek. The ash-free dry weight of periphyton and the sediment plus ash weight data indicate that upper Miller Creek was more polluted relative to the other stream sites during the May sampling dates. Primary production increased during July at all sites and did not differ significantly among sites, including the reference site (Buzzard), possibly due to heavy nutrient loading resulting from recent heavy rains. Relatively high rates of primary production were measured in September at all sites except Buzzard, possibly influenced by unseasonably high temperatures and clear skies during the sampling period.

Organic pollution of the waterway is indicated by high concentrations of heterotrophic biomass and AI values greater than 100 (Lowe and Pan 1996). The AI values obtained in this study support this contention, with Buzzard Creek having the lowest AI value during the May and July sampling (Table 2). Upper Caleb Creek is heavily impacted by animal access and urban development and this organic pollution is reflected by the high AI values, despite its upper location in the watershed. Autotrophic index values typically increase downstream and during the late summer due to increased input of organic matter as detritus which, in turn, supports a larger biomass of heterotrophs (Vannote *et al.* 1980). An increase in heterotrophic biomass in lower Buzzard, which has extensive canopy cover, during the late summer is revealed by the increased September AI value.

Determination of the effects of water quality on the physiological status of primary producers is a prerequisite to understanding and monitoring changes in watershed ecosystems (Shubert 1984, Clesceri *et al.* 1989, Naiman 1983, de Madariaga and Joint 1992). The quantum efficiency of photosystem II (PS II) is an indicator of the efficiency in which absorbed light energy is converted into initial electron flow which, in turn, is used to convert inorganic carbon into organic molecules (Lebkuecher *et al.* 1998). This measurement is very accurate and is widely used as an indicator of photoautotroph physiological status (Powles 1984, Bjorkman and Demmig 1987). Significantly lower growth rate (cell doublings/d) and lower photosystem-II photochemical efficiency of *Selenastrum capricornutum* grown of upper Miller Creek during September suggest poor water quality relative to the other sites (Table 3). This result was not indicated by the photoautotroph biomass determinations, although it was indicated by the AI values (Table 2). These results demonstrate the value of determining the effects on growth rate and physiological status of a pollution-sensitive organism along with *in situ* evaluations of natural communities.

Table 2. Periphyton characteristics, sediment weights (plus periphyton ash), and autotrophic indexes determined from artificial substrates in Sulphur Fork Creek watershed and Buzzard Creek. Means ± SE represent four replicate determinations. Means followed by the same superscript letter are not significantly different at the experimentwise error rate of alpha = 0.05 probability level.

Assay	Lower Buzzard	Lower Miller	Upper Miller	Upper Caleb
<u>May 1998</u>				
Chlorophyll ($mg/m^2 \cdot d$)	0.11 ± 0.01^a	0.28 ± 0.06^b	0.51 ± 0.06^c	0.09 ± 0.01^a
Photoautotrophic biomass ($mg/m^2 \cdot d$)	7.3 ± 0.7^a	18.4 ± 1.3^b	34.0 ± 3.8^c	6.3 ± 0.7^a
Periphyton dry weight (ash-free) ($mg/m^2 \cdot d$)	10.3 ± 2.3^a	71.7 ± 4.0^b	99.7 ± 6.5^c	26.9 ± 3.2^a
Sediment weight ($mg/m^2 \cdot d$)	92 ± 16^a	481 ± 24^b	891 ± 59^c	141 ± 18^a
Autotrophic index	96 ± 12^a	273 ± 35^b	201 ± 19^b	285 ± 8^b
<u>July 1998</u>				
Chlorophyll ($mg/m^2 \cdot d$)	0.34 ± 0.07^a	0.46 ± 0.006^a	0.67 ± 0.18^a	0.47 ± 0.10^a
Photoautotrophic biomass ($mg/m^2 \cdot d$)	22.8 ± 4.7^a	30.8 ± 4.02^a	44.9 ± 12.1^a	31.5 ± 6.7^a
Periphyton dry weight (ash-free) ($mg/m^2 \cdot d$)	33.3 ± 3.92^a	143.6 ± 16.4^b	168.1 ± 23.1^b	144.2 ± 25.3^b
Autotrophic index	110 ± 24^a	319 ± 39^b	250 ± 37^b	310 ± 10^b
<u>September 1998</u>				
Chlorophyll ($mg/m^2 \cdot d$)	0.16 ± 0.03^a	0.38 ± 0.03^b	0.43 ± 0.06^b	0.49 ± 0.04^b
Photoautotrophic biomass ($mg/m^2 \cdot d$)	10.5 ± 1.8^a	25.7 ± 2.0^b	28.9 ± 3.8^b	33.0 ± 2.5^b
Periphyton dry weight (ash-free) ($mg/m^2 \cdot d$)	66.4 ± 4.4^a	86.9 ± 1.9^d	310.8 ± 6.0^c	174.7 ± 5.6^b
Sediment weight ($mg/m^2 \cdot d$)	429 ± 32^a	514 ± 13^a	2638 ± 88^c	784 ± 67^b
Autotrophic Index	458 ± 70^a	230 ± 17^a	765 ± 114^b	360 ± 22^a

Origin fluorescence yield (F_O) represents emission by excited antenna chl *a* molecules prior to the reduction of quinone$_A$, the first stable electron acceptor of PS-II (Butler 1977, Krause and Weis 1984). Thus, increases in F_O are typically indicative of decreases in the efficiency of resonance energy transfer within the pigment bed (Walker 1990, Lebkuecher 1997). High F_O values, significantly lower PS-II concentration, and significantly lower PS-II photochemical efficiency of *Selenastrum capricornutum* grown in upper Miller Creek during September support the conclusions from the *Selenastrum capricornutum* growth and periphyton characteristics data which suggest poor water quality in upper Miller Creek.

Table 3. Growth and primary photochemical characteristics of *Selenastrum capricornutum* grown *in situ* in the Sulphur Fork Creek watershed and Buzzard Creek. Means ± SE from July, 1998 represent three replicate determinations following 4 d of growth and are not significantly different at the experimentwise error rate of alpha = 0.05 level of probability. Means ± SE September, 1998 represent four replicate determinations following 6 d of growth. September means ± SE followed by the same superscript letter are not significantly different at the experimentwise error rate of alpha = 0.05 level of probability.

Assay	Lower Buzzard	Lower Miller	Upper Miller	Upper Caleb
July 1998				
Cell doublings/d	1.02 ± 0.15	1.78 ± 0.15	1.44 ± 0.08	1.10 ± 0.37
Origin fluorescence (F_O)	71 ± 5	102 ± 24	71 ± 10	90 ± 32
Relative concentration of PS II (F_V)	168.7 ± 7.1	168.3 ± 24.6	157.7 ± 25.7	228 ± 70.5
Photochemical efficiency of PS II (F_V/F_M)	0.71± 0.01	0.69 ± 0.03	0.69 ± 0.007	0.72 ± 0.012
September 1998				
Cell doublings/d	4.16 ± 0.30[a]	3.55 ± 015[a]	2.27 ± 0.30[b]	4.91 ± 0.60[a]
Origin fluorescence (F_O)	60 ± 3[a]	87 ± 6[ab]	114 ± 10[b]	78 ± 7[ab]
Relative concentration of PS II (F_V)	151.8 ± 9.4[ab]	186.3 ± 17.1[a]	126.3 ± 7.9[b]	184.5 ± 3.5[ab]
Photochemical efficiency of PS II (F_V/F_M)	0.71 ± 0.01[a]	0.68 ± 0.01[a]	0.53 ± 0.02[b]	0.71 ± 0.03[a]

This study provides information on the effects of water quality on the growth and physiological status of a pollution-intolerant algae, primary production, and autotrophic-heterotrophic relationships at different sites within the Sulphur Fork Creek watershed and Buzzard Creek as baseline data for future comparisons. As a whole, the data indicate that all sites in the Sulphur Fork Creek watershed have poor water quality relative to Buzzard Creek, especially the west fork of upper Miller Creek. In conclusion, primary production was greatest in the west fork of upper Miller Creek during May, suggestive of excessive nutrient loading. Primary production increased during July at all sites and did not differ significantly among sites, including the reference site (Buzzard), possibly due to heavy nutrient loading at all sites as a result of recent heavy rains. Growth rate and physiological status of *Selenastrum capricornutum* grown *in situ* during September (Table 3) support the conclusions from the periphyton characteristics data (Table 2) which indicate poor water quality in the west fork of upper Miller Creek relative to the other sites.

ACKNOWLEDGMENTS

The research is funded by the Tennessee Department of Agriculture (Environmental Protection Agency 319 Fund ID-98-06718-00) and The Center for Field Biology of Austin Peay State University. We thank Dr. B. P. Stone for reviewing the manuscript.

LITERATURE CITED

Arnon, D.I. 1949. Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiology* 24:11-15.

Bartsch, A.F. 1971. Accelerated eutrophication of lakes in the United states: ecological repsonse to human activity. *Environ. Pollut.* 1(2):133-140.

Baskin, J.A., E.W. Chester, and C.C. Baskin. 1997. Forest vegetation of the Kentucky karst plain (Kentucky and Tennessee)review and synthesis. *J. Torrey Bot. Soc.* 24(4):322-335.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. Ann. Rev. ecol. Syst., 8:255-283.

Bjorkman, O., and B. Demmig. 1987. Photon yield of O_2 evolution and chlorophyll fluorescence characteristics among vascular plant of diverse origins.. *Planta* 170:489-504.

Braun, E.L. 1950. Deciduous forests of eastern North America. Blakiston, Philadelphia, PA.

Butler, W.L. 1977. Chlorophyll fluorescence: a probe for electron transfer and energy transfer. Pp. 149-167 *in:* Encyclopedia of plant physiology, vol.5 (V. A. Trebst and M. Avron, eds.), Springer-Verlag, Berlin.

Chester, E.W., and W.H. Ellis. 1989. Plant communities of northwestern middle Tennessee. *J. Tenn. Acad. Sci.* 64(3):75-78.

Clesceri, E., Greenberg, and R.R. Trussel. 1989. Standard Methods for the Examination of Water and Waste Water, ed. 17, American Public Health Association.

Day, R.W., and G.P. Quinn. 1989. Comparisons of treatments after an analysis of variance in ecology. *Ecol. Monogr.* 59:433-463.

Dodds, W.K. 1991. Micro-environmental characteristics of filamentous algal communities in flowing freshwaters. *Freshwater Biol.* 25:199-209.

Finley, M.T., J.A. Gore, and S.W. Hamilton. 1992. Proposed best management practices for improving water quality in the West Sandy watershed. The Center For Field Biology, Austin Peay State Univ., Clarksville, TN.

Gordon, N.D., T.A. McMahon, and B.L. Finlayson. 1992. Stream Hydrology, An Introduction for Ecologists. John Wiley and Sons, New York, NY.

Guenther, J.E., J.A. Nemson, and A. Melis. 1990. Development of photosystem II in dark grown *Chlamydomonas reinhardtii*. A light dependent conversion of PS II_{β}, Q_B-nonreducing centers to the PS Ii_{α}, Q_B-reducing form. *Photosyn. Res.* 24:35-46.

Hupp, C.R. 1992. Riparian vegetation recovery patterns following stream channelization: a geomorphic perspective. *Ecol.* 73:1209-1226.

Keithan, E.D., and R.L. Lowe. 1985. Primary productivity and spatial structure of phytolithic growth in streams in the Great Smoky Mountains National Park, Tennessee. *Hydrobiol.* 123:59-67.

Klotz, R.L., J.R. Cain, and F.R. Trainor. 1975. A sensitive algal assay: An improved method for analysis of freshwaters. *J. Phycol.* 11:411-414.

Krause, G.H., and E. Weis. 1984. Chlorophyll fluorescence as a tool in plant physiology. II. Interpretation of fluorescence signals. *Photosyn. Res.* 5: 139-15.

Lamberti, G.A., and A. D. Steinman. 1997. A comparison of primary production in stream ecosystems. *J. N. Am. Benthol. Soc.* 16:95-104.

Lebkuecher, J.G. 1997. Desiccation-time limits of photosynthetic recovery in *Equisetum hyemale* (Equisetaceae) spores. *Am. J. Bot.* 84:792-797.

Lebkuecher, J.G., C.J. Chabot, and T.D. Neville. 1996. Phytoplankton production in West Sandy Bay, Kentucky Lake. *J. Tenn. Acad. Sci.* 71(2):36-40.

Lebkuecher, J.G., and W.G. Eickmeier. 1991. Reduced photoinhibition with stem curling in the resurrection plant *Selaginella lepidophylla*. *Oecol.* 28:597-604.

Lebkuecher, J.G., T.D. Neville, K.L. Wallace, and L.F. Barber. 1998a. Primary production in sandy-bottom streams of the West Sandy Creek Watershed of Tennessee. *Castanea* 63(2):130-137.

Lebkuecher, J.G., L.F. Barber, and M.L. Shoultz. 1998b. The use of chlorophyll *a* fluorescence to detect photosystem-II heterogeneity. *So. Assoc. Ag. Sci.* 11:51-56.

Lowe, R.L., and Y. Pan. 1996. Benthic algal communities as biological monitors. Pp. 705-739 *in*: Algal Ecology. (J.R. Stevenson, M.L. Bothwell, and R.L. Lowe, eds.) Academic Press Inc., San Diego, CA.

de Madariaga, I., and I. Joint. 1992. A comparative study of phytoplankton physiological indicators. *J. Exp. Mar. Biol. Ecol* 158:149-165.

McIntire, C.D. and J.A. Colby. 1978. A hierarchical model of lotic ecosystems. *Ecol. Monogr.* 48:167-190.

Miller, R.A. 1974. The geologic history of Tennessee. Bulletin 74, State of Tennessee Department of Conservation, Division of Geology, Nashville TN.

Morin, A., and A. Cattaneo. 1992. Factors affecting sampling variability of freshwater periphyton and the power of periphyton studies. *Can. J. Fish. Aquat. Sci.* 49:1695-1703.

Naiman, R.J. 1983. The annual pattern and spatial distribution of aquatic oxygen metabolism in boreal forest watersheds. *Ecol. Monogr.* 53:73-94.

Powles, S.B. 1984. Photoinhibition of photosynthesis induced by visible light. *Ann. Rev. Plant Physiol.* 35:15-44.

Shubert, L E. 1984. Algae as Ecological Indicators. Academic Press Inc. New York, NY.

Sokal, R.R., and F.J. Rohlf. 1981. Biometry. W.H. Freeman, New York, NY.

Strasser, R.J., A. Srivastava, and Govindjee. 1995. Polyphasic chlorophyll a fluorescence transient in plants and cyanobacteria. *Photochem. and Photobiol.* 61: 32-42.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. *Can. J. Fish. Aquat. Sci.* 37:130-137.

Walker, D. 1990. Use of the oxygen electrode and fluorescence probes in simple measurements of photosynthesis. Oxygraphics Limited, Sheffield, United Kingdom.

LONG-TERM MONITORING OF VEGETATION AND SEDIMENTATION PATTERNS IN THE OBION CREEK FLOODPLAIN

JENNIFER L. BOTTOM, JOHN RUNDLE AND WILLIAM SPENCER

Department of Biological Sciences, Murray State University, Murray, KY 42071

ABSTRACT. The Obion Creek floodplain is home to many biological and economically significant flora and fauna. Since the channelization of the Obion in the 1920's major hydrological and vegetation changes have occurred altering many communities. The goal of this project is to initiate a long term vegetation and sedimentation monitoring program to detect changes in vegetation community composition caused by changes in hydrology and sedimentation patterns. The natural plant associations and communities found in the area will be determined. The methodology used to collect data from the transects is a standardized format widely used by the Kentucky State Nature Preserves Commission that is based upon the Vegetation Classification Standards set by the Federal Geographic Data Committee (FGDC). This format requires information regarding aspect, geology, topographic position, moisture, slope, and previous land use. Vegetation information includes species composition and richness, of canopy, subcanopy, and herbaceous layers. Sedimentation monitoring is conducted using dendrochronology and sediment collection traps. Plant and community responses will be assessed upon completion of data collection. A total of eight transects containing sixty plots were established in the Obion Creek floodplain. Summer and fall vegetation data were collected. Sediment collection traps were installed in each of the transects. Investigation and detection of the effects of altered hydrology and sedimentation rates upon natural plant communities is important for proper management of both public and private lands. Prolonged flooding and excessive sedimentation can cause tree mortality by restricting root aeration. Crop production and recreational land use (hunting) could also be adversely affected by excessive flooding and sedimentation. The project will also serve as a baseline for long-term monitoring of the area. Future tasks include collection and analysis of sediment cores from the area and continued sedimentation monitoring. Vegetation will be continuously monitored through the spring, summer, and fall months. The entire area will also be re-sampled in the spring and summer for additional plant species.

BIOMONITORING IN THE WEST SANDY CREEK WATERSHED: FIVE YEARS DOWN THE ROAD

STEVEN W. HAMILTON[1,2], JOSEPH R. SCHILLER[2], DEBORAH L. HAMILTON[3], AND MACK T. FINLEY[1,2]

[1]The Center for Field Biology, Austin Peay State University, Clarksville, TN 37044
[2]Department of Biology, Austin Peay State University, Clarksville, TN 37044
[3]Clarksville Academy, Clarksville, TN 37040

ABSTRACT. The U.S. EPA has developed benthic macroinvertebrate survey methods to monitor water quality. These Rapid Bioassessment Protocols apply readily to point source discharge monitoring. However, are they sensitive enough to detect subtle effects of nonpoint source (NPS) pollution and to document water quality benefits of NPS abatement efforts? To monitor for water quality responses to various agricultural, riparian, and instream best management practices, we sampled benthic macroinvertebrates at seven stream sites the West Sandy Creek Watershed (WSCW) from 1992 to 1995. The sandy-bottomed streams of the WSCW lack the typical riffle habitat from which semiquantitative samples are normally collected following the EPA protocols. As an alternative to riffle habitats, we collected semiquantitative samples from submerged root masses along the stream banks. These are stable, complex substrates inhabited by a rich macroinvertebrate fauna. Semiquantitative samples were subsampled in the lab using 100-pick subsampling methods described by EPA. Qualitative samples were also collected by hand picking specimens from substrates in other habitats (riffle or riffle-like habitats, rooted macrophytes, accumulated coarse organic matter, woody debris-snags, and roots, as available). Many barriers exist to obtaining reliable results using these monitoring protocols. For example, good reference streams are lacking, especially for streams greater than second order. Significant barriers to improving water quality also exist in these streams. Most streams in the WSCW are partly, even substantially, channelized with head-cutting and streambank erosion being widespread; agricultural and urban development continues in the watershed with associated land conversion and road construction.

ISOLATION AND DETERMINATION OF RNA FROM THE SUBMERSED AQUATIC WEED *HYDRILLA VERTICILLATA*

KRISTI L. HARRIS[1], BRETT WIMBERLEY[1], ENENG SUSILAWATI[1], DAVID FERGUSON[2], TIMOTHY JOHNSTON[1] AND WILLIAM SPENCER[1]

[1]Departments of Biological Sciences, and [2]Agriculture, Murray State University, Murray, KY 42071

ABSTRACT. The submersed aquatic angiosperm, *Hydrilla verticillata*, is a noxious exotic weed originating in southern Asia and is currently spreading throughout the southeastern United States. It was likely introduced into the United States via the aquarium plant industry in south Florida in the early 1960's. Only the female plant of the dioecious strain was introduced. Its spread throughout the southeastern U.S. has been facilitated by its enormous capacity for vegetative reproduction and the production of millions of buried tubers that facilitate regrowth. An additional factor to *Hydrilla's* ability to thrive in extremely dense, warm, and CO_2-depleted conditions is that it exhibits unique physiological plasticity. Without any anatomical alteration, *Hydrilla* converts from C_3 ($\Gamma \geq 60$) to C_4-like ($\Gamma \leq 15$) ($\Gamma = CO_2$ compensation point, ppm) photosynthetic physiology under stressful summer conditions. Environmentally, this change occurs within the mat habitat of the population, where the biomass is most dense and carbon resources the most depleted. The edge habitat primarily remains C_3. The switch to C_4-like physiology appears to result in the *de novo* synthesis of an isozyme of phosphoenolpyruvate carboxylase (PEPCase, the enzyme responsible for C_4 photosynthetic CO_2 fixation). The overall objective of this research is to better understand the environmental control of gene expression in plants. Since an isozyme of PEPCases appears to be expressed when the species is in the C_4-like state, the next step will be to determine whether two forms of mRNA for the two isozymes of PEPCase can be identified in C_4-like *Hydrilla*. This presentation will describe protocol developed during isolation and determination of purified mRNA that will be used for Northern analyses and construction of a cDNA library.

There are potentially important economical and environmental consequences associated with understanding environmental control of gene expression in *Hydrilla*. The competitive nature of *Hydrilla* results in the eradication of native plant species within aquatic ecosystems which has a profound negative effect upon fishing, boating, other recreational activities, and flood control and irrigation. A more complete understanding of the environmental control of gene expression could lead to novel methods of control and management. In contrast, there may be a beneficial aspect associated with *Hydrilla's* unique physiology and hardiness. If its physiological plasticity (ability to switch to C_4 –like photosynthesis under stressful conditions) can be transferred into C_3 crops, then perhaps yield could be increased without further addition of fertilizer or irrigation.

BACTERIAL PRODUCTIVITY, DISSOLVED NUTRIENT AND DISSOLVED OXYGEN FLUX IN SEDIMENTS OF KENTUCKY LAKE

S.P. HENDRICKS, G.W. KIPPHUT, AND G.L. RIDOUT

Center for Reservoir Research, Murray State University, Murray, KY, 42071

ABSTRACT. Bacterial activity in reservoir sediments can strongly influence mineralization and nutrient cycling and consequently affect overlying water quality in these important man-made ecosystems. Sediment bacterial community characteristics were examined in conjunction with biogeochemical processes at several Ledbetter Embayment and main channel sites along a transect across Kentucky Lake. Chamber experiments showed that dissolved O_2 and NH_4 fluxes significantly increased with temperature (r^2=0.768, p=0.001). Temperature and NO_3 flux were the most significant predictors of sediment bacterial secondary productivity (r^2=0.584, p=0.001). Bacterial productivity also exhibited some site dependence. For example, outer bay sediments generally exhibited 3-4 fold higher incorporation rates than inner bay sediments. C:N ratios at inner bay sites were 2 times outer bay ratios, suggesting potentially higher nutritive carbon quality toward the outer bay. Elucidating the role of the sediment bacterial community in reservoirs will contribute to an understanding of processes, which determine the transport, accumulation, and utilization of nutrients and organic carbon in these human-created, human-dominated ecosystems.

TETRACYCLINE-RESISTANT ENTEROCOCCI IN THE SULPHUR FORK CREEK WATERSHED, ROBERTSON COUNTY, TENNESSEE

MARY MCREYNOLDS AND DON C. DAILEY

The Center for Field Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. Chlortetracycline is an analog of tetracycline that is added in low doses to livestock feed to enhance animal growth and digestion efficiency. This low concentration of tetracycline could select for tetracycline-resistant bacteria within the livestock. The fecal contamination of the Sulphur Fork Creek (SFC) watershed from livestock has been well documented for the past three years. The enterococci isolated from the SFC-watershed were screened for tetracycline-resistance. Water samples were collected from six sites within the SFC-watershed and recorded, antibiotic resistance confirmed, and enterococci were speciated by standard biochemical techniques. Interestingly, tetracycline-resistant enterococci were detected at all sites within the watershed. These findings demonstrate the need for continued research in this area.

DIVERSITY AND HABITAT PREFERENCE OF FRESHWATER MUSSELS (MOLLUSCA: UNIONOIDEA) IN SULPHUR FORK CREEK AND LOWER RED RIVER, TENNESSEE AND KENTUCKY

R. ADAM RAY, STEVEN W. HAMILTON, AND MACK T. FINLEY

The Center for Field Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. The Sulphur Fork Creek/lower Red River watershed as investigated in this study occupies the majority of Robertson County, Tennessee. The lower Red River was studied only between Dot, Logan County, Kentucky and Port Royal, Montgomery County, Tennessee and include neither the upper mainstem of the Red River, the South Fork of the Red River nor the lower Red River between Port Royal and Clarksville, Tennessee. The segment of the watershed investigated in this study is approximately 74 km long, averages between 29-35 km in width, and is part of the Cumberland River drainage. To date, there have been 93 species of freshwater mussels observed in Cumberland drainage. The Sulphur Fork Creek/lower Red River watershed possesses characteristics comparable to many of Tennessee's waterways, creating the potential for constructing a model applicable to other mussel studies in the state. Also, this study provides new and valuable information for this region and the state. A total of 347 man-hours were dedicated to research in the summer and fall of 1998 to determine abundance, diversity and habitat of unionoid mussels based on living individuals and remnant shells. Mussels were hand-collected by snorkeling, canoeing, walking stream banks and utilizing a Needham bottom scraper at 22 sample sites, 18 in Sulphur Fork Creek and four in Lower Red River. Living species encountered in the watershed were (greatest → least abundant): *Amblema plicata*, Threeridge; *Potamilus alatus*, Pink Heelsplitter; *Lampsilis ovata*, Pocketbook; *Ptychobranchus fasciolaris*, Kidneyshell; *Cyclonaias tuberculata*, Purple Wartyback; *Tritogonia verrucosa*, Pistolgrip; *Elliptio crassidens*, Elephantear; *Lampsilis fasciola*, Wavyrayed Lampmussel; *Lasmigona costata*, Flutedshell; *Quadrula cylindrica*, Rabbitsfoot; and *Fusconaia flava*, Wabash Pigtoe. Species encountered only as remenant shells were: *Cumberlandia monodonta*, Spectaclecase; *E. dilatata*, Spike; *Obovaria subrotunda*, Round Hickorynut; *Toxolasma lividus*, Purple Lilliput; *Villosa iris*, Rainbow; *V. taeniata*, Painted Creekshell; *V. vanuxemensis*, Mountain Creekshell. Lower Red River held the highest frequency of living and remnant species. It is interesting to note that most living and remnant species encountered in Sulphur Fork Creek were limited to the lower one-fifth of the watershed, downstream of a man-made impoundment near Hills Mill, Robertson County, Tennessee. Furthermore, an uncharacteristically large, living *A. plicata*, weighing over 1,300 g (wet weight) and measuring over 19 cm in length, was observed in Sulphur Fork Creek. No evidence of unionoid mussel recruitment was discovered, however, a variety of potential host fish species were observed during the survey. Judging by the numbers of remnant shells observed and results of the few investigations in this watershed, it appears that the mussel fauna in this watershed has declined significantly in recent years.

THE EFFECT OF WATERSHED CHARACTERISTICS UPON STREAM BENTHIC ALGAE COMMUNITIES IN WESTERN KENTUCKY

WILLIAM SPENCER

Department of Biological Sciences, Murray State University, Murray, KY 42071

ABSTRACT. Watersheds of streams can experience a variety of land-use activities. Certain of these activities are disturbances that indirectly affect the structure and function of benthic stream communities. Streams within agricultural watersheds can experience increased deposition of sediment, nutrients, and pesticides compared to streams within forested watersheds. The objective of this study was to compare the structure and function of the benthic community of a stream within an agricultural watershed (Ledbetter Creek) with one within a forested watershed (Panther Creek).

Samples of the benthic microflora community were obtained using a benthic algae sampling array (BASA) specifically designed for this study. The BASAs were placed within the up-welling and down-welling zones of both Ledbetter and Panther creeks. Forty holes were drilled into the sheets to accommodate specially constructed scanning electron microscope (SEM) stubs to which was glued a 1 cm diameter clear acrylic disk. The stubs were collected periodically, placed in a fixative, dried, coated with gold, and observed using scanning electron microscopy. The percent bare surface, percent debris, number of community layers, number of diatom cells, number of bacterial cells, and the number of bacterial taxa were determined for each stub. Twenty (SEM) observations were made across a randomly selected transect of each stub. The mean of the twenty observations was determined for each stub.

Six parameters (see above paragraph) were measured in two zones (upwelling and downwelling) in two creeks (Panther and Ledbetter) after 3, 7, 14, and 28 days post-installation of the BASAs in the streams. At each sampling date one stub was removed from each of the four BASAs at each zone/creek combination. The mean values (see above) from the four stubs were used for statistical comparisons.

After only 3 days exposure in Panther Creek and Ledbetter Creek the percent bare surface on the stubs was 48.8 and 22.3, respectively. Colonization of new substrate occurred more quickly in Panther Creek than in Ledbetter Creek. Because there were no differences in the percent coverage of debris at day 3, the differences in bare surface area cannot be explained by differences in the amount of attached debris. The density of bacterial cells was 36% greater in Ledbetter Creek than in Panther when measured at day 3, while that of diatom cells was 24% greater. The thickness of the benthic microflora layer was about 40% greater in Ledbetter Creek than in Panther Creek when measured at day 3. The number of diatom taxa was about 25% greater in Ledbetter Creek compared to Panther Creek.

By day 14 there was over 200% more debris had accumulated in Ledbetter Creek than in Panther Creek. And the density of diatoms in Panther Creek was 100% greater than in Ledbetter Creek. The ratio of diatom to bacterial density for Panther and Ledbetter Creeks was 3.18 and 1.34, respectively.

The ratio of light saturated community photosynthesis to community dark respiration for Ledbetter and Panther Creeks was 1.56 and 3.66, respectively. These metabolism data indicate that the benthic community of Panther Creek was more autotrophic than that of Ledbetter Creek.

THE PHOTOSYNTHETIC ECOLOGY OF THE RARE WHITE-WATER STREAM MACROPHYTE *PODOSTEMUM CERATOPHYLLUM*

WILLIAM SPENCER[1] AND HEATHER JEVANS[2]

[1]Department of Biological Sciences, Murray State University, Murray, KY 42071
[2]Department of Biology, Asbury College, Wilmore, KY 40390

ABSTRACT. Shade and sun populations of the rare white-water stream angiosperm *Podostemum ceratophyllum* (Buffalo River, TN) were studied to better understand its autecology. Individuals from sun populations exhibited a total carotenoid:chlorophyll ratio of 0.16, and a chl_a:chl_b ratio of 12.9 compared to 0.114 and 10.7 for individuals from shade populations. Net photosynthesis measured as O_2 evolution was saturated at 931 and 1,112 μmol/m²/s of light for the individuals from the shade and sun populations, respectively. The light compensation point for individuals from the sun population was higher than that for individuals from the shade population. Dark respiration was also higher for individuals from the shade compared to those from the sun populations. The dissolved inorganic carbon concentration required to saturate net photosynthesis was approximately 2.0 mM for individuals from both populations. The standing crop biomass for the sun and shade populations was 185.6 and 40.9 g/m² (dry weight), respectively. To estimate the level of disturbance experienced by individuals from both sun and shade populations the percentage of biomass lost per day was measured. The sun population lost 0.27% while the shade population lost 0.86% of its standing crop per day under base flow conditions. When averaged over a year the loss rate exceeds the standing crop biomass. Maintenance of *P. ceratophyllum* populations requires high levels of net carbon gain.

ENVIRONMENTAL CONTROL OF GENE EXPRESSION IN THE SUBMERSED AQUATIC WEED *HYDRILLA VERTICILLATA*

ENENG SUSILAWATI[1], KRISTI L. HARRIS[1], DAVID FERGUSON[2], TIMOTHY JOHNSTON[1], AND WILLIAM SPENCER[1]

[1]Departments of Biological Sciences, and [2]Agriculture, Murray State University, Murray, KY 42071

ABSTRACT. The submersed aquatic angiosperm *Hydrilla verticillata* normally exhibits C_3 photosynthesis, but when grown under conditions of carbon deprivation it is induced to express C_4-like photosynthetic traits. In order to determine the effect of the environment on gene expression in *Hydrilla*, leaves from both C_3 (CO_2 compensation point = 118 ppm) and C_4-like (CO_2 compensation point = 10 ppm) plants were homogenized and proteins analyzed using SDS-PAGE followed by Western analysis using antibodies for the C_4 photosynthetic enzyme phosphoenolpyruvate carboxylase (PEPCase). Results showed that protein extracts from C_4-like individuals contained two electrophoretic protein bands recognized by PEPCase antibodies, while that from C_3 individuals contained only one band. The results suggest that two genes each coding for a form of PEPCase may be expressed in *Hydrilla*. A carbon deprivation environment appears to elicit the induction of two rather than one PEPCase protein.

AMPHIBIAN LARVAE AS BIOINDICATORS OF WATER QUALITY IN THE SULPHUR FORK CREEK/RED RIVER WATERSHED, ROBERTSON COUNTY, TENNESSEE

CHRISTINA L. THERRELL AND CINDY L. TAYLOR

The Center for Field Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. **Due to an agriculturally based population and growing urbanization, nonpoint source pollution is becoming a major concern in the Sulphur Fork Creek/Red River Watershed (SFC/RRW). The objective of this study was to evaluate the effects of nonpoint source pollution on the survival and development of anuran larvae (tadpoles). Six sites in the SFC/RRW were selected: sites included upper Millers Creek, lower Millers Creek, upper Calebs Creek, Johnston Springs, Little Buzzard Creek, and Big Buzzard Creek. At each site, we placed three enclosures with 10 tadpoles per enclosure. The enclosures were made from plastic Rubbermaid © containers that had all sides removed and replaced with mosquito netting that allowed water flow and hindered predatory attacks. We additionally had three enclosures with 10 tadpoles in a controlled growth chamber (22° C, 12 L: 12 D). Enclosures were monitored every other day for larval mortality. Additionally, water temperature (HOBO© data loggers), air temperature, relative humidity, pH, and precipitation were monitored at each field site. Other researchers associated with this project monitored bacteria (fecal coliform and fecal streptococci) and aquatic primary production at some of the sites. Each experiment was approximately two weeks in duration. Three experiments were completed in the summer of 1998 with *Bufo fowleri* (experiment II, 8-22 July) and *Hyla chrysoscelis* (experiment I, 10-28 June and III, 31 July - 14 August).**

Water temperatures ranged from 14° C at Johnston Springs to 21.8° C at lower Millers. Johnston Springs was the only field site at which temperature remained constant throughout experiment III. At all other sites, water temperature fluctuated throughout experiments I, II, and III. Big Buzzard, upper Calebs, and upper Millers ranged from 18.9-21.1° C. There were no significant differences in the pH at all the sites in experiments I - III. In experiment I and II, tadpoles at the Big Buzzard site exhibited the highest survivorship (80%). In experiment III, tadpoles at the Johnston Springs and Little Buzzard sites exhibited the highest survivorship, 97% and 80%, respectively. Tadpoles grown in the controlled growth chamber had a combined 93% survivorship for all three experiments. High mortality of tadpoles at the field sites appears to be associated with extremely high levels of fecal coliform and fecal streptococci. Little Buzzard and Johnston Springs sites were not able to be used during experiments I and II due to flooding of these creeks. Excessive rainfall at all sites during July influenced all factors of these experiments.

CYCLOMORPHOSIS IN *DAPHNIA LUMHOLTZI* INDUCED BY TEMPERATURE

PEDER M. YURISTA

Hancock Biological Station, Murray State University, Murray, KY 42071

ABSTRACT. Cyclomorphosis is a well known phenomenon in *Daphnia* that involves a regular, seasonal, or induced change in body allometry. The change in morphology may include helmet size and/or shape, tail spine length, antennae length, and "neck-teeth" (jagged outgrowths along the dorsal mid-line). Long helmets and tail spines were induced in laboratory cultures of *Daphnia lumholtzi* with temperature as the proximal cue. The helmets and spines receded in length with time at temperature or as temperature was decreased. Cyclomorphosis has been correlated with temperature in past field studies on *Daphnia* however most current research has focused on chemical cues from predators as being the proximate cue with predation as the ultimate causation. The induced helmet in this experiment (0.65mm) was significantly longer than reported in the literature when induced by a planktivorous fish (0.25mm). However the helmet was shorter than observed in natural populations (0.95mm) from which the laboratory cultures were obtained. Predation as the ultimate cause for cyclomorphosis in *Daphnia lumholtzi* is difficult to reconcile with temperature as a strong proximal cue. A synergistic explanation with two cues may be more appropriate.

CONTRIBUTED PAPERS

SESSION II: ZOOLOGY

Saturday, March 20, 1999

Moderator:

A. Floyd Scott
Austin Peay State University

Editor:

Steven W. Hamilton
Austin Peay State University

RED MILKSNAKE OR SCARLET KING? *LAMPROPELTIS TRIANGULUM* IN LAND BETWEEN THE LAKES AND ADJACENT AREAS

MICHAEL ARMSTRONG, DAVID FRYMIRE, AND EDMUND J. ZIMMERER

Department of Biological Sciences, Murray State University, Murray, KY 42071

ABSTRACT. The *Lampropeltis triangulum* species group ranges from portions of South American northward through Central America, Mexico and most of the United States. Milk snakes show a great degree of variation in both size and color pattern. In the eastern United States, one putative subspecies, the scarlet kingsnake, *L. t. elapsoides*, differs more in certain characters than perhaps any other member of this group particularly in regards to size and scutellation. In western Kentucky and adjacent areas of Northwest Tennessee it has been reported as integrating with the red milk snake, *L. t. syspila*. This judgment has however been based on a relatively small number of specimens. In our study, data for 27 pattern and meristic characters were obtained from reference samples for *L. t. syspila* (n = 16) from Missouri and Kansas, and *L. t. elapsoides* (n = 23) from South Carolina, Georgia, Florida and Mississippi. These were compared to those obtained from *L. triangulum* specimens from far western Kentucky and adjacent Tennessee (n = 64). Multivariate Analysis with plots of canonical coefficients for the western Kentucky/Tennessee animals compared to reference specimens of *L. t. syspila* and *L. t. elapsoides* show the Kentucky/Tennessee individuals falling out as clear *L. t. syspila* or *L. t. elapsoides* with little or no evidence of intergradation. The only exception to this is in the tendency of some *L. t. elapsoides* from this area to have incomplete banding across the belly. However, this may be a peripheral or disjunct population effect and not evidence of gene flow. In certain parts of the Land Between The Lakes they exist in sympatry and, therefore, act as distinct species.

MORE ON THE DISTRIBUTION AND HABITAT OF THE PLAINBELLY WATER SNAKE (*NERODIA ERYTHROGASTER*) IN THE LOWER CUMBERLAND RIVER BASIN, TENNESSEE AND KENTUCKY

ANGELO P. BUFALINO AND A. FLOYD SCOTT

Department of Biology and Center for Field Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. The distribution and habitat of the plainbelly water snake in the lower Cumberland River Basin has received only anecdotal and opportunistic attention by a few field biologists. Prior to this study a distributional hiatus between the Dover and Clarksville Tennessee populations of the plainbelly water snake existed and there were no data on available habitat or habitat trends. We found the plainbelly water snake in suitable palustrine habitats throughout the lower Cumberland River Basin with habitat availability being lowest below Barkley Dam and above Ashland City. From the early 1980's to the mid 1990's there has been an 11% reduction in available habitat due mainly to draining wetlands for agricultural purposes.

THE TAXONOMIC STATUS OF THE PLAINBELLY WATER SNAKE (*NERODIA ERYTHROGASTER*) IN THE LOWER CUMBERLAND RIVER BASIN, TENNESSEE AND KENTUCKY: A QUANTITATIVE ANALYSIS

ANGELO P. BUFALINO AND A. FLOYD SCOTT

Department of Biology and Center for Field Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. Since the yellowbelly and copperbelly subspecies of the plainbelly water snake were described, considerable confusion has surrounded which subspecies is found in the lower Cumberland River Basin and surrounding area. The lower Cumberland River Basin population of the plainbelly water snake has been described as either an intergrade between the two subspecies or as a good population of the copperbelly subspecies. These references are anecdotal in nature having relied on a qualitative comparison of available specimens to the written description of the subspecies. This research uses digital image analysis techniques to provide quantitative data of pattern and pigment characteristics. Results suggest the lower Cumberland River Basin population of the plainbelly water snake is most like the copperbelly subspecies. A wide area of intergradation between these two subspecies in western Tennessee and Kentucky is also indicated.

DISTRIBUTION AND HABITAT ANALYSIS OF A POPULATION OF KIRTLAND'S SNAKES, *CLONOPHIS KIRTLANDI*, IN GRAVES COUNTY, KENTUCKY

MARK HATFIELD, SCOTT SHUPE, DAVE FRYMIRE, CHRIS CROCKETT, ERIC SKINNER, AND EDMUND J. ZIMMERER

Department of Biological Sciences, Murray State University, KY 42071

ABSTRACT. Since the discovery of the first specimen of Kirtland's snake in Graves County, Kentucky, in July of 1997, three others have been found to date. All were found on roads bisecting marsh or swamp habitats of the Terrapin Creek drainage in the southern part of the county between 1.0 and 5.0 kilometers from the Tennessee/ Kentucky border. This population represents a significant range extension for this species, and is roughly 150 km from the closest known population. Two of the specimens were female, one male, and one of indeterminate sex. Size ranged from 160 mm to 350 mm, and characters such as scutalation and body pattern are typical of other populations. The Kirtland's snake has been described as a species of wet meadows, open swamps, and adjacent woodlands. This is consistent with our observations. Although the area has a history of agriculture, with the Terrapin Creek itself being channeled, much of the area is marsh, swamp, and forest in various stages of secondary succession. Another interesting habitat characteristic unique in the Purchase Area to this area is the presence of scattered cold water spring fed pools and streams. Although the existing specimens were found in a relatively small area in the Terrapin Creek drainage, other suitable habitat exists where the Kirtland's snake may be found. This is particularly true in relation to points south. The Terrapin Creek drains south into the Obion River, and ultimately into the Mississippi with suitable habitat scattered though much of this area. We therefore feel that this population may extend significantly southward into Tennessee. However, until the present range of this population is extended, or the numbers observed greatly increases, this has to be considered a small population of limited number which may require protection and habitat management for its continued existence.

CONSERVATION OF SONGBIRDS AT ARNOLD AIR FORCE BASE, TENNESSEE

JOHN W. LAMB

1100 Kindel Drive, Arnold Air Force Base, TN 37389-1800

ABSTRACT. Arnold Air Force Base (AAFB) comprises ca. 15,800 hectares and is situated in the Eastern Highland Rim physiographic province of south-central Tennessee in an area known as the barrens. AAFB is an active participant in the Partners in Flight Program. AAFB began ongoing breeding bird monitoring in 1994 in the form of nocturnal and diurnal point counts. Results of nocturnal counts indicate that Whip-poor-wills have a higher frequency of occurrence and relative abundance than Chuck-wills-widows at AAFB. Diurnal counts have documented 82 species of breeding birds at AAFB. The most frequently occurring species on diurnal counts are the Northern Cardinal, Indigo Bunting, and Eastern Tufted Titmouse. AAFB has initiated a Neotropical and Temperate Bird Surveys and Monitoring Project which was developed with the Tennessee Field Office of the Nature Conservancy as a step down plan from the Partners in Flight Interior Low Plateaus Bird Conservation Plan. The project identifies initial management goals, monitoring objectives, and inventory and monitoring protocols for songbirds at AAFB. Goals, objectives, protocols, and targeted species and habitats were identified to support those identified in the Partners in Flight Interior Low Plateaus Bird Conservation Plan. Priority species are those identified by Partners in Flight as having high concern scores in barrens habitats including Bewick's Wren, Prairie Warbler, White-eyed Vireo, Blue-winged Warbler, Bachman's Sparrow, Field Sparrow, and Henslow's Sparrow. Inventory and monitoring protocols involve spring migration monitoring, diurnal and nocturnal point counts, breeding bird census plots, and species specific searches. Goals, objectives, and protocols will be revised annually as results from inventory and monitoring efforts clarify the status of priority species and their habitats. Other avian projects at AAFB include a bird banding program and monitoring of a Great Blue Heron rookery. Bird and bird habitat management will be integrated with other management activities through a site conservation planning process that was developed by The Nature Conservancy.

SEASONAL ACTIVITY OF REPTILES AT WOODLAND AND OLD-FIELD PONDS IN LAND BETWEEN THE LAKES: RESULTS AFTER SEVEN YEARS OF DATA COLLECTION

CHARLES A. ROZELLE AND A. FLOYD SCOTT

Department of Biology and Center for Field Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. We analyzed data on reptile captures and selected abiotic conditions collected from 1 July 1987 through 31 July 1994 at two closely situated ponds in the Tennessee portion of Land Between The Lakes. Our objectives were to: 1) compare yearly changes in the composition, richness, relative abundance, activity levels, and directional movements of reptile species at each pond; 2) attempt correlating fluctuations in activity levels with means of the abiotic factors monitored; 3) evaluate the potential impact of habitat alteration (clearing, discing, and seeding grass) at the field pond on community dynamics; and 4) look for evidence of any population or community trends developing over the study period. Ponds were visited every other day (except during colder periods of winter) to collect data. Reptiles were captured in pit traps set in pairs on either side of metal drift fences placed around the periphery of each pond. Abiotic variables monitored included air temperature, soil temperature, soil moisture, relative humidity, and rainfall. Overall, 337 captures (207 at the woodland pond and 129 at the field pond) were recorded. Although captures at the woodland pond exceeded those at the field pond, the average captures per pit for the study period was 6.5 and 6.6, respectively. Species richness for the study period was 14 at the woodland pond and 13 at the field pond. Four species of lizards and three species of turtles were documented at each pond; snakes numbered seven species at the woodland pond and six species at the field pond. Lizard captures dramatically exceeded those of turtles and snakes, comprising 78% at both ponds. Seasonal changes in activity levels were similar at the two ponds peaking in summer at both, but the second-most active period was fall at the field pond and spring at the woodland pond. Movements toward and away from the ponds were statistically equal (Yates corrected chi square) at 112 versus 95 (woodland pond) and 62 versus 67 (field pond). Results of correlation analyses (Spearman rank-order coefficient) comparing changes in cumulative monthly captures and monthly means of abiotic factors were also similar at the two ponds. At each, captures were positively correlated with soil temperature and air temperature but negatively correlated with rainfall. Habitat modification at the field pond (beginning in Fall, 1991 and occurring periodically through Fall, 1993) coincided with a 50% decrease (6 to 3) in species richness that lasted for two years (1992 and 1993). Average captures per pit decreased steadily at both ponds from 1991 through the end of the study. Results indicate the following about the reptile communities at the two ponds: 1) species composition and levels of activity are similar; 2) fluctuating levels of activity over the annual cycle correlate with temperature and rainfall; 3) directional movement in relation to each pond is random; 4) yearly activity appears to be decreasing; and 5) the influence of habitat alteration (if any) at the field pond was not readily discernable.

HABITAT, HIBERNACULA, AND SEASONAL OCCURRENCE OF THE WESTERN COTTONMOUTH (*AGKISTRODON PISCIVORUS LEUCOSTOMA*) AT MARK'S CREEK WILDLIFE MANAGEMENT AREA, CHEATHAM COUNTY, TENNESSEE

BRANT T. SMITH AND A. FLOYD SCOTT

Department of Biology and Center for Field Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. In the Cumberland River drainage, western cottonmouths (*Agkistrodon piscivorus leucostoma*) are known as far upstream as Mark's Creek Wildlife Management Area (MCWMA) in Cheatham County, Tennessee (river mile 156.5). MCWMA is 60-hectare tract consisting of cultivated fields, moist soil management plots and permanently flooded forested swamp bordered by limestone bluffs. The cottonmouth population at MCWMA is centered in the forested swamp. Crevices in the nearby limestone bluff are used as hibernacula. Two of these hibernacula at the base of the bluffs were monitored for snakes in the spring of 1998 and the falls of 1997-1998. Data loggers were used to monitor air temperature and relative humidity throughout the year inside and outside of one hibernaculum. Ten living cottonmouths (five adult females, three adult males, two juveniles) and one dead individual (adult) were encountered and examined over the study period. Males were significantly larger than females ($p<0.05$) in total body length, snout-vent length, tail length, head width, head length, and weight. Cottonmouths were present around den openings from late September through early November and again from late March through early April. Ingression of the population into hibernation appeared to be more prolonged than egression.

IMPACT OF LARGE UNGULATES ON SMALL MAMMAL FAUNA AT LAND BETWEEN THE LAKES, KENTUCKY

C.C. WEICKERT, J.C. WHITTAKER, AND G.A. FELDHAMER

Southern Illinois University at Carbondale, Carbondale, IL 62901

ABSTRACT. Mammalian herbivores have been shown to affect primary vegetation production, plant and animal species composition, nutrient cycling, and soil properties. A study is underway at the Tennessee Valley Authority's Land Between The Lakes (LBL) to study the effects of reintroduced elk (*Cervus elaphus*) and bison (*Bison bison*) on the local small mammal fauna. In 1996, a 324-ha enclosure was stocked with elk and bison. From June through December, 1998, traps were set in open-canopy hardwood, closed-canopy hardwood, and pine sites both inside the enclosure and elsewhere on LBL, for a total of 4860 trap nights. Both the number of individuals captured and the total number of captures were significantly greater inside than outside the enclosure ($p < .05$). These results should be interpreted cautiously, as the more intensive management practices in use inside the ungulate enclosure may also affect the small mammal community there.

DEMOGRAPHICS OF SOUTHERN SHORT-TAILED SHREWS (*BLARINA CAROLINENSIS*) IN A SOUTHERN ILLINOIS WOODLOT

J. C. WHITTAKER AND G. A. FELDHAMER

Department of Zoology, Southern Illinois University, Carbondale, IL 62901

ABSTRACT. Southern short-tailed shrews (*Blarina carolinensis*) are common members of the mammalian fauna in southern Illinois. Because of the high metabolic requirements of shrews and resulting trap mortality, few studies have detailed shrew demographics in the wild. A trapping grid was set in a woodlot in Jackson County, Illinois, for 100 trapping sessions over 30 months (Feb. 1996-Aug. 1998). To minimize trap mortality, traps were checked every 3 hours during a trapping session. All captured small mammals were individually marked. A total of 319,488 trap checks (15,782 trap nights) resulted in 3,435 captures of 306 individual short-tailed shrews. Both diel patterns of shrew captures and seasonal patterns of shrew density were observed.

THE BIRDS OF FORT CAMPBELL MILITARY RESERVATION, KENTUCKY AND TENNESSEE

GENE A. ZIRKLE[1] AND PATRICIA L. ZIRKLE[2]

[1]G3/Range Division, Fort Campbell Military Reservation, KY 42223
[2]Northwest High School, Clarksville, TN 37042

ABSTRACT. In 1992, Fort Campbell initiated the Land Condition Trend Analysis program to conduct flora and fauna surveys of the installation. Avian surveys were undertaken to establish impacts trends within habitats on the reservation. This paper will present all species recorded from 182 point count plots located throughout the reservation. All species were within their known ranges and appear unaffected by military activities. Species richness and total counts for the reservation have increased since 1992. "True" neotropical migrants dominate all habitats on the reservation. Twenty-seven species are published as listed species by Kentucky and Tennessee. One species, Bald Eagle (*Haliaeetus leucocephalus*), is listed as threatened by the United States Fish and Wildlife Agency. Avian populations on Fort Campbell appear to be stable; however, further studies are needed to establish cause and effect relationships between long-term military activities and local breeding populations.

THE SMALL MAMMALS OF FORT CAMPBELL MILITARY RESERVATION, KENTUCKY AND TENNESSEE

GENE A. ZIRKLE[1] AND PATRICIA L. ZIRKLE[2]

[1]G3/Range Division, Fort Campbell Military Reservation, KY 42223
[2]Northwest High School, Clarksville, TN 37042

ABSTRACT. Fort Campbell initiated the Land Condition Trend Analysis (LCTA) program in 1992 with the mission to inventory and monitor all natural resources on the reservation. It serves as the mechanism for habitat evaluations, establishing training land conditions, researching wildlife and vegetation associations, and recommends training area remediation actions. Small mammal monitoring is one facet LCTA utilizes to assess environmental impacts. Small mammals were trapped from 60 LCTA wildlife plots from December to March for the years 1992-98. Nineteen species have been recorded from Fort Campbell from two surveys, LCTA annual small mammal inventories, and the Nature Conservancy's Rare and Threatened Vertebrate survey. LCTA plots have recorded 16 species from 30,000 trap-nights with a 3.7% trap success rate. Six species, *Peromyscus leucopus*, *Microtus ochrogaster*, *Ochrotomys nuttalli*, *P. maniculatus*, and *Reithrodontomys humulis*, were common each season. Two species, *M. pennsylvanicus* and *Synaptomys cooperi*, were significant discoveries for the area. Forty-nine percent of captures were from upland old fields. Yearly habitat abundance was significant for all habitats except successional wet meadows. Species richness was uniform for all habitats. Old field habitats had the highest richness for the survey period. LCTA and the Nature Conservancy study identified five state-listed species, *Sorex cincereus*, *Sorex hoyi*, *Sorex longirostris*, *Synaptomys cooperi*, and *Zapus hudsonius*. No correlations exist between species richness and abundance with military habitat disturbances. Results suggest military activities have very little effect on reservation small mammal populations.

CONTRIBUTED PAPERS

SESSION III: BOTANY

Saturday, March 20, 1999

Moderator and Editor:

Edward W. Chester
Austin Peay State University

A QUANTITATIVE ASSESSMENT OF SOME SOUTHERN PENNYROYAL PLAIN BARRENS, KENTUCKY AND TENNESSEE

EDWARD W. CHESTER

The Center for Field Biology, Austin Peay State University
Clarksville, TN 37044

ABSTRACT. Grass-dominated areas on fertile, deep soils and nearly flat topography of the southern Pennyroyal Plain (Kentucky Karst Plain) in northwestern Middle Tennessee and west-central Kentucky were referred to as barrens by the first European settlers in the late 1700s. These barrens were apparently anthropogenically-derived, resulting (mostly) from regular burning by Native Americans. Almost all now are in tilth except for extensive areas on the Fort Campbell Military Reservation where regular burning since 1942 has allowed a barrens vegetation to re-develop on sites that had been tilled before 1942. A previously-published floristic list from 22 of these stands on the Fort Campbell Reservation included 342 species. Plot studies on ten of these sites are reported here. The data show that these barrens are clearly dominated by *Schizachyrium scoparium* (little bluestem), making up nearly one-third of IV. Along with one other grass (*Elymus virginicus*), one woody vine (*Smilax glauca*), and 13 herbs (*Agalinis tenuifolia, Aster dumosus, Chamaecrista fasciculata, Desmodium ciliare, Eupatorium hyssopifolium, Helianthus mollis, H. occidentalis, Lespedeza virginica, Pycnanthemum pilosum, P. tenuifolium, Sericocarpus linifolius, Solidago juncea, S. nemoralis*), 75% of IV is accounted for.

INTRODUCTION

The Kentucky Karst Plain (KKP), as defined by Quarterman and Powell (1978), includes the Pennyroyal Plain and the Elizabethtown Plain subsections of the Highland Rim Section, Interior Low Plateaus Physiographic Province. Smalley (1980) notes that a variety of landtype associations and community types occur on the KKP, ranging from upland swamps to cedar glades. However, the area is best known for "barrens," the name given by the first European explorers and settlers in the late 1700s to the extensive grass-dominated, nearly treeless areas. The region came to be called the Big Barrens in Kentucky, while the relatively small extension into north-central Tennessee was referred to by Shanks (1958) as the Kentucky Prairie Barrens. Transeau (1935) included the Big Barrens as part of the Prairie Peninsula, or the wedge-shaped projection of tallgrass prairie extending into the deciduous forests, but Braun (1950) suspected that the barrens were of more recent origin. Küchler (1964) mapped the potential vegetation as a mosaic of bluestem prairie and oak-hickory forests.

Literature Review

There is a considerable amount of historical (pre-1950), mostly non-botanical literature on the barrens of the KKP. Since about 1960, there has been renewed interest in these barrens; major references since then are given in the Literature Cited. In addition to reviewing historical literature, these papers (especially Baskin *et al.* 1994a, 1994b, 1999), describe the history (presettlement, settlement era, and recent), geology, physiography, soils and climate, and give information on the flora and vegetation. General conclusions advanced are:

1. The presence of extensive grass-dominated, essentially treeless areas on the KKP at the time of settlement (late 1700s) is well documented and the name "barrens" was early applied.

2. Barrens are on level-rolling topography and on deep, fertile soils that developed under forest vegetation.

3. Barrens are of anthropogenic (Native American) origin, resulting from and maintained by fires at a grass-dominated seral stage that will culminate in a deciduous forest if fire is suppressed, or if cultivated and abandoned.

4. Although fires mostly were set by Native Americans for hunting, maintaining wildlife habitat, and land clearing, lightning may have cause some fires, and trampling/grazing/browsing by large herds of herbivores (bison, deer, elk) may have had some influence on barrens development and maintenance.

5. Floristic relationships between the Big Barrens Region and the North American tallgrass prairie are minimal and for the most part, species in common are geographically widespread eastern North American taxa of open habitats that are not restricted to prairies.

6. These barrens are not part of the eastward extension of tallgrass prairie into the deciduous forest, *i.e.*, the Prairie Peninsula.

7. None of these barrens escaped agriculture and no pre-settlement examples are known to us.

8. The best existing examples of barrens are within the confines of the extensive Fort Campbell Military Reservation of Kentucky and Tennessee. Extensive barrens present at the time of settlement were converted to agriculture and used for row-crops and pasture until 1942 when the Reservation was established. Many areas have now returned to a grass-dominated vegetation as a result of rotational burning to maintain open landscapes for military training.

Studies Documenting the Flora and Vegetation

Since the barrens were converted to agriculture soon after settlement, there are no complete records of their plant life before tillage. Recent efforts to describe the flora include that of Chester (1988), who presented an historical and floristic overview of Tennessee Big Barrens, gleaning data mostly from herbarium specimens, especially collections of Royal E. Shanks and Alfred E. Clebsch (APSC and TENN) from Montgomery, Robertson, and Stewart counties, Tennessee, late 1930s-early 1950s. DeSelm and Chester (1993) provided quantitative data for one site in Montgomery County, Tennessee, called the Oakwood Barrens. That site was partly on private property and extended onto the Fort Campbell Military Reservation (FCMR). The portion on private property was used in the DeSelm and Chester study and was converted into a housing area in 1995. That study also provided floristic data from Warfield Barren, a narrow strip between the L. & N. Railroad and U.S. HW 41 just southwest of Guthrie, Kentucky, in Montgomery County, Tennessee; now that site is a meadow-like landscape of non-native grasses.

The most extensive floristic data available is that presented by Chester *et al.* (1997). That list of 342 species came from 22 sites in two Kentucky and two Tennessee counties, all part of the FCMR. Access to the Reservation, normally off-limits for studies of this type, was granted to myself, Eugene Wofford (The University of Tennessee), and Landon McKinney (at that time a botanist for the Kentucky State Nature Preserves Commission), to conduct a survey for federal and state-listed taxa on the Reservation. Jerry and Carol Baskin spent several days on the Reservation during that study, which covered the period 15 March 1993-31 October 1994. From 1 July 1996-30 June 1998, Chester and Wofford were authorized to gather additional data that would be of value to FCMR environmentalists in developing management plans for some listed taxa on the Reservation. During that time, I collected the quantitative data presented here.

METHODS

Ten of the 22 sites used in the floristic study by Chester *et al.* (1997) were selected for quadrat sampling. Six of the sampled sites are in Montgomery County, Tennessee, one is in Stewart County, Tennessee, two are in Christian County, Kentucky, and one is in Trigg County, Kentucky. For each site, one or two temporarily-marked transects were established that bisected the site (if one transect was used) or divided the site into approximate equal units (when two transects were used). Twenty m^2 quadrats were placed at equal distances along the transect(s). Initial and ending quadrats along a transect avoided edge effects. Transects did not include "swales" and other lower parts of sloping sites; however, those landscapes were included in the cited floristic list. All plants in each of the 200 quadrats were listed and the percentage of each plot covered by each included species was estimated. Nomenclature follows Wofford and Kral (1993). Data collected were used to determine several community parameters. Frequency (the percent of 200 plots in which a species occurred), relative (%) frequency, total cover, average cover per plot (total cover divided by 200), and relative (%) cover were calculated for each species. An importance value (IV) was calculated by summing the two relative values and percentage IV determined (IV/2).

RESULTS AND DISCUSSION

The ten sites studied are numbers 1, 2, 4, 5, 7, 8, 10, 12, 18, and 22 in the floristic study of Chester *et al.* (1997), who give the location, size, topography, bedrock, soils, and other data. A total of 114 species was sampled, distributed among sites as: site 1 (68 species), 2 (62), 3 (70), 4 (69), 5 (68), 6 (63), 7 (53), 8 (54), 9 (57), 10 (69). Average number of species per site was 60. Quantitative data [number of sites (of 10), number of quadrats (of 200), relative frequency, relative cover, IV-200, and percent IV] are shown in Table 1 (tables are appended) for an alphabetical listing of taxa. In addition, a ranked listing of dominant taxa is shown in Table 2 (appended).

SUMMARY

As noted in the floristic list from these barrens (Chester *et al.* 1997), it appears that the flora of the Fort Campbell Military Reservation barrens is representative of conditions that existed at the time of European settlement. The combined list included 342 species; 114 (33.3%) of these were sampled in this study. This low percentage of sample species is not unusual since presence is atypical. In the floristic study, 34.2% of the 342 taxa are presence classes 4 and 5 (mostly and constantly present), while 55.8% are in presence classes 1 and 2 (rare and seldom present). Obviously, many of the rare-seldom present species would not appear in the sampling data.

The data show that these barrens are clearly dominated by *Schizachyrium scoparium* (little bluestem), making up nearly one-third of IV. Along with one other grass (*Elymus virginicus*), one woody vine (*Smilax glauca*), and 13 herbs (*Agalinis tenuifolia, Aster dumosus, Chamaecrista fasciculata, Desmodium ciliare, Eupatorium hyssopifolium, Helianthus mollis, H. occidentalis, Lespedeza virginica, Pycnanthemum pilosum, P. tenuifolium, Sericocarpus linifolius, Solidago juncea, and S. nemoralis*), 75% of IV is accounted for.

LITERATURE CITED AND MAJOR RECENT REFERENCES ON THE FLORA AND VEGETATION OF BARRENS WITHIN THE BIG BARRENS REGION OF KENTUCKY AND TENNESSEE

Baskin, J. M., and C. C. Baskin. 1977. Observations on the plant ecology of cedar glades in the former Big Barrens Region of Kentucky. Bull. Assoc. Southeastern Biologists 25:35.

Baskin, J. M., and C. C. Baskin. 1978. Plant ecology of cedar glades in the Big Barrens Region of Kentucky. Rhodora 80:545-557.

Baskin, J. M., and C. C. Baskin. 1981. The Big Barrens of Kentucky not part of Transeau's Prairie Peninsula. Pages 43-48 in: R. L. Stuckey and K. J. Reese (eds.). The Prairie Peninsula - in the "shadow" of Transeau. Proceedings of the sixth North American Prairie Conference, The Ohio State University, Columbus, Ohio, 12-17 August, 1978. Ohio Biological Survey, Notes Number 15.

Baskin, J. M., C. C. Baskin., and E. W. Chester. 1994a. The Big Barrens Region of Kentucky and Tennessee: Further observations and considerations. Castanea 59:226-254.

Baskin, J. M., C. C. Baskin., and E. W. Chester. 1994b. The Big Barrens Region of Kentucky and Tennessee: A short review. Pages 305-309 in: J. S. Fralish, R. C. Anderson, J. E. Ebinger, and R. Szafoni (eds.). Proceedings of the North American Conference on barrens and savannas at Illinois State University, Normal, Illinois, October 15-16, 1994. Illinois State University, Normal, Illinois.

Baskin, J. M., C. C. Baskin, and E. W. Chester. 1999. The Big Barrens Region of Kentucky and Tennessee. Chapter 11, pages 190-205 in: Savannas, barrens, and rock outcrop plant communities of North America (edited by Anderson, R. C., J. S. Fralish, and J. M. Baskin). Cambridge University Press, United Kingdom.

Baskin, J. M., E. W. Chester, and C. C. Baskin. 1997. Forest vegetation of the Kentucky Karst Plain (Kentucky and Tennessee): Review and synthesis. J. Torrey Botanical Society 124:322-335.

Braun, E. L. 1950. Deciduous forests of eastern North America. Blakiston, Philadelphia, Pennsylvania.

Chester, E. W. 1988. Some aspects of northern Middle Tennessee barrens. J. Tennessee Acad. Sci. 63:38-39.

Chester, E. W. 1988. The Kentucky Prairie Barrens of northwest Middle Tennessee: an historical and floristic perspective. Pages 145-163 in: D. H. Snyder (ed.). Proceedings of the first annual symposium on the natural history of lower Tennessee and Cumberland River Valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Chester, E. W., B. E. Wofford, J. M. Baskin, and C. C. Baskin. 1997. A floristic study of barrens on the southwestern Pennyroyal Plain, Kentucky and Tennessee. Castanea 62:161-172.

DeSelm, H. R. 1961. Remarks on Tennessee barrens. J. Tennessee Acad. Sci. 36:137.

DeSelm, H. R. 1981. Characterization of some southeastern barrens, with special reference to Tennessee. Pages 86-88 in: R. L. Stuckey and K. J. Reese (eds.). Proceedings of the Sixth North American Prairie Conference. The Ohio State University, Columbus, Ohio.

DeSelm, H. R. 1986. Natural forest openings on uplands of the eastern United States. Pages 366-375 in: D. L. Kulhavy and D. N. Conner (eds.). Wilderness and natural areas in the eastern United States, a management challenge. Center for Applied Studies, School of Forestry, Stephen F. Austin State University, Nacogdoches, Texas.

DeSelm, H. R. 1989. The barrens of Tennessee. J. Tennessee Acad. Sci. 64:89-95.

DeSelm, H. R. 1994. Tennessee barrens. Castanea 59:214-225.
DeSelm, H. R. 1994. Observations on Tennessee barrens. Pages 321-322 in: J. S. Fralish, R. C. Anderson, J. E. Ebinger, and R. Szafone (eds.). Proceedings of the North American Conference on barrens and savannas at Illinois State University, Normal, Illinois, October 15-16, 1994. Illinois State University, Normal.
DeSelm, H. R., and E. W. Chester. 1993. Further studies on the barrens of the Northern and Western Highland Rims of Tennessee. Pages 137-160 in: S. W. Hamilton, E. W. Chester, and A. F. Scott (eds.). Proceedings of the fifth symposium on the natural history of lower Tennessee and Cumberland River Valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.
Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States. Map and accompanying manual. Amer. Geographical Soc. Publ. No. 36.
Quarterman, E., and R. L. Powell. 1978. Potential ecological/geological natural landmarks on the Interior Low Plateaus. U.S. Department of the Interior, Washington, DC.
Shanks, R. E. 1958. Floristic regions of Tennessee. J. Tennessee Acad. Sci. 33:194-210.
Smalley, G. W. 1980. Classification and evaluation of forest sites on the Western Highland Rim and Pennyroyal. U.S. Department of Agriculture, Forest Service, Gen. Tech. Rep. SO-30.
Transeau, E. N. 1935. The Prairie Peninsula. Ecology 16:423-437.
Wofford, B. E., and R. Kral. 1993. Checklist of the vascular plants of Tennessee. Sida, Botanical Miscellany No. 10. Botanical Research Institute of Texas, Fort Worth, Texas.

APPENDIX: TABLES 1 AND 2

Table 1. Quantitative data and IV computation for the 114 species sampled in ten barrens sites, southern Pennyroyal Plain, Kentucky and Tennessee.

Taxa	No. Sites	No. Quads.	Rel. Freq.	Rel. Cover	I.V. 200	% of I.V.
Acer rubrum	2	4	0.15	0.08	0.23	0.12
Achillea millefolium	4	6	0.23	0.06	0.29	0.15
Agalinis fasciculata	8	16	0.61	0.17	0.78	0.39
Agalinis tenuifolia	10	90	3.48	1.24	4.72	2.36
Allium vineale	10	31	1.19	0.17	1.36	0.68
Ambrosia artemisiifolia	10	18	0.69	0.17	0.86	0.43
Ambrosia bidentata	9	26	1.00	0.26	1.26	0.63
Andropogon gerardii	5	7	0.27	0.17	0.44	0.22
Andropogon gyrans	8	28	1.08	0.35	1.43	0.72
Andropogon ternarius	1	1	0.03	-	0.03	0.02
Anemone virginiana	3	3	0.11	0.02	0.13	0.07
Antennaria plantaginifolia	2	3	0.11	-	0.12	0.06
Apocynum cannabinum	5	5	0.19	0.05	0.24	0.12
Asclepias amplexicaulis	5	6	0.23	0.06	0.29	0.15
Asclepias tuberosa	4	4	0.15	0.05	0.20	0.10
Aster dumosus	10	133	5.14	4.44	9.58	4.79
Aster pilosus	8	19	0.73	0.26	0.99	0.50
Bidens polylepis	3	3	0.11	0.06	0.17	0.09
Buchnera americana	8	35	1.35	0.35	1.70	0.85
Carex complanata	4	7	0.27	0.03	0.30	0.15
Chamaecrista fasciculata	10	134	5.18	3.02	8.20	4.10
Chamaecrista nictitans	5	10	0.38	0.08	0.46	0.23
Chasmanthium latifolium	1	1	0.03	0.08	0.11	0.06
Chrysanthemum leucanthemum	2	1	0.03	0.01	0.04	0.02
Cirsium discolor	9	14	0.54	0.17	0.71	0.36
Coreopsis major	9	26	1.00	0.26	1.26	0.63
Coreopsis tripteris	3	5	0.19	0.08	0.27	0.14
Cornus florida	4	4	0.15	0.08	0.23	0.12
Daucus carota	7	13	0.50	0.08	0.58	0.29
Desmodium canescens	1	2	0.07	0.17	0.24	0.12
Desmodium ciliare	10	147	5.68	3.73	9.41	4.71
Desmodium paniculatum	2	3	0.11	0.03	0.14	0.07
Desmodium sessilifolium	8	22	0.85	0.26	1.11	0.56
Diodia teres	2	3	0.11	0.01	0.12	0.06
Diospyros virginiana	10	26	1.00	0.35	1.35	0.68
Elymus virginicus	10	50	1.93	0.44	2.37	1.19
Eragrostis spectabilis	8	11	0.42	0.01	0.43	0.22
Erianthus alopecuroides	1	1	0.03	0.02	0.05	0.03
Erigeron strigosus	3	3	0.11	0.01	0.12	0.06
Eupatorium altissimum	10	34	1.31	0.35	1.66	0.83
Eupatorium hyssopifolium	10	77	2.97	0.80	3.77	1.89
Eupatorium rotundifolium	5	8	0.30	0.08	0.38	0.19
Eupatorium serotinum	3	6	0.23	0.03	0.26	0.13

Euphorbia corollata	10	28	1.08	0.26	1.34	0.67
Euthamia graminifolia	2	2	0.07	0.03	0.10	0.05
Fragaria virginiana	8	19	0.73	0.26	0.99	0.50
Galium pilosum	9	10	0.38	0.07	0.45	0.23
Gaura biennis	6	13	0.50	0.17	0.67	0.34
Gnaphalium obtusifolium	3	3	0.11	0.02	0.13	0.07
Gymnopogon ambiguus	2	2	0.07	0.02	0.09	0.05
Hedyotis purpurea	3	4	0.15	0.03	0.18	0.09
Helianthus angustifolius	7	12	0.46	0.17	0.63	0.32
Helianthus hirsutus	9	18	0.69	0.26	0.95	0.48
Helianthus mollis	10	39	1.50	0.71	2.21	1.11
Helianthus occidentalis	10	101	3.90	3.37	7.27	3.64
Hieracium gronovii	4	4	0.15	0.04	0.19	0.10
Hieracium longipilum	1	1	0.03	0.01	0.04	0.02
Hypericum drummondii	3	7	0.27	0.03	0.30	0.15
Hypericum gentianoides	1	1	0.03	-	0.03	0.02
Hypericum punctatum	8	14	0.54	0.08	0.62	0.31
Juniperus virginiana	2	4	0.15	0.07	0.22	0.11
Lespedeza capitata	2	3	0.11	0.04	0.15	0.08
Lespedeza procumbens	7	21	0.81	0.35	1.16	0.58
Lespedeza virginica	10	105	4.06	1.95	6.01	3.01
Liatris spicata	1	8	0.30	0.08	0.38	0.19
Liatris squarrosa	8	18	0.69	0.17	0.86	0.43
Liatris squarrulosa	8	24	0.92	0.26	1.18	0.59
Linum striatum	3	3	0.11	0.02	0.13	0.07
Lobelia puberula	8	28	1.08	0.26	1.34	0.67
Lonicera japonica	1	1	0.03	0.01	0.04	0.02
Manfreda virginica	2	2	0.07	0.01	0.08	0.04
Monarda fistulosa	2	3	0.11	0.03	0.14	0.07
Nyssa sylvatica	5	9	0.34	0.17	0.51	0.26
Oxalis stricta	5	6	0.23	0.02	0.25	0.13
Panicum anceps	5	8	0.30	0.08	0.38	0.19
Panicum dichotomum	2	4	0.15	0.04	0.19	0.10
Physalis heterophylla	1	1	0.03	0.01	0.04	0.02
Polygala incarnata	6	7	0.27	0.06	0.33	0.17
Polygala sanguinea	3	5	0.19	0.02	0.21	0.11
Polygala verticillata	3	5	0.19	0.02	0.21	0.11
Potentilla simplex	10	34	1.31	0.35	1.66	0.83
Prunella vulgaris	1	1	0.03	0.01	0.04	0.02
Prunus angustifolia	1	1	0.03	-	0.03	0.02
Pycnanthemum pilosum	10	62	2.39	0.71	3.10	1.55
Pycnanthemum tenuifolium	10	117	4.52	2.66	7.18	3.59
Rhus copallina	10	33	1.27	0.53	1.80	0.90
Rhus glabra	1	2	0.07	0.02	0.09	0.05
Rosa carolina	10	23	0.89	0.26	1.15	0.58
Rubus argutus	1	1	0.03	0.03	0.06	0.03
Rubus flagellaris	10	22	0.85	0.26	1.11	0.56
Rudbeckia hirta	5	5	0.19	0.05	1.35	0.68
Rudbeckia subtomentosa	1	1	0.03	0.01	0.04	0.02
Sabatia angularis	7	13	0.50	0.08	0.58	0.29

Sassafras albidum	7	17	0.65	0.26	0.91	0.46
Schizachyrium scoparium	10	196	7.58	57.80	65.38	32.69
Scleria pauciflora	7	19	0.73	0.26	0.99	0.50
Scleria triglomerata	1	1	0.03	0.02	0.05	0.03
Sericocarpus linifolius	10	52	2.01	0.62	2.63	1.32
Setaria parviflora	10	38	1.47	0.35	1.82	0.91
Silphium integrifolium	1	2	0.07	0.02	0.09	0.05
Smilax glauca	10	56	2.16	0.62	2.78	1.39
Solidago canadensis	2	5	0.19	0.08	0.27	0.14
Solidago juncea	10	141	5.45	3.94	9.39	4.70
Solidago nemoralis	10	91	3.52	1.95	5.47	2.74
Sorghastrum nutans	7	13	0.50	0.26	0.76	0.38
Spiranthes lacera	3	3	0.11	0.01	0.12	0.06
Strophostyles umbellata	7	14	0.54	0.17	0.71	0.36
Stylosanthes biflora	10	10	0.38	0.05	0.43	0.22
Symphoricarpos orbiculatus	1	2	0.07	0.02	0.09	0.05
Tephrosia virginiana	2	3	0.11	0.05	0.16	0.08
Tomanthera auriculata	2	3	0.11	0.02	0.13	0.07
Toxicodendron radicans	1	1	0.03	0.01	0.05	0.03
Tridens flavus	5	10	0.38	0.08	0.46	0.23
Vitis aestivalis	3	3	0.11	0.05	0.16	0.08

Table 2. Ranked listing of dominant species in ten sampled barrens sites, southern Pennyroyal Plain, Kentucky and Tennessee.

Taxa	%IV
Schizachyrium scoparium	32.69
Aster dumosus	4.79
Desmodium ciliare	4.71
Solidago juncea	4.70
Chaemicrista fasciculata	4.10
Helianthus occidentalis	3.64
Pycnanthemum tenuifolium	3.59
Lespedeza virginica	3.01
Solidago nemoralis	2.74
Agalinis tenuifolia	2.36
Eupatorium hyssopifolium	1.89
Pycnanthemum pilosum	1.55
Smilax glauca	1.39
Sericocarpus linifolius	1.32
Elymus virginicus	1.19
Helianthus mollis	1.11
TOTAL % IV FOR THESE 16 SPECIES	74.78
TOTAL % IV FOR THE OTHER 98 SPECIES	25.22

VEGETATION RESULTS FROM EARLY LAND SURVEYS IN FIVE COUNTIES OF TENNESSEE, 1788-1839

H. R. DESELM

Department of Botany, The University of Tennessee, Knoxville, TN 37996

ABSTRACT. Metes and bounds land surveys for property ownership from the period 1788-1839 were used to characterize the forest composition in four Tennessee county areas. Counties (dates)/number of surveys/number of corner trees used were: Hawkins (1788-1800)/267/1397, Marion (1819-1830)/248/1413, Putnam-Jackson (1826-1839)/783/4442, and Stewart (1789-1818)/327/1933. Comparison of percent species or species group composition in the surveys with modern inventories reveals that certain taxa usually have increased in importance, *e.g.* (*Pinus* spp., *Juniperus virginiana*, *Liriodendron tulipera*), some are decreasers (usually mesophytes as *Fagus grandifolia* and *Acer saccharum*), and some percentages of taxa or groups of taxa differ considerably from the surveys possibly because of geographically localized surveying or modern sample plot placement. Plant communities known today are suggested by species-survey co-occurrence data. In spite of problems of survey or methodology and survey location, they contain considerable information about Tennessee's forest landscape near the time of its settlement.

INTRODUCTION

Landscape vegetation cover at or near the time of settlement by European-Americans is of interest to field scientists. Such information is relevant to historians (Williams 1989), paleoecologists (Delcourt *et al.* 1986), pedologists (Jenny 1980), anthropologists (Chapman and Shea 1981) and vegetation biomass modelers (Waring and Schlesinger 1985). Vegetation ecologists (DeSelm 1994) use past vegetation patterns to interpret the impacts of environmental and historical factors on present vegetation (Mueller-Dombois and Ellenberg 1974).

Congressional Land Survey records, or similar survey records, have been used extensively to characterize vegetation and interpret its boundaries (cf. DeSelm 1994). Such rectilinear surveys, which have north-south and east-west lines with regularly spaced landscape/tree/other vegetation observations, contrast with metes and bounds surveys with less geographical and chronological pattern. The less well-organized metes and bounds surveys have been little used in studies of early settlement vegetation (but see DeSelm 1995, 1997, and DeSelm and Rose 1995).

This paper reports vegetation results obtained from metes and bounds surveys of the period in Hawkins, Marion, Putnam and Jackson, and Stewart counties, Tennessee (Figure 1). I report here average percentage forest composition seen by the surveyors and compare that information with that from more modern inventories.

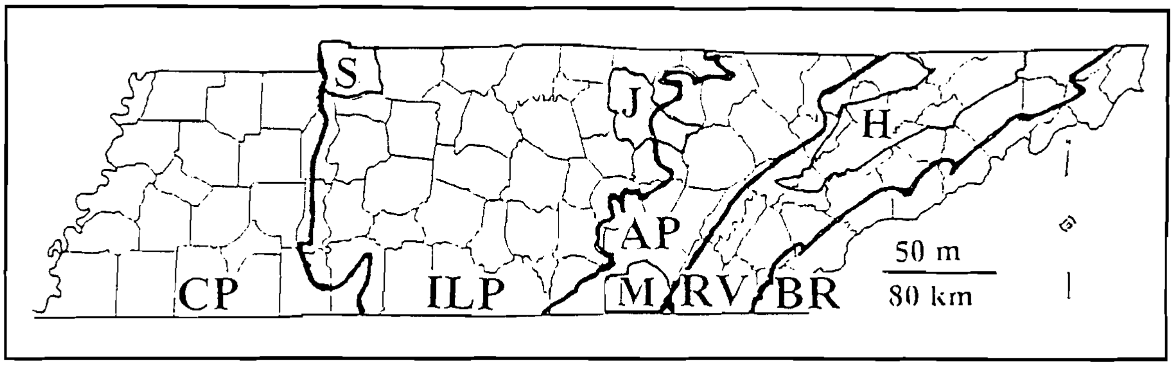


Figure 1. Map of Tennessee showing boundaries: CP = Coastal Plain; ILP = Interior Low Plateaus; AP = Appalachian Plateau; RV = Ridge and Valley; BR = Blue Ridge Physiographic Provinces. H = Hawkins County of 1795 (Foster 1923); M = Marion County; J = Jackson and Putnam counties; S = Stewart County.

CHARACTER OF THE SURVEYED AREAS

Hawkins County lies in the Ridge and Valley Physiographic Province, Marion County lies in the Appalachian Plateaus Province (Cumberland Plateau), Putnam and Jackson counties lie in the Interior Low Plateaus Province (eastern Highland Rim) (eastern Putnam County extends into the eastern edge of the Appalachian Plateaus), and Stewart County lies at the western edge of the Interior Low Plateaus Province (northern Highland Rim) (Fenneman 1938).

These parts of Tennessee have a subtropical humid climatic type. Precipitation varies from 112-152 cm per year; floods and late seasonal droughts are common (Trewartha 1968, Dickson 1960). January mean maximum temperatures are in the 9 to 10°C range; mean minima are in the -1.5 to 0°C range. July mean maximum temperatures range from about 29 to 33°C; mean minima range from about 18 to 20°C (Dickson 1960).

Hawkins County in 1790, in the middle of the survey period, was one of seven East Tennessee counties. It extended in the Ridge and Valley from the Virginia line southwest at least into the present Loudon and Roane counties. It included all or parts of the present Hawkins, Hancock, Claiborne, Grainger, Union, Knox, Roane, and Loudon counties. Most surveys came from the present Hawkins County but a few came from the Ridge and Valley part of the counties as far south as Knox. Topography of the Ridge and Valley part of this area is characterized by southwest-northeast trending parallel ridges and valleys underlain by Paleozoic sandstones, dolomites, limestones and shales. The major ridges, Powell, Clinch, and Bays Mountain, pass through the area; the Holston and Tennessee rivers flow through the middle of the area (Rodgers 1952). Elevations range from about 210 m on the river to 1170 m. The rolling to steep topography is mapped in six state level soil associations. Four of these occupy the hills and higher valleys. Old high terrace soils occur and flood plain and terrace soils occur on the major rivers and their tributaries. The soils are classed as Alfisols, Inceptisols and Ultisols (Springer and Elder 1980).

Marion County and eastern Putnam County are underlain by horizontal Pennsylvanian beds of sandstone, shale, and coal above upper Mississippian limestones (Hardeman 1966). The counties are dissected tablelands; the surfaces are generally at 300-610 m elevation falling to about 240 m on the Tennessee River and in the Sequatchie Valley in Marion County and to about 200 m in western Putnam County. The undulating to steep topography of Marion County is classed in three state level soil associations on the Plateau surface and slopes. The more gentle slopes and deeper soils of the Sequatchie Valley include several low to high terrace soils. Soils are classed as Alfisols, Inceptisols and Ultisols (Springer and Elder 1980).

The western Putnam County and Jackson County areas occupy a dissected tableland underlain by flat-lying Mississippian limestones. To the west in Putnam County, and in the southwest part and along the Cumberland River in Jackson County, flat-lying Ordovician limestones outcrop (Hardeman 1966). Highland Rim surface elevations of 330-360 m fall to about 150 m along the Cumberland River. The undulating to steep portions of the Plateau part of Putnam County are covered by soils similar to those of Marion County–acid, sandy, mostly rocky and shallow to deep. The Highland Rim parts of Putnam and Jackson counties have quite varied soils. The largest areas are the undulating to rolling to steep soils derived from loess or from limestone. On the eastern edge of the Rim are high terrace soils, often sinkhole pitted. Westward in Putnam County, and along the Cumberland River in Jackson County, soils derived from shale and high grade limestones occur. Six State soil associations are mapped; soils are Alfisols, Inceptisols, Mollisols and Utisols (Springer and Elder 1980).

Stewart County is a dissected tableland with surface elevations of about 200 to 240 m falling to a little below 120 m on the Cumberland River and in the Wells Creek Structure. Mississippian limestones are mapped throughout the County; they are covered by deep alluvial deposits along the Cumberland River course. Small areas of Devonian, Silurian and Ordovician-Cambrian rocks outcrop in the Wells Creek Structure. Some ridges are capped by Cretaceous gravels (Hardeman 1966). The undulating to steep parts of Stewart County are classed in four State soil associations. Generally, upland undulating to gently rolling soils are loess derived. Steep slope soils are derived chiefly from cherty limestones. Along the Cumberland River are flood plain and poorly to well-drained terrace soils. The soils are classed as Alfisols, Entisols, Inceptisols, Mollisols, and Ultisols (Springer and Elder 1988).

The flora of the several study areas are relatively well known (Wofford and Kral 1993). Collections of native plant taxa range from 349 (in Jackson) to 984 taxa in Stewart County (University of Tennessee Herbarium 1998). Forest vegetation has been described (Bryant *et al.* 1993, Hinkle *et al.* 1993, Stephenson *et al.* 1993); the barrens are described by DeSelm and Murdock (1993) and the Plateau sandstone outcrops by Perkins (1981). Generally, the vegetation falls into bottomland types, mesic lower slope and cove hardwood types (sometimes with hemlock), and upland oak, oak-hickory, oak-pine or oak-cedar types. These general classes of communities are mapped in Hawkins and Marion counties (Tennessee Valley Authority 1941).

The study areas were visited or occupied by Native American cultures beginning at least 10,000 years before present (Paleoindian and Archaic cultures). Later cultures built villages along major streams and the uplands were used for hunting and the gathering of wild plant good. The use of fire in the forests was common (Hudson 1976). European-American settlement occurred following a series of treaties with the occupying Native Americans over the period 1790-1819 (Folmsbee *et al.* 1969). Forests were cleared, some valley lands drained and row crops were cultivated. Slopes were logged for farm timber and forests were grazed and often burned (surface fires) in the spring (Killebrew *et al.* 1874).

METHODS

Deed Books (or Survey or Plat Books) were obtained for Hawkins, Marion, Putnam and Stewart counties. These describe land transfer surveys from various periods: Hawkins 1788-1800, Marion 1819-1830, Putnam 1826-1839, and Stewart 1789-1818. The Putnam County record is the surveyor Richard F. Cooke's Survey or Plat Book which includes surveys from both Putnam and Jackson counties. These handwritten records from the State Archives in Nashville were typed 1937-1939, as part of the Works Progress Administration Copying Historical Records Project. They are available in book form from Mountain Press. The numbers of surveys used and trees cited were: Hawkins - 269 and 1397, Marion - 248 and 1413, Putnam - 783 and 4442, and Stewart - 326 and 1933. Surveys came from the Hawkins County of the period, Marion County, Putnam and Jackson counties (a few other surveys from adjacent counties have been excluded) and Stewart County, including a few surveys from adjacent Montgomery and Houston counties. Compilation of average forest composition is made possible by the surveyor's recording of corner trees by name.

The use of the typed versions of the manuscripts survey descriptions means that possible spelling or other errors have been introduced by the typists. A few typographical errors have been seen (but indeed, these may also be in the original). The typists apparently copied the records as they found them, eighteenth and nineteenth spellings included (plant name spellings are compiled in the tables).

The surveys generally recorded a tree at each corner, rarely a topographic feature was used instead. Sometimes a stake was recorded with or instead of a tree. The botanical qualifications of the surveyors are unknown. Surveyors used the compass and measured distances in poles (rarely perches, rods, or chains and links). No attempt is made to find the surveyor's lines on the ground. No diameters or point-to-tree distances are given. For the most part, the specific locations are unknown.

A few surveys used stakes only–usually these were city lots as in Dover or Jasper. The earliest surveys were through wild, little-modified forest land, but most surveys, early and later, started from known corners of existing property lines. Some surveys crossed roads, or paths, or fields. Non-native species–as peach–are mentioned occasionally. Some surveys duplicated corners, apparently representing resale of the same lands described by the same corners; such tree data have been eliminated when recognized.

RESULTS

General

Tree-form descriptors, and landform/landscape descriptors were similar in these surveys to those used in other mainly nineteenth century surveys (DeSelm 1995, 1997, DeSelm and Rose 1997). Most place names could be found in modern gazetteers (Fullerton 1974, United States Geological Survey 1991). A few place names (as John's Mill Creek) mentioned once or twice cannot be found and are either too local to be recorded or perhaps use has been discontinued. One, Huchins Creek, described as west of Pilot Knob (on the Whitleyville, Tenn. U.S.G.S. 7.5 minute quadrangle) in Putnam County was referred to by Cooke repeatedly, but cannot be located.

Hawkins County

Table 1 contains the percentage by "species" of stems recorded in the Hawkins County surveys (left column), also (next column to the right) the percent of those trees of the left column which were recorded as growing on creek or river banks. The high proportion of sycamore and some elm taxa is related to the tolerance of these taxa to wet or flooded soils (Burns and Honkala 1990). Mesophytic taxa (as sugar maple and beech) are also higher here. Upland taxa as chestnut, post oak and black oak, avoiding wet or mesic sites or competition with those species, exhibit low percentages.

Table 1. Data showing percent of stems of species and species groups from the Hawkins County Surveys: percent of all stems and percent of those stems noted along streams and rivers. TVA reports are mean percent of stems ≥ 5 inches diameter from Anderson-Knox-Union counties (TVA 1964), Claiborne County (TVA 1960), Grainger-Hamblen-Hawkins-Jefferson counties (TVA 1968), Greene County (TVA 1952), and Hancock County (TVA 1961). The Cowan (1946) data is the average percent composition from Clairborne, Grainger, Greene, Hancock, Hamblen, Jefferson, Knox and Sullivan counties. The Peterson (1931) data are the mean old growth board feet data from Grainger and Hamblen counties (Woolrich and Neely 1934a,b).

Taxa	Percent Stems	Percent on rivers, streams	Peterson 1931	Cowan 1946	TVA 1952-68
Acer rubrum, maple	0.7				3.1[a]
A. saccharum, sugar tree	5.4	35.2			1.9[b]
A. spp., maples	6.4			2.7	5.0
Aesculus octandra, buckeye	1.7	52.2			
Amelanchier spp., service tree	0.1				
Asimina triloba, papaw	0.1				
Carya spp., hickory	7.4	13.0	4.0	8.8	12.0
Castanea dentata, chesnut, chestnut	2.3	4.5	19.8		2.9[c]
Celtis spp., hackberry	<0.1				
Cercis canadensis, redbud	0.2				
Cornus spp., dogwood	4.5				
Corylus spp., hazel	<0.1				
Diospyros virginiana, persimmon					
Fagus grandifolia, beech, beach	6.2	18.6		6.2	2.1
Fagus sp./*Acer* spp., beech-maple	12.6		0.4		7.1
Fraxinus spp., ash	4.5	25.3	<0.1		2.6[a]
F. sp., hoop ash	<0.1				
Gleditsia triacanthos/Robinia pseudoacacia, locust	0.4				2.8[b]
Ilex sp., hoopwood	0.1				

Taxa	Percent Stems	Percent on rivers, streams	Peterson 1931	Cowan 1946	TVA 1952-68
Juglans cinerea, white walnut	0.6				
J. nigra, black walnut	1.4	20.0			1.4[d]
J. spp., walnut	1.4				
Juniperus virginiana, cedar, cidar, cider, ceadar	0.1			1.3	4.1
Liquidambar styraciflua, gum	0.6				
Liriodendron tulipifera, poplar	4.7		8.0	8.8	8.7
Magnolia acuminata, cucumber	0.1				
Morus rubra, mulbery	0.7				
Nyssa sylvatica, black gum	0.3			2.7	2.1[c]
Ostrya virginiana, ironwood	0.6				
Oxydendrum arboreum, sourwood, sowerwood	0.3				
Pinus spp., yellow pines			9.9	18.1	17.2
P. spp., pine	5.2				
Platanus occidentalis, sycamore	2.2	82.1			1.1[c]
Prunus spp., cherry	0.4				1.2[c]
P. spp., plum, plumb	<0.1				
P. persica, peach	<0.1				
Quercus spp., all oaks	41.0		40.0	46.6	28.1
Q. alba, white oak	18.4	6.5			5.7
Q. coccinea, scarlet oak					2.9
Q. coccinea, Q. rubra, Q. shumardii, red oak	3.9				
Q. falcata, Q. rubra, Q. velutina					9.5
Q. falcata, Spanish oak	2.4	15.2			
Q. montana, chestnut oak	6.3				8.8
Q. nigra, water oak	0.1				
Q. spp. red oaks				31.7	
Q. spp., oak	1.1				
Q. stellata, post oak	5.1	1.3			1.2[b]
Q. velutina, black oak	9.7	4.4			
Q., all white oaks	23.5			14.9	
Quercus spp., *Carya* spp., oak, hickory	48.4				
Quercus spp., *Castanea*, oak, chestnut	43.3				
Quercus spp., *Pinus* spp., oak, pine	46.2				
Sassafras albidum, sassafras	0.4				
Tilia spp., lyn, lynn, lime tree	2.4	38.2			0.9[c]
Ulmus spp., elm	2.4	70.6			1.0[c]
Viburnum prunifolium, black haw	<0.1				

[a]Data included from three TVA reports.
[b]Data included in two TVA reports.
[c]Data included in one TVA report.
dData included in four TVA reports.

Comparison of the survey data with modern inventories (Table 1) is made difficult by inclusion of some taxa in the "other hardwood" or "other softwoods" inventory categories. Thus comparable data for many taxa is not available. Probable increaser taxa among the three sets of modern inventory data are red maple, hickories, cedars, poplar and black gum. The increaser behavior of pine and locust (*Robinia*) may be due to their invasion of opened forest stands, increased forest edge due to fragmentation, old field invasion, and planting (Smith 1968, Burns and Honkala 1990). Note the increase in pine percentages between Peterson (1931) and Cowan (1946) and the TVA reports.

Taxa in which percentage abundance has decreased include chestnut and the elms; this is due largely to disease (Hepting 1971). Decreases in abundance of sugar maple, buckeye, beech, ash, sycamore, the oaks (especially white and post oaks) and lynn are probably due to land use conversion from forest to agricultural or other uses. Losses among oaks may be augmented by succession (Fralish and Crooks 1989) and oak decline (Starkey and Oak 1989).

Non-forest sites, a "grassy plain" on Rosebury Creek, Knox County, and a "grassy hill" on Caney Creek, Hawkins County were recorded. Barrens were mentioned between German and Richland Creeks in Grainger County. A meadow was noted on Bull Run Creek, Anderson County. The origin of these openings is unknown. They could be Indian old fields, cleared land used as pasture of the period, or barrens or glades known in the area (DeSelm 1993, Hicks 1968). It is assumed that the use of stakes and the (rare) citation of shrub corners were matters of convenience rather than meaning the absence of trees.

A "species" co-occurrence table was prepared (not shown) of joint "species" occurrences at single survey corners. Occurrences total 1102 among the 22 taxa recorded. The xeric forests of ridge tops are suggested by the co-occurrence of pine, post oak and hickories. The abundant white oak was recorded mainly with black oak, dogwood, hickory, and red oak. Spanish oak was recorded with several taxa but especially post oak. The mesic forests are suggested by the association of beech with poplar, sugar maple and ash; buckeye, lynn, and white walnut were also associated with beech or sugar maple. Swamp forests are suggested by the association of the elms with sycamore.

Marion County

The list of 52 taxa from the surveys (Table 2) includes three names which are completely unknown; the others are known species, or genera, or are assigned to species groups. Survey and inventory "species" percentages approximate one another in several taxa. Increasers include pines, hemlock, chestnut, oak, white oaks, red oaks, oaks, hickory and cedar. Decreasers include beech, chestnut, ash and perhaps sweetgum, poplar, black gum and lynn.

Examination of survey place names indicates that the surveys were conducted mainly in the Sequatchie Valley and near the Tennessee and Sequatchie rivers, thus the bottomland and mesic slopes taxa stem percentages total about 50, while oak and pine percentages total about 43. In the last inventory (TVA 1965) swamp and low slope taxa total about seven percent while upland oak, hickory and pine stems total nearly 83 percent. The reduction in the former and the increases in the latter probably represent the change in forest land available to sample. The deep soil of swamps and mesic forests are now in agriculture and modern samples come chiefly from the Cumberland Plateau coves, slopes and upland surface. Disappearance of chestnut is due to disease (Hepting 1871). The rarity of trends within species or species groups across surveys may represent variability resulting from low sample numbers.

No open lands such as marshes, old fields, meadows or barrens are cited. Three fields, as "Gott's field" are mentioned. One survey includes the Native American "Old Deerhead Town" without further comment.

Table 2. Percent occurrences in surveys from Marion County, Tennessee. Peterson (1931) is old growth board foot data from Woolrich (1934), TVA (1965) data is for Grundy and Marion counties combined. Their data excludes cull trees and non-commercial species. Several commercial species are included in "other soft textured" and "hard textured hardwoods."

Taxa	Surveys	Peterson 1931	Cowan 1946	TVA
Acer negundo, boxelder	0.5			
A. rubrum/saccharinum, maple	1.1			
A. saccharum, sugar tree	3.1			
Acer spp., maples			1.0	
Aesculus octandra, buckeye	0.6			
Ardar?	0.1			
Carpinus caroliniana, hornbeam	2.3			
Carya spp., hickory	9.3	11.0	8.6	19.3
Castanea dentata, chestnut	1.1			
Celtis spp. hackberry	1.3			
Cercis canadensis, redbud	0.3			
Cornus spp., dogwood	5.1			
Diospyros virginiana, persimmon	0.2			
Fagus grandifolia, beech, beach	11.6		2.6	
Fraxinus quadrangulata, blue ash	0.2			
Fraxinus spp., ash	3.4	2.0		1.0
Gleditsia/Robinia, locust	0.6			
Hornbrier?	0.1			
Ilex spp., holly	1.1			
Juglans cinerea, white walnut	0.8			
J. nigra, black walnut	0.8			
J. sp., walnut	2.1			
Juniperus virginiana, cedar	0.3	2.0		
Liquidambar styraciflua, sweet gum, white gum	2.7	5.2		1.6
Liquidambar/Nyssa, gum	1.3			
Liriodendron tulipifera, poplar	5.4	6.0	3.3	2.9
Locust elder?	0.1			
Magnolia acuminata, cucumber, black lynn	0.2			
Morus rubra, mulberry	0.5			
Nyssa sylvatica, black gum	3.8		2.0	1.7
Ostrya caroliniana, ironwood	0.9			
Oxydendrum arboreum, sourwood	0.5			

Taxa	Surveys	Peterson 1931	Cowan 1946	TVA
Pinus spp., pine	0.1	10.0	27.0	17.0
P. echinata, shortleaf pine				9.1
P. virginiana, Virginia pine				7.9
Platanus occidentalis, sycamore	1.4			
Prunus spp., cherry	0.4			
P. spp., plum, plum bush	0.1			
Quercus spp., oak	0.4			
Q. alba, white oak	13.1			11.1
Q. falcata, Spanish oak	1.0			
Q. falcata, Q. rubra, Q. velutina, red oaks				9.0
Q. coccinea, scarlet oak				8.1
Q. coccinea, Q. rubra, red oak	1.3			
Q. marilandica, blackjack	0.1			
Q. montana, chestnut oak	0.1			14.5
Q. muhlenbergii, chineapine, chingnepine	0.2			
Q. nigra, water oak	0.1			
Q. palustris, swamp oak	0.1			
Q. stellata, post oak	4.7			3.9
Q. velutina, black oak	10.9			
Quercus, all spp.	32.0	58.8	50.6	46.6
Quercus spp., red oaks	13.5		28.9	17.1
Quercus spp., white oaks	18.1		21.7	29.5
Quercus spp., *Carya* spp., oak, hickory	41.3			
Quercus spp., *Castanea*, oaks, chestnut	33.1			
Quercus spp., *Pinus* spp., oak, pine	32.1			
Sambucus canadensis, elder	0.1			
Sassafras albidum, sassafras	0.1			
Tilia heterophylla, lynn, lyn	1.8			0.9
Tsuga canadensis, spruce pine	0.1			0.5
Ulmus spp., elm, elum	2.3			
Viburnum prunifolium, black haw	0.2			

School lands were mentioned in two surveys and school lot No. 2 and school field No. 2 were mentioned. This suggests that there was a requirement to set aside lands for schools or sale of lands for school funding as in the Virginia Military District in Ohio (Thrower 1966).

A table of 382 co-occurrences of species cited at the survey point was prepared (not shown here). An association between beech and white oak, hickory and sugar maple are shown. Often mesophytes as lynn, poplar and walnut also appear together, suggesting that the mesic forests of lower slopes and coves had been sampled. Swamp taxa as elm, ash and hackberry were not greatly associated together but with mesophytes indicated that swamps were little sampled. The prevalent oak, white oak, was recorded with beech, sweet gum and black oak in most abundance.

Putnam County

In his many surveys in Putnam and Jackson counties, surveyor Richard Cooke recognized 56 problematic taxa of which 46 can be recognized as modern species (Table 3). Nearly 60 percent of the total stems were oaks, hickories, and chestnut. About 25 percent were the mesophytes of ravines and lower slopes. About four percent of the stems were species which usually grow on upper slopes or ridges and about four percent are swamp taxa. Clearly he surveyed chiefly the rolling to dissected uplands.

Comparative data of Cowan (1946) and Wooden and Caplenor (1972) are available. Some species and species group percentages are comparable between the data sets. Increasers with landscape and forest disturbance include poplar, black gum, pine and red oaks. Such increases are to be expected with disturbance. Decreasers are the white oaks (chiefly white and post oaks). It is not known for sure whether the white oaks decrease and the red oaks increase are real phenomena or whether they are due to e.g. Cowan's sample locations. The Wooden and Caplenor (1972) samples come only from north-facing slopes and do not represent the usual upland forests of the area. Increase in importance of red oaks, scarlet, Spanish and black, may follow logging of oak-hickory stands as in the Ozarks (Mitchell et al. 1988). Chestnut decrease is due to disease (Hepting 1971).

Table 3. Percentages of all stems in the Richard Cooke surveys from Putnam and Jackson counties. The Cowan (1946) data is the mean of Putnam and Jackson percentages (board feet). The Wooden and Caplenor (1972) data is the mean of two north-facing slopes in Warren County

.

Taxa	% of surveys 1826-39	Cowan 1946	Wooden 1972
Acer rubrum, maple	1.6		
A. saccharum, sugar tree	6.3		15.8
A. spp.		2.5	
Aesculus octandra, buckeye	1.4		3.0
Alnus serrulata, alder	0.1		
Asimina triloba, pappaw	0.1		
Carpinus caroliniana, hornbeam	0.4		7.0
Carya, spp., hickory	11.8	10.1	4.3
Castanea dentata, chesnut, chisnut	7.6		
Celtis spp., hackberry	0.1		
Cercis canadensis, redbud	0.1		
Cladrastis kentuckea, yellow wood	0.1		2.6
Cornus florida, dogwood	5.3		1.3
Crataegus sp. haw, crabapple, thorn	0.1		
Diospyros virginiana, possimon	0.2		
Fagus grandifolia, beech	10.5	11.5	1.9
Fraxinus spp., ash	1.4		
F. americana, white ash	0.1		4.4
F. quadrangulata, blue ash	0.1		
Gleditsia triacanthos, honey locust	0.1		
J. cinerea, white walnut	0.6		7.1

Taxa	% of surveys 1826-39	Cowan 1946	Wooden 1972
J. nigra, black walnut	0.8		
Juglans sp., walnut	0.2		
Kalmia latifolia, laurel	0.1		
Juniperus virginiana, cedar	0.1		
Lindera benzoin, spice	<0.1		
Liquidambar styraciflua, sweetgum	0.4	0.3	1.8
Liquidambar/Nyssa sylvatica, gum	<0.1		
Liriodendron tulipifera, poplar	3.8	12.4	22.7
Magnolia acuminata, cucumber	0.1		1.3
Morus rubra, mulberry	0.4		
Nyssa sylvatica, blackgum	2.7	6.0	2.6
Ostrya virginiana, ironwood	0.5		
Oxydendrum arboreum, sourwood	0.8		
Pinus spp., pine	0.1	5.9	
Platanus occidentalis, sycamore	0.5		6.4
Prunus persica, peach	0.1		
P. spp., cherry	0.2		
P. spp., plum	0.1		
Quercus spp., oak	0.2		
Q. alba, white oak	10.4		
Q. coccinea/Q. rubra, red oak	5.2		0.7
Q. falcata, Spanish oak	2.2		
Q. imbricaria, shingle tree	<0.1		
Q. marilandica, blackjack	1.6		
Q. montana, chestnut oak	0.9		1.3
Q. muhlenbergii, chinquapin	0.1		
Q. palustris, Q. shumardii, pin oak	0.2		
Q. stellata, post oak	10.7		
Q. velutina, black oak	9.1		
Quercus, all white oaks	22.1	11.3	
Quercus, all red oaks	18.4	33.6	
Quercus, all oaks	40.7	44.9	
Quercus and *Pinus*, oak and pine	40.8	50.8	
Quercus and *Carya*, oak and hickory	52.5	55.0	
Quercus and *Castanea*, oak and chestnut	48.3		
Rhus glabra, shoemake	0.1		
Robinia pseudoacacia, black locust	0.1		0.5
Sambucus canadensis, elder	<0.1		
Sassafras albidum, sassafras	0.5		
Tilia heterophylla, lyn, lynn	1.8		8.1
Ulmus americana, white elm	<0.1		3.7
Ulmus sp., elm	1.3		
Viburnum prunifolium, black haw	<0.1		

A few vegetation types are suggested by Cooke's corners: hawbaw (name unknown but perhaps a hawthorn, *Crataegus,* thicket), ivy ridge (mountain laurel, *Kalmia*), maple swamp (*Acer*), pine bluff (*Pinus*), pine in Jackson's old field (*Pinus*), spice patch (spicebush, *Lindera*), swamp, walnut flat (*Juglans*), poke patch (pokeweed, *Phytolacca*), plumford and plum hollow (*Prunus*), dogwood flat (*Cornus*), and sugar camp (*Acer saccharum*).

Overlap in specific corners suggests that Cooke used the term glade and barrins (barrens) interchangeably to mean forest opening. Barrens are well known on the eastern Highland Rim (DeSelm 1990). Glade corners are reported in Jackson County, on Stanley Branch of Pigeon Roost Creek and in Putnam County on Bear Creek, Blackburn Fork of the Roaring River and the headwaters of Cane Creek. Barrens are reported in Jackson County on "Williams Mill Creek," and in Putnam County on Blackburn Fork.

Cooke's surveying style resulted in survey tree percent results slightly different from those of surveyors in other counties. At many corners he recorded two or more stems of the same species (as well as stems of other species). Thus among the six oak taxa (798 co-occurrences), 38.3 percent were with the same oak species. This compares with 26.6 percent in Marion County recorded by various surveyors.

A table of "species" co-occurrences was prepared (not shown). A total of 2105 co-occurrences were recorded among 25 taxa, low co-occurrences of e.g. red maple (maple), sycamore and the elms suggest that river swamps were rarely sampled; the low percentage of shingle and pin oaks (Table 3) suggests that upland Highland Rim swamps were rarely seen (as in the Bright survey of the southeastern Highland Rim, DeSelm 1994). The co-occurrence of sugar maple, beech, lynn, buckeye and poplar indicates the presence of the mesic lower slope and cove forests. A strong association was found among the oaks. White oak was associated with black, Spanish, "red" oaks as well as poplar, hickories, dogwood, beech and chestnut. Black oak was associated with post and white oaks, hickories and chestnut. Post oak was associated with hickories (and black oak). "Red" oaks were associated with hickory, white, and post oaks. Blackjack was associated with the hickories and post oak. These associations suggest but do not confirm the occurrence of communities on the Highland Rim seen by Smith *et al.* (1968), Wooden and Caplenor (1972) and Stubblefield and Ballal (1972).

Stewart County

The surveys made available 52 problematic taxa for study (Table 4). The oaks comprise 45.6 percent of the total stems reported. The oak taxa rank white oak > black oak > post oak. Hickories and poplar are as numerous as any oak except white oak. The mesophytes, sugar maple and beech, were much less numerous. The low presence of swamp taxa suggests that few swamps were surveyed (as Chester *et al.* 1995). Dry ridge taxa, common eastward (Hinkle *et al.* 1993, Stephenson *et al.* 1993), such as chestnut oak, chestnut, the pines (as Schibig and Chester 1988) and sourwood were rare or absent. These taxa become less common westward across the Highland Rim of Tennessee (see maps in Chester *et al.* 1993, 1997).

Percentages from the Stewart County surveys (Table 4) are compared with data from Cowan (1946), the study of the forests of Montgomery County (Duncan and Ellis 1969), the study of the

Montgomery-Stewart County forests (Chester *et al.* 1995) and two studies of smaller areas including lower Bear Creek watershed (Stack 1982) and 53 upland forest stands in the Tennessee portion of the Land Between the Lakes (Fralish and Crooks 1989).

Comparison of survey percentages with the geographically larger area surveys reveal many percentages which are quite similar (although the group in Cowan of "other hardwoods," not shown, eliminated many taxa from that data set). The extraordinarily high percentage of red oaks in Cowan is not comparable to other inventories and is not understood. Increasers are cedar, the elms, sassafras and sweet gum. All of these are species, or in the case of the elms contain species as red and winged elms, that invade open stands and stand edges (Burns and Honkala 1990). Decreasers taxa include chestnut (due to disease, Hepting 1971), white and black oaks, the red oak group and the white oak group. The decline in oak percentages reflects the conversion of oak forests to agriculture and other land use, and oak succession (Fralish and Crooks 1989), or oak decline (Starkey 1989).

Table 4. Percent density of woody taxa in Stewart County, Tennessee, in the surveys (1789-1818) and inventories.

Taxa	Surveys	Cowan 1946	Duncan, Ellis 1969	Chester *et al.* 1995	Stack 1982	Fralish & Crooks 1989
Acer negundo, boxelder	0.3		0.3	4.1	5.0	
A. rubrum, A. saccharinum, maple	0.5		0.4	3.9		0.1
A. saccharum, sugar	4.6		5.5	4.0	21.4	9.6
A. spp., maples	5.1	1.0	5.9	7.9	21.4	9.7
Aesculus sp., buckeye	<0.1					<0.1
Carpinus caroliniana, hornbeam	1.1		2.4	1.0	0.6	<0.1
Carya spp., hickory	13.2	12.5	13.0	10.8	13.3	5.7
C. ovata, white hickory	<0.1					
C. sp., scaly bark hickory	<0.1					
Castanea dentata, chesnut, chestnut	0.5					
Celtis spp., hackberry	0.7		3.2	2.1	0.5	0.1
Cercis canadensis, redbud	<0.1		0.9	0.2	1.0	<0.1
Cornus spp., dogwood	9.8		8.6	1.2	0.7	0.2
Crataegus spp., white thorn, redhaw	0.1					
Diospyros virginiana, persimmon	0.5		2.1	0.2	0.2	
Fagus grandifolia, beech	3.6		2.4	3.3	12.6	6.3
Fraxinus spp., ash	2.7		1.4	3.1	2.3	1.1
Gleditsia triacanthos, honey locust	0.4			0.6	0.1	
Juglans cinerea, white walnut	0.7			0.2	0.1	
J. nigra, black walnut	0.9		1.7	1.3	0.9	0.4
J. spp., walnut	0.8					
Juniperus virginiana, cedar		3.1	3.3	6.4	0.1	
Liquidambar styraciflua, sweetgum	0.6	6.3	2.7	3.1	3.3	1.2
Liquidambar/Nyssa, gum	1.2					
Liriodendron tulipifera, poplar	9.2	2.1	6.3	3.1	5.9	1.1
Morus rubra, mulberry	1.1		0.6	0.4	0.1	
Nyssa sylvatica, black gum	2.7	1.0	4.6	6.9	3.1	2.2

Taxa	Surveys	Cowan 1946	Duncan, Ellis 1969	Chester *et al.* 1995	Stack 1982	Fralish & Crooks 1989
Ostrya virginiana, ironwood	0.7		3.5	1.0	1.9	0.2
Oxydendrum arboreum, sourwood, sour	0.2		0.3	0.9	1.4	1.7
Pinus spp., pine						6.1
Platanus occidentalis, sycamore	0.7		0.7	2.9	1.3	
Populus deltoides, cotton tree	0.1		<0.1	0.8	0.2	
Prunus persica, peach	0.1					
P. serotina, wild cherry, cherry	0.7		2.4	1.6	2.0	3.2
P. spp. plum	0.7					
Quercus alba, white oak	15.6		4.6	7.8	5.2	25.0
Q. coccinea, Q. rubra, Q. shumardii, red oak	5.2		5.7	2.9	0.6	5.7
Q. falcata, Spanish oak	1.4		3.5	0.7	0.3	1.3
Q. marilandica, blackjack	0.2		<0.1	1.1	0.1	0.9
Q. montana, chestnut oak	<0.1		2.9	3.1	2.5	13.4
Q. muhlenbergii, chinquapin oak	0.2		0.3	1.8	0.5	0.1
Q. nigra, water oak	0.2		<0.1			
Q. spp., oak	0.6					
Q. spp., red oaks	18.4	52.1	10.2	8.0	5.3	14.2
Q. spp., white oaks	27.2	15.6	13.3	16.3	8.3	45.8
Q. stellata, post oak	1.6		5.5	3.6	0.1	7.3
Q. velutina, black oak	12.6		0.9	4.4	4.4	8.2
Quercus spp., all oaks	46.2					
Quercus spp., *Carya* spp., oak, hickory	59.4					
Quercus spp., *Castanea*, oak, chestnut	46.7					
Quercus spp., *Pinus* spp., oak, pine	46.2					
Robinia pseudoacacia, locust	0.1		0.5			<0.1
Sambucus canadensis, elder	<0.1					
Sassafras albidum, sassafras	0.3		6.2	1.0	2.2	0.1
Tilia spp., lynn	0.5		<0.1			
Ulmus spp., elm	2.9		5.5	7.6		1.4
U. americana, white elm	<0.1		0.5	0.2	1.4	
U. rubra, red elm	<0.1		1.9	5.5	5.7	0.9
Vaccinium spp., blueberry	<0.1					
Viburnum prunifolium, black haw	<0.1					

The Stack survey (Stack 1982, Stack and Chester 1987) on mesic Bear Creek slopes and stream borders shows high boxelder, beech, sugar maple and red elm. The Fralish and Crooks (1985) study of upland forests shows high percentages of sugar maple, beech, white oak, chestnut oak and post oak. Samples from such special environments reveal the existence of unique combinations of forest taxa not seen in the general sampling across the county in the Survey.

Barrens are mentioned twice on the Red River (Montgomery County), twice on south Cross Creek (Stewart County) and in the "First District" on the State line (in Montgomery and Stewart counties). Barrens are well known on the northern Highland Rim (DeSelm and Chester 1993, Chester *et al.* 1997). Occasional mention of wagon roads is made (as Walton Road in Putnam County). However, in Stewart County, no survey crossed a road suggesting heavy use of the Cumberland and Tennessee rivers as travel and transportation modes.

Most surveys, even early ones, started from existing property lines (corners) indicating the presence of previous metes and bounds ownership boundary surveys. In the "First District" of Stewart County, ranges and sections were given in some surveys on North Cross Creek and on Wells Creek. They were also mentioned in some surveys on White Oak Creek and Cane Creek in adjacent Houston County. There may have been previous systematic surveys in these areas.

A table of the co-occurrence of taxa (trees mentioned together at the same survey corner) was prepared (not shown). This involved 36 taxa in 461 associations. The taxa most commonly seen with itself or other taxa are white oak at 21.3 percent, the hickories 18.4 percent, poplar 13.0 percent, dogwood 11.7 percent and black oak 5.4 percent. Communities dominated by white oak with poplar, hickory and black oak are suggested in these data. Mesic tree communities with beech, sugar maple, lynn, ash, red oaks and the elms are suggested. Swamp communities with black gum, the elms and sycamore may have been present. The associations may suggest a few communities seen on the Highland Rim by Smith *et al.* (1968), Duncan and Ellis (1969), Chester et al. (1995), Fralish and Crooks (1989), and Stack (1982).

DISCUSSION AND CONCLUSIONS

In the absence of data from Congressional Land Surveys in Tennessee, the metes and bounds surveys from the eighteenth and nineteenth centuries became the most useful data source for reconstruction of early forest composition (see DeSelm 1995, 1997, DeSelm and Rose 1995). From the four survey data sets in this study, 51 taxa can be assigned to species, 10 more names are assigned to two or three species (as red oak) and nine more names are assigned to a genus (as dogwood). A very few names (as arbor and hornbrier) are unknown. It is only in Stewart County, where detailed modern forest studies have been accomplished, that comparative percent density data are available for most of the survey taxa (32 taxa). In other areas, data are available by species for only about half that number which results from the grouping of species in the modern inventory data sets (as maple, hickory, hackberry, ash, lynn, the elms, red oaks and white oaks). The surveyors also grouped species (several groupings are the same) but the oaks in particular are grouped in various ways in the inventories. The use by TVA of the categories "soft textured" and "hard textured" hardwoods is a particularly useless statistic for this work. Also, the exclusion of cull and non-commercial species by TVA makes their data less useful.

Surveyors worked mainly on potential agricultural lands, undulating to steep uplands where they reported hardwood forest trees (with very few shrubs) and none to 5.3 percent pine and cedar. The forests were mainly of oak, 32.0-46.2 percent of the stems. The sequence of abundance was in Hawkins: oaks > hickories > beech > sugar maple. This county is in the Appalachian-Oak Forest Region (Kuchler 1964, Stephenson *et al.* 1993), formerly the Oak-Chestnut Forest Region (Braun 1950, Shantz and Zon 1924). Here chestnut runs a poor eight in abundance among important trees (including dogwood). The surveys bring little data to support the former name Oak-Chestnut region. The former abundance of chestnut on upland forests is suggested by Martin (1971) who found chestnut stumps in 68 percent of his 78 upland forest types; relative density ranged to 43 stumps per acre. In Marion County tree abundance was oak > beech > hickories > poplar. The beech and poplar importance reflects the mainly lowland surveys. In Putnam and Jackson counties, abundance was oaks > hickories > beech > chestnut. The high hickory abundance supports the modern Oak-Hickory Forest Region name (Bryant *et al.* 1993). In Stewart County abundance of important trees was oak > hickory > dogwood > poplar which again supports the Forest Region name.

In Stewart and Montgomery counties communities described by Duncan and Ellis (1969), Chester *et al.* (1995), Stack (1982) Fralish and Crooks (1985) and Smith *et al.* (1968) are scarcely distinguishable in the survey data–though some are suggested by species co-occurrences. Similarly the various forest types included in the tables of data in the TVA reports are no more than suggested by survey co-occurrences. The low percentages of pines, hemlock, and swamp oak taxa indicate that the surveyors worked little in the Plateau coves, nor the Highland Rim upland and river swamps.

Taxa which behave as increasers in at least two of the four survey areas are the pines, cedar, poplar, the hickories, black gum and the red oaks (probably chiefly scarlet oak). The first of these are invaders which populate forest openings and edges (Smith 1968, Burns and Honkala 1990). The last three taxa include sprouters of low to intermediate tolerance which are permanent to temporary increasers, in post chestnut death, and post logging forests (Rhoades 1992, 1995, Thor and Summers 1972).

Taxa which behave as decreasers in at least two of the four study areas are chestnut (due to disease), white and post oaks, beech, ash and lynn. Here, the forest sites and soils on which they were formerly important have been converted to agriculture and other uses and modern inventories are on other kinds of sites. In the case of the oaks, losses by succession (Fralish and Crooks 1989) or oak decline (Starkey and Oak 1989) may be involved.

Two taxa, the elms and the red oaks, are decreasers and increasers in different county areas. In the case of the elms, the loss of some trees due to Dutch elm disease and phloem necrosis (Hepting 1971) may be confounded by the invasive behavior of *e.g.* red and winged elms (Burns and Honkala 1990). In the case of the red oaks, the loss of northern and southern red oaks and black oaks (Starkey and Oak 1989) in one area of logged stands may be confounded elsewhere by the increase in scarlet oak after the death of chestnut in logged stands (Rhoades 1992, Thor and Summers 1971).

The four tables were examined for east to west species or species group percentage trends. The expected decrease in abundance of pines and chestnut oak is seen in the data (compare Tables 1-4). An unexpected linear increase in hickory abundance was seen. Other common taxa exhibit non-linear abundance changes across the state.

Deficiencies appear in both Congressional Land Survey and metes and bounds methods or data: the unknown taxonomic expertise of the surveyors, the possible non-random choice of corner trees, and the grouping of species by the surveyors. Deficiencies of metes and bounds surveys in particular are: lack of the knowledge of the location of survey starting points and the subsequent lines surveyed, surveying through disturbed areas as roads, and the use of small trees and (rarely) shrubs at corners. Despite these deficiencies, the metes and bounds survey results constitute the only detailed record of the vegetation present near the time of settlement. Thus, they contribute greatly to own historical botanical geographic knowledge.

LITERATURE CITED

Bryant, W. S., W. C. McComb, and J. S. Fralish. 1993. Oak -hickory forests (Western Mesophytic/Oak-Hickory Forests). pp. 143-201. *In*: W. H. Martin, S. G. Boyce and A. C. Echternacht (eds.), Biodiversity of the southeastern United States. Upland Terrestrial Communities. John Wiley and Sons, Inc., New York.

Burns, R. M. and B. H. Honkala. 1990. Silvics of North America. Vol. 1: Conifers, Vol. 2: Hardwoods. Handbook 654. U.S. Dept. of Agriculture, Washington, D. C.

Carpenter, J. S. and E. W. Chester. 1987. Vascular flora of the Bear Creek Natural Area, Stewart County, Tennessee. Castanea 52: 112-128.

Chapman, J. and A. B. Shea. 1981. The archaeobotanical record: early Archaic period to contact in the lower Little Tennessee River valley. Tennessee Anthropologist 6: 61-84.

Chester, E. W., B. E. Wofford, J. M. Baskin and C. C. Baskin. 1997. A floristic study of barrens on the southwestern Pennyroyal Plain, Kentucky and Tennessee. Castanea 62: 161-172.

Chester, E. W., B. E. Wofford, R. Kral, H. R. DeSelm, and A. M. Evans. 1993. Atlas of Tennessee vascular plants, Vol. 1: Pteridophytes, Gymnosperms, Angiosperms: Monocots. Misc. Publ. No. 9. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Chester, E. W., R. J. Jensen, and J. Schibig. 1995. Forest communities of Montgomery and Stewart counties, northwestern Middle Tennessee. J. Tennessee Acad. Sci. 70: 82-91.

Chester, E. W., S. M. Noel, J. M. Baskin, C. C. Baskin, and M. L. McReynolds. 1995. A phytosociological analysis of an old growth upland wet woods on the Pennyroyal Plain, southcentral Kentucky, USA. Natural Areas J. 15: 297-307.

Chester, E. W., B. E. Wofford, and R. Kral. 1997. Atlas of Tennessee Vascular Plants. Vol. 2: Angiosperms: Dicots. Misc. Publ. No. 13. The Center for Field Biology, Austin Peay State University. Clarksville, Tennessee.

Cowan, W. F. 1946. The forest resources of Tennessee. Processed report. American Forestry Association and Tennessee Conservation Department, Forestry Division. Nashville, Tennessee.

Delcourt, P. A., H. R. Delcourt, P. A. Cridlebaugh, and J. Chapman. 1986. Holocene ethnobotanical and paleoecological record of human impact on vegetation in the Little Tennessee River Valley, Tennessee. Quaternary Research 25: 330-349.

DeSelm, H. R. 1990. Barrens of the eastern Highland Rim of Tennessee. Castanea 55: 187-206.

DeSelm, H. R. 1993. Barrens and glades of the southern Ridge and Valley. Pp. 81-135. *In*: S. W. Hamilton, E. W. Chester, and A. F. Scott (eds.). Proceedings of the fifth annual symposium on the natural history of lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee

DeSelm, H. R. 1994. Vegetation results from a 1807 Land Survey of southern Middle Tennessee. Castanea 59: 51-68.

DeSelm, H. R. 1995. Vegetation results from the 1807-1810 land surveys in the Fifth Survey District of Tennessee. Pp. 281-290. *In*: S. W. Hamilton, D. S. White, E. W. Chester, and A. F. Scott (eds.). Proceedings of the sixth symposium on the natural history of the lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

DeSelm, H. R. 1997. Vegetation results from Early Land Surveys Recorded in Register's Books, Campbell County, Tennessee, 1806-1833. Pp. 193-203. *In*: A. F. Scott, S. W. Hamilton, E. W. Chester, and D. S. White (eds.). Proceedings of the seventh symposium on the natural history of the lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

DeSelm, H. R. and E. W. Chester. 1993. Further studies on the barrens of the northern and western Highland Rims of Tennessee. Pp. 137-160. *In*: S. W. Hamilton, E. W. Chester, and A. F. Scott (eds.). Proceedings of the fifth annual symposium on the natural history of the lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University. Clarksville, Tennessee.

DeSelm, H. R. and D. M. Rose, Jr. 1995. Vegetation results from early land surveys of northern Sevier County, Tennessee. Pp. 291-230. *In*: Hamilton, S. W., W. S. White, E. W. Chester, and A. F. Scott (eds.). Proceedings of the sixth symposium on the natural history of the lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Dickson, R. R. 1960. Climate of Tennessee. Climatography of the United States 60-40. U.S. Department of Commerce, Weather Bureau, Washington, D. C.
Duncan, S. H. and W. H. Ellis. 1969. An analysis of the forest communities of Montgomery County, Tennessee. J. Tennessee Acad. Sci. 44: 25-32.
Fenneman, N. M. 1938. Physiography of eastern United States. McGraw Hill Book Company, Inc., New York, New York.
Folmsbee, S. J., R. E. Corlew, and E. L. Mitchell. 1969. Tennessee, a short history. The University of Tennessee Press, Knoxville, Tennessee.
Foster, A. P. 1923. Counties of Tennessee. Department of Education, Division of History, State of Tennessee, Nashville. New material Copyright, 1990, Southern Historical Press, Inc., Greenville, South Carolina.
Fralish, J. S. and F. B. Crooks. 1989. Forest composition, environment and dynamics at Land Between the Lakes in northwest Middle Tennessee. J. Tennessee Acad. Sci. 64: 107-111.
Fullerton, R. O. 1974. Place names of Tennessee. Tennessee Department of Conservation, Division of Geology Bull. No. 73. Nashville, Tennessee.
Hardeman, W. D. 1966. Geologic map of Tennessee. Tennessee Geological Survey, Nashville, Tennessee.
Hawkins County Deed Book No. 1, 1788-1800. Works Progress Administration, Copying Historical Records Project No. 465-44-3-115. 1937. Mountain Press, Signal Mountain, Tennessee.
Hepting, G. H. 1971. Diseases of forest and shade trees of the United States. Handbook 386. U. S. Dept. of Agriculture, Washington, D. C.
Hicks, N. L. 1968. The John Adair section of Knox County, Tennessee. Privately published, Knoxville, Tennessee.
Hinkle, C. R., W. C. McComb, J. M. Safley, Jr., and P. A. Schmalzer. 1993. Mixed mesophytic forests. Pp. 203-253. *In*: W. H. Martin, S. G. Boyce, and A. C. Echternacht (eds.). Biodiversity of the southeastern United States: Upland terrestrial communities. John Wiley and Sons, Inc., New York, New York.
Hudson, C. 1976. The southeastern Indians. The University of Tennessee Press. Knoxville, Tennessee.
Jenny, H. 1980. The soil resource. Origin and behavior. Springer Verlag, New York, New York.
Killebrew, J. B. and J. M. Safford, assisted by C. W. Carlton and H. L. Bentley. 1874. Introduction to the resources of Tennessee, 1st and 2nd reports of the Bureau of Agriculture. Tavel, Eastman and Howell Printers, Nashville, Tennessee.
Küchler, A. W. 1964. Potential natural vegetation of the conterminous United States. American Geographical Society Special Publication 36.
Marion County, Deed Book A, B. 1819-1830. Works Progress Administration, Historical Records Project No. 465-44-3-115. 1938. Mountain Press, Signal Mountain, Tennessee.
Martin, W. H. 1971. Forest communities of the Great Valley of East Tennessee and their relationship to soil and topographic properties. Ph.D. Diss., The University of Tennessee, Knoxville.
Mitchell, R. J., R. A. Musbach, K. Lowell, H. E. Garrett, and C. S. Cox. 1985. Thinning coppice regenerated oak-hickory stand: thirty years of growth and development. Pp. 19-24. *In*: J. O. Dawson and K. A. Majerus (eds.). Fifth Central Hardwoods Forest Conference Proceedings. Society of American Foresters Publ. 85-05. Urbana, Illinois.
Perkins, B. E. 1981. Vegetation of sandstone outcrops of the Cumberland Plateau. M. S. Thesis. University of Tennessee, Knoxville.
Putnam County, Richard F. Cooke's Survey on Plat Book, 1825-1839. Works Progress Administration, Historical Records Survey, Transcription Unit, Tennessee State Archives, Nashville, 1939. Mountain Press, Signal Mountain, Tennessee.
Rhoades, R. W. 1992. Compositional changes in an oak forest in southwestern Virginia after twenty years. Castanea 57: 252-263.
Rhoades, R. W. 1995. Succession in a mature oak forest in southwest Virginia. Castanea 60: 98-106.
Rodgers, J. 1953. Geologic map of East Tennessee with explanatory text. Bull. 58. Tennessee Divison of Geology, Nashville, Tennessee.
Schibig, J. and E. W. Chester. 1988. Vegetational and floristic characterization of a mixed hardwoods-shortleaf pine stand in Stewart County, Tennessee. J. Tennessee Acad. Sci. 63: 83-88.
Shantz, H. L. and R. Zon. 1924. Natural Vegetation. *In*: O. E. Baker. Atlas of American Agriculture. U.S. Department of Agriculture,Washington, DC. 1936. Map dated 1923.
Smith, D. W. 1968. Vegetational changes in a five-county area of East Tennessee during secondary succession. M. S. Thesis. The University of Tennessee, Knoxville.

Smith, L. R., E. Bridges, D. Durham, D. Eagar, A. Lowell, S. Pearsall, T. Smith, and P. Somers. 1968. The Highland Rim in Tennessee: Development of a community classification and identification of potential natural areas. Processed Report. Tennessee Department of Conservation Natural Heritage Program. Nashville, Tennessee.

Springer, M. E. and J. A. Elder. 1980. Soils of Tennessee. Bull. 596. Agric. Exp. Station, The University of Tennessee, Knoxville.

Stack, J. C. 1982. A study of the vascular flora and certain vegetational aspects of the Lower Bear Creek Watershed, Stewart County, Tennessee. M. S. Thesis. Austin Peay State University, Clarksville, Tennessee.

Starkey, D. A. and S. W. Oak. 1989. Silvicultural implications of factors associated with oak decline in southern upland hardwoods. Pp. 579-586. *In*: J. H. Miller (compiler). Proceedings of the Fifth Biennial Southern Silvicultural Research Conference. Memphis, Tennessee, November 1988. U. S. Forest Service Gen. Tech. Report SO-74.

Stephenson, S. L., A. N. Ash, and D. F. Stauffer. 1993. Appalachian oak forests. Pp. 225-303. *In*: W. H. Martin, S. G. Boyce, and A. C. Echternacht (eds.). Biodiversity of the southeastern United States–Upland terrestrial communities. John Wiley and Sons, Inc., New York, New York.

Stewart County Deed Record Book, Vol. 3, 1789-1818. Works Progress Administration, Historical Records Project No. 165-44-6999, Tennessee State Archives, Nashville, 1938. Mountain Press, Signal Mountain, Tennessee.

Stewart County Deed Record Book, Vol. 4, 1810-1813. Works Progress Administration, Historical Records Survey, Transcription Unit, Tennessee State Archives, Nashville, 1939. Mountain Press, Signal Mountain, Tennessee.

Stubblefield, S. M. and S. K. Ballal. 1972. Available soil moisture and plant community differentiation in Davies Island, Middle Tennessee. J. Tennessee Acad. Sci. 47: 112-117.

Tennessee Valley Authority. 1941. Areas characterized by general forest types in the Tennessee Valley. Map. Tennessee Valley Authority, Division of Forest Relations, Norris, Tennessee.

Tennessee Valley Authority. 1952. Forest Inventory Statistics for Greene County, Tennessee. Forestry Bull. No. 19. Division of Forestry Relations, Norris, Tennessee.

Tennessee Valley Authority. 1960. Forest Inventory Statistics for Claiborne County, Tennessee. Bull. 79. Division of Forestry Relations, Norris, Tennessee.

Tennessee Valley Authority. 1961. Forest Inventory Statistics for Hancock County, Tennessee. Forestry Bull. No. 94. Division of Forestry Relations, Norris, Tennessee.

Tennessee Valley Authority. 1964. Forest Inventory Statistics, Anderson-Knox-Union County Units, East Tennessee. Forestry Bull. No. 117. Division of Forestry Development, Norris, Tennessee.

Tennessee Valley Authority. 1965. Forest Inventory Statistics, Grundy-Marion Unit, Southeastern Tennessee. Forestry Bull. No. 122. Division of Forestry Development, Norris, Tennessee.

Tennessee Valley Authority. 1968. Forest Inventory Statistics for the Grainger-Hamblen-Hawkins-Jefferson County Unit. Forestry Bull. No. 136. Division of Forest Development, Norris, Tennessee.

Thor, E. and D. D. Summers. 1971. Changes in forest composition on Big Ridge Natural Study Area, Union County, Tennessee. Castanea 36: 114-122.

Thrower, N. J. W. 1966. Original survey and land subdivision. American Association of Geographers Monogr. No. 4. Rand McNally and Co., Chicago, Illinois.

Trewartha, G. T. 1968. An Introduction to Climate. Fourth Ed. McGraw-Hill Book Co., New York, New York.

United States Geological Survey. 1991. Geographic Names Information System–Tennessee. Interim Product. National Cartographic Information Center, Reston, Virginia.

University of Tennessee Herbarium. 1998. County Collection Diversity Map of Tennessee. Herbarium Internet Homepage http://www.bio.utk.edu/botany/herbarium/vascular/atlas.html. 5 October 1998.

Waring, R. H. and W. H. Schlesinger. 1985. Forest Ecosystems. Concepts and Management. Academic Press, New York, New York.

Williams, M. 1989. Americans and their forests. A historical geography. Cambridge University Press, Cambridge, England.

Wofford, B. E. and R. Kral. 1993. Checklist of the vascular plants of Tennessee. Sida Bot. Misc. No. 10.

Wooden, J. and D. Caplenor. 1972. A comparative vegetational study of two north-facing slopes at Rock Island State Park, Tennessee. J. Tennessee Acad. Sci. 47: 146-151.

Woolrich, W. R. 1934. Agricultural-Industrial Survey of Marion County. Tennessee Valley Authority and Civil Works Administration, Knoxville, Tennessee.

Woolrich, W. R. and J. L. Neeley, Jr. 1934a. Agricultural and Industrial Survey–Grainger County, Tennessee. Tennessee Valley Authority and Civil Works Administration, Knoxville, Tennessee.

Woolrich, W. R. and J. L. Neeley, Jr. 1934b. Agricultural and Industrial Survey–Hamblen County, Tennessee. Tennessee Valley Authority and Civil Works Administration, Knoxville, Tennessee.

PRESENCE OR FREQUENCY OF WOODY PLANTS IN VEGETATION SAMPLES IN THE COASTAL PLAIN AND INTERIOR LOW PLATEAU OF TENNESSEE

H.R. DESELM[1], W.L. PATTERSON[2], VERNON BATES[3], D.B. DURHAM[4], R.K. ABERNETHY[4], D.C. EAGAR[4], R.P. FORD[4], P.B. HAMEL[5]

[1]Department of Botany, The University of Tennessee, Knoxville, TN 37996; [2]School of Forestry, Louisiana Technological University, Ruston, LA 71272; [3]Formerly, Biology Department, University of Memphis, Memphis, TN 38152; [4]Formerly, Ecological Services, Tennessee Department of Environment and Conservation, Nashville, TN 37243; [5]U.S. Forest Service, Stoneville, MS 38776

ABSTRACT. Records of the woody flora, based on nearly 1500 plots/stands of mainly forest vegetation of West and Middle Tennessee, have been compiled. The data are from 1155 transects (data collected 1993-1995) and 343 0.1 ha plots (data collected 1985-1986). Taxa total 246 species and lesser forms. The dominant woody plants sort into many community types occupying the small remaining areas of natural landscape. Results are reported as percent presence or frequency of stands seen. Some taxa are common–in ca. 85% of the stands; others are rare. Some taxa occur only on the Coastal Plain, others only on the Plateaus, and some occupy both areas. The range of some species centers in the Central Basin and that of other species exclude the Basin.

INTRODUCTION

Field botanists, ecologists, foresters, and wildlife personnel often need to know the vegetation matrix in which a certain species or biological phenomenon under study lives. The absolute range of many woody taxa has been mapped by Little (1971, 1977) and in Tennessee, all of them are mapped by Chester *et al.* (1993) and Chester *et al.* (1997). The expected frequency of occurrence, however, cannot be determined by such range maps or "dot" maps; frequencies are needed. It is the purpose of this paper to provide those presences/frequencies of the woody taxa from nearly 1500 sample stands or plots. The samples may substantiate known distributions but also show relative abundance in parts of the range (as in timber volume mapped by county, Beltz *et al.* 1992, and detailed ranges mapped by May (1991).

THE STUDY AREA

The study area is the Gulf Coastal Plain of West Tennessee and the Interior Low Plateau of Middle Tennessee (Fenneman 1938). The Plateau area is herein referred to as Middle Tennessee (Fig. 1).

Climate

Middle and West Tennessee have a humid temperate climate which characterize land areas of this latitude and proximity to the Gulf of Mexico. Precipitation varies from 122-142 cm annually, decreasing irregularly northward and westward. Precipitation is well distributed

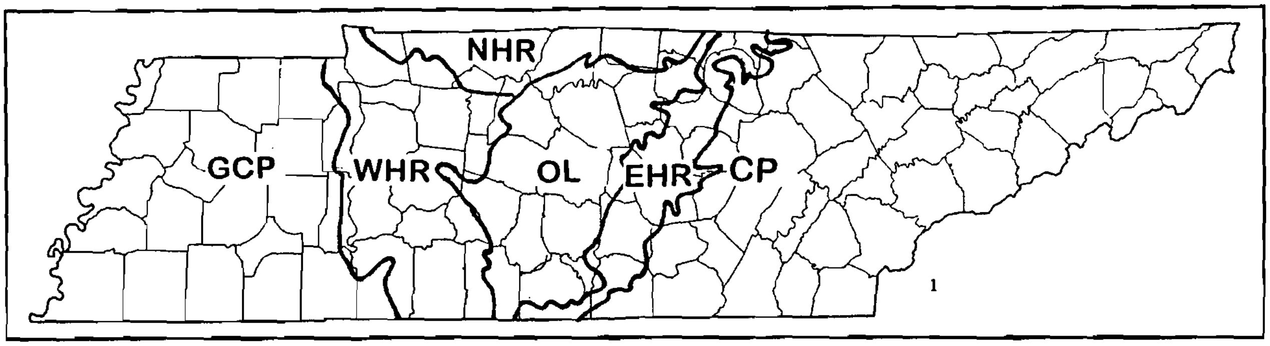


Figure 1. Tennessee showing physiographic divisions in West and Middle Tennessee. GCP = Gulf Coastal Plain (largely West Tennessee), Interior Low Plateaus: WHR = Western Highland Rim, NHR = Northern Highland Rim, EHR = Eastern Highland Rim, OL = approximate extent of Ordovician limestones enclosing the Central Basin and most of the dissected Highland Rim (DeSelm 1959). Some of these limestones also occur elsewhere in the Highland Rim. CP = Cumberland Plateau.

through the year though summer and/or autumn droughts are common (Dickson 1960). During one 38-year period, 38% of the months had slight to severe or extreme drought (Vaiksonoras and Palmer 1973). Seven-day growing season droughts have a 13-33% chance of occurrence (Safley and Parks 1974). Tornado force winds are occasional (Vaiksonoras 1971); winds, drought and snow (and especially ice storms) may open forest canopies and change vegetation structure (Hursh and Haasis 1931). The winds may also be important propagule carriers (Ridley 1930). Temperatures are also variable. Mean July maxima average 31-33°C and mean July minima of 19-22°C occur. In the winter mean January maxima of 10-11°C and mean January minima of -2°C occur (Dickson 1960).

Topography, Geology, Soils

Middle and West Tennessee are characterized by a generally undulating to rolling landscape but the landscape also exhibits such landforms as narrow to broad valley bottom, ridges, steeply sloping hills, bluffs and cliffs. Elevation varies from about 220-450 m on the Highland Rim (higher on Cumberland Plateau outliers and lower on the Cumberland River) to 200-250 m in the Central Basin. Uplands in eastern West Tennessee vary around 200 m but fall to about 110 m on the Tennessee River; these uplands descend westward to about 120 m above major flood plains and may fall to about 100 m on the flood plain of the Mississippi River.

Western West Tennessee is underlain by soft sands and clays of Tertiary age which overlay Cretaceous beds exposed to the east; the latter generally terminate near the Tennessee River though they also appear in parts of Hardin and Wayne counties. Topography westward is undulating to rolling; eastward toward the Tennessee River, sharp ridges and slopes occur. Much of the land is overlain by loess which thickens westward forming high loess bluffs or loess hills on the east side of the Mississippi River flood plain (Hardeman 1966, Miller 1974, Safford 1869).

Middle Tennessee is underlain by more or less horizontally disposed beds of Mississippian limestone in most areas, but Ordovician limestone is exposed in the Central Basin and in valleys around the Basin, and the Devonian Chattanooga Shale encircles the Basin in a narrow band.

Devonian and Silurian limestones, shales and clays are exposed widely in the southwestern Tennessee River valley and to a lesser extent in the dissected parts of the western and northern Rim (Hardeman 1966, Miller 1974, Safford 1969).

The soils of the study area are mapped in hundreds of series and generalized by Elder and Springer (1978) and Edwards *et al.* (1974) into 38 soil associations containing Alfisols, Ultisols, Inceptisols, Mollisols and Entisols. The series (and types) vary greatly in their depth, rockiness, pH, nutrient availabilities, water storage capacity/water content and aeration (Brady 1974, Black 1968). These factors combine with such site factors as stand aspect, slope position, slope shape, and slope protection which, along with history, account for the varied floras (Patterson 1989, Braun 1950, Heineke 1987, DeSelm and Murdock 1993).

Land Use

Middle and West Tennessee were the living and/or hunting areas of a sequence of Native American cultures that populated eastern North America late in the Pleistocene. Evidence of Paleoindians, Archaic settlements, Woodland mounds and Mississippian cultural mounds abound (Lewis and Kneberg 1958, Swanton 1946).

Native American populations were low when found by French and English/American explorers and early settlers. Pressure from the Cherokee Nation, living in East Tennessee, caused the Shawnee to leave Middle Tennessee by 1514 and probably the Euchee left earlier (Williams 1937). West Tennessee was controlled by the Chickasaw Nation. Effects of the cultures on vegetation are unknown for certain but villages and fields were cleared and the people hunted for food and medicinal plants (as well as animals). The setting of surface fires to clear underbrush to facilitate large animal sighting and hunting were to be expected (Williams 1989). An increase in oak, chestnut, and pine pollen occurred in peat and pond sediments (as Cliff Palace Pond, Cumberland Plateau, southeastern Kentucky) after 3000 YBP after the beginning of intensive use here by Archaic people. The authors, Delcourt and Delcourt (1998), attribute these increases to spread of oak-chestnut and oak-pine vegetation following increased use of fire by the local Archaic and Woodland populations.

In the 1760s, the Long Hunters came from the eastern Appalachians to hunt big game in eastern and Middle Tennessee and Kentucky and they may also have hunted in West Tennessee (Haywood 1823, Williams 1930, Goodspeed 1887). Middle Tennessee was opened to settlement in 1780 and was settled gradually thereafter and West Tennessee was opened in 1818. Settlement involved land clearing, extensive crop cultivation of uplands, and draining and cultivation of lowlands. Forests were cut and burned, or cut for board use and some wood products were shipped outside the area. Forests not cut were usually grazed and the understory burned periodically (Williams 1930, Killebrew *et al.* 1874).

Flora and Vegetation

The early explorers, such as the Long Hunters, spoke of only a few plants seen (in Tennessee and Kentucky) but they were impressed by the extensive and luxuriant forest, barrens and cane, *Arundinaria gigantea* (Haywood 1823, Filson 1784, Boon 1784). Late in the eighteenth century, the settlers at Nashville spoke of the large cedar (*Juniperus virginiana*) (Donaldson party in Williams 1928). Michaux (1793-1796) traveled through Middle Tennessee and collected and wrote of some plants. The land survey of southern Middle Tennessee mentioned 35 problematic taxa (DeSelm 1994). Taxa mentioned in West Tennessee at the time of settlement are the oaks (*Quercus* spp.), tulip tree (*Liriodendron*), cane (*Arundinaria gigantea*), peavine (*Amphicarpa*) and cypress (*Taxodium distichum*) (Williams 1930, DeSelm 1989). Modern studies by scientifically trained persons living in Tennessee began with Safford (1869) and Killebrew *et al.* (1874), who noted forest species and forest types by regional or county location. Gattinger listed the flora first of the Nashville area (Gattinger 1887), and then of all of Tennessee (Gattinger 1901) with short notations on collection or occurrence locations. Other species lists appeared subsequently but the maps in Chester *et al.* (1993) and Chester *et al.* (1997) are of particular use here. The species live in the vegetation matrix described by Braun (1950), Heineke 1987), Skeen *et al.* (1993), Quarterman *et al.* (1993), DeSelm and Murdock (1993) and Bryant *et al.* (1993). The modern vegetation pattern based on sampling, especially of older forests, is under study (DeSelm 1995).

Elements of the Flora

The varied climate, climatic history such as Pleistocene coolings and warmings, a mild Holocene Hypsithermal warm or dry period (DeSelm 1989, 1994), land use by Native Americans and past and present Tennesseans have stimulated creation of a large and varied flora (Wofford and Kral 1993). Plant introductions, extinctions and virtual elimination of some landforms and natural vegetation of many types, disease and insect pests and weed competitor introductions have further influenced the composition of the flora. From these positive and negative historical impacts, some of which continue, several species range types (floristic elements) are now known. Lamson-Scribner (1892, 1894), and Gattinger (1901) commented on the range of many species of which they knew in the late nineteenth century. Modern studies of floristic regions/elements are those of Underwood (1945), Shanks (1958), Wofford (1989), and DeSelm *et al.* (1994).

Shanks mapped the collective county distributions of woody species characteristic of the state's floristic regions. Among these are the Appalachian taxa of which a few taxa have an occasional specimen extending westward into Middle and West Tennessee. Some Cumberland Plateau species behave similarly. Species characteristic of the Central Basin may have individuals found also on the Highland Rim and in the Loess Bluffs of West Tennessee. Species of the Mississippi Embayment region (Gulf Coastal Plain), of which some extend occasionally eastward, occur. Southern taxa were mapped. Underwood (1945) using sedges, DeSelm (1994) using grasses, and Shaver (1954) using ferns all found species ranges with many similarities to those shown for woody plants by Shanks (1958).

METHODS

During the field season (May-September or October) 1993-1995, in West and Middle Tennessee to the west edge of the Cumberland Plateau, the landscape was reconnaissanced for vegetation to sample for the study of the terrestrial vegetation of Tennessee. Suitable forests, marshes and woody borders of cedar glades and of barrens were sampled. In 1993, 301 useable samples were obtained in West Tennessee; in 1994, 418 samples were obtained on the Western Highland Rim and Central Basin; in 1995, 436 samples were obtained from the Northern and Eastern

Highland Rims. Forest stands with trees ≥24 inches d.b.h. were sought. The procedure was to walk a transect across uniform topography and geology in the forest, obtaining d.b.h. measurements of about 80 trees (≥ 5 inches) by species. On the transect, the names of seedlings, saplings, shrubs, woody vines and herbs were recorded. Samples were generally well distributed among and within counties. All 57 counties or parts of counties, except Lake, were included. Since a study of the bottomland forests of West Tennessee had already been made, the 1993-5 study sampled mainly uplands. Unknown plants were collected and determined each autumn using facilities at TENN. Some specimens were given to TENN or EKU.

During the summers of 1985 and 1986, Vernon Bates, under contract with the Ecological Services Division, Tennessee Department of Environment and Conservation, sampled West Tennessee bottomland forests using 351 0.1 ha plots (Durham *et al.* 1988, Durham *et al.* 1988). These were well distributed in the bottoms of the Mississippi River and its tributaries, the Forked Deer, Hatchie, Loosahatchie, Obion and Wolfe rivers, as well as the Tennessee River. Relative basal areas, relative density and relative frequency were summed forming an Importance Value 300 for each tree species in each plot. A set of 343 plots were used in the hierarchical, agglomerative, centroid linkage cluster analysis using CLUSTER (SAS Institute, Inc. 1985). Forest communities were classified and described (Patterson 1989). In addition to the above, subcanopy species frequency, mean and relative density was calculated. Shrub and herb frequency and mean cover were calculated by community (Patterson 1989).

The data obtained by DeSelm (1993-1995) and those reported by Patterson (1989) total 1498 plots/stands and constitute the data from which Table 1 was constructed. Here the writer did not apply a species number cut off as was applied for the sake of brevity in the list of characteristic barrens plants (DeSelm 1995). Nomenclature essentially follows Chester *et al.* (1993) and Chester *et al.* (1997), and Gleason and Cronquist (1991). Nomenclatural authorities should be sought in the above publications.

RESULTS

Woody taxa seen total 246 species, including varieties, subspecies and four oak hybrids (Table 1, appended). There also were 18 generic categories such as *Carya* spp. or *Wisteria* spp. (Table 1). The total taxa constitute about 59% of the Tennessee woody flora (Shanks 1952). The percentage of native taxa is 91.5.

The taxa occupy many landforms, geologic beds (Hardeman 1966) and soil series (Elder and Springer 1978), and sort into many plant communities. There are 16 bottomland types (using IV-300 of the more important taxa) (Patterson 1989) and many upland types (using relative tree density) (DeSelm 1995).

A primary objective of this study is to provide the field botanist in West and Middle Tennessee with a list of woody species likely to be seen (especially in forests) and the frequency with which they are to be expected. Thus, *Quercus alba* is to be expected in 73-84 of the stands (but not in the bottoms). *Parthenocissus* may be expected with 55-79 percent frequency and *Toxicodendron radicans* in 78-84% of the stands. Most taxa occur in the study area with a percent presence/frequency of 3-4 to 30-40%.

Some taxa occur across the study area but are uncommonly seen as *Calycocarpum lyoni*, *Ceanothus americanus*, *Hypericum prolificum* and *Lonicera sempervirens*. Eight rare taxa (Nordman 1997) were found in the studies (see maps in Chester 1997 and Table 1). Many taxa occur chiefly in (sometimes East and) Middle Tennessee but not West Tennessee such as *Aesculus glabra*, *A. flava* (*A. octandra*), *Forestiera ligustrina* and *Fraxinus quadrangulata* (maps in Chester *et al.* 1997 and Table 1). Some taxa (especially from the bottoms) occur in West Tennessee but do not occur, or scarcely occur eastward in the State (as *Gleditsia aquatica*). Other West Tennessee taxa have a few counties represented eastward (as *Carya aquatica*). Of the 13 southern taxa reaching Tennessee along the southern border mapped by Shanks (1958), seven still fit that description; one is *Decumaria barbata* found in this study (Table 1). A few woody taxa occur in Middle Tennessee are disjunct in the loess bluffs or swamps of West Tennessee (see *e.g.*, *Cladrastis lutea*) (Shanks 1958, Chester *et al.* 1997).

Currently recognized floristic elements are mapped in Chester *et al.* (1993) and Chester *et al.* (1997). What such "dot" maps do not illustrate is the relative abundance or rarity of a species in a region. Species' ranges in and around the Central Basin are of particular interest. Here, number of stands sampled per county averaged 13 (range 4-38). Illustrated are the concentration of occurrence of *Quercus shumardii* (Fig. 2) and *Ulmus serotina* (Fig. 3) in the Basin and their relative minor importance in the surrounding Rim. In the case of the *Quercus*, presence on the Rim averages 2.7 per county, in the Basin it averages 12.1 per county. In the case of *Ulmus*, presence where seen on the Rim averages 1.0 per county, whereas in the Basin counties it averages 13.1 per county. *Vitis rotundifolia* behaves another way; it seems to encircle the Basin (Shanks 1952, Chester *et al.* 1997). The average presence in the Basin is <1 per county; in the Rim it is 8.8% presence in the adjoining or nearby 25 counties (Fig. 4).

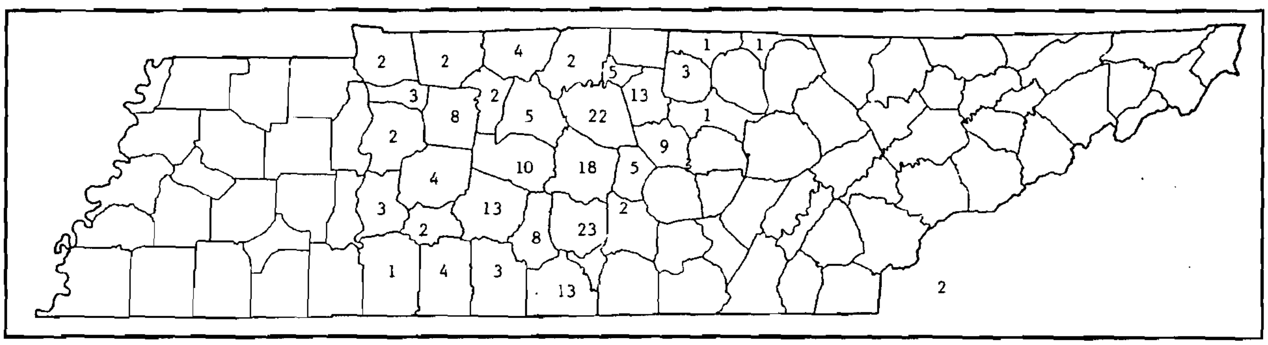


Figure 2. Tennessee showing presence of *Quercus shumardii* in stands per county on and off the Ordovician limestone area in Middle Tennessee.

DISCUSSION

The determination of the pre-Columbian ranges of the species of our flora is difficult at best. Our best records, those in herbaria, are historical accumulations of specimens collected from the beginning of the period of occupation by European peoples to the present. Determination errors in herbarium specimens of woody plants are doubtless few, but species concepts change (compare *Tilia* in Shanks, 1952, with that in Chester *et al.* 1997). Range maps may be produced from exsiccate

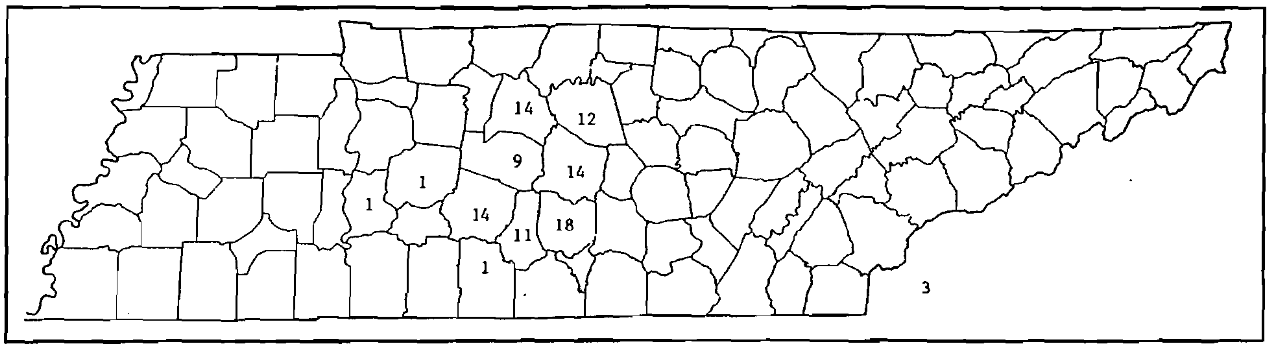


Figure 3. Tennessee showing presence of *Ulmus serotina* in stands per county on and off the Ordovician limestone area in Middle Tennessee.

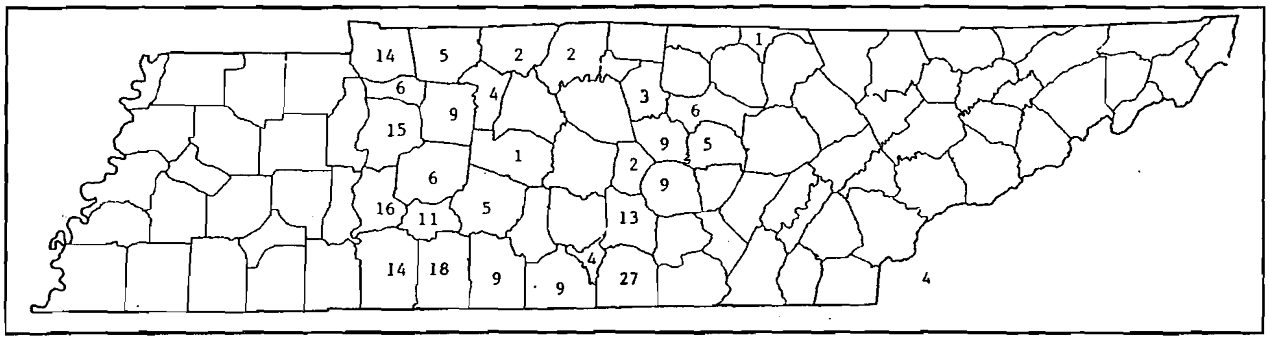


Figure 4. Tennessee showing presence of *Vitis rotundifolia* in stands per county on and off the Ordovician limestone area in Middle Tennessee.

from fewer than all relevant collections. Range maps (as Little 1971, 1977) are made from a variety of sources of which some are "dot" maps with necessary interpolations between dots. Some parts of some maps are based upon sight records (Little 1971).

Elimination of natural vegetation by logging, draining lowlands, grazing/browsing stock and by fire are well known. Local elimination of *Fagus* by hogs stripping the bark from the trees occurs. Fire may eliminate fire-sensitive forest mesophytic herbs (DeSelm and Clebsch 1991). Unfortunately for our study of the ranges of our native species and determination of their relative abundance, logging of the forests continue–indeed clearcutting is now very common with serious changes in dominants and drastic changes in understory composition species resulting (Duffy and Meier 1992, Elliott and Swank 1994). The loss of forest to agricultural use continues. The rate of insertion of primary and secondary homes into forest lands seems to increase. Though forests are seldom burned intentionally now, the species which require the open canopy or understory that fire produces are in peril (White 1982). In large areas of forest land formerly grazed/browsed by low density stock, understory herbs and woody plants survived in patches. Increased use of fencing today results in the concentration of few to many, *e.g.*, cattle, in the forest understory and may result in its virtual elimination. In areas not fenced, the herds of white-tailed deer have grown to the extent that their grazing/browsing pressure results in some forest stands with sparse to no herbs, shrubs or tree seedlings and saplings smaller than 10 cm diameter. Hunting of individual species for food use

(Fernald and Kinsey 1958), medicinal use (Foster and Duke 1990) and for use as landscape/garden plants continues (Phillips 1985). The discontinuous range of many species of our flora (Chester *et al.* 1993, Chester *et al.* 1997) may be the result of this habitat modification/elimination since settlement.

Most native species have numerous bacterial (and viral) and fungal disease to which they are subject which may cause temporary or long-term population declines (Hepting 1971). *Fagus grandifolia* was eliminated at Beech Grove Church (Williamson County) by such attack in the past. Diseases transported by accident from other continental deciduous forests, to which our native taxa are not immune, may be catastrophic (cf. *Castanea dentata, Ulmus americana*). *Juglans cinerea* is currently at risk (Campbell and Schlarbaum 1994).

Similarly native insects may cause local population declines (Baker 1972, Solomon 1995); an example is the current losses in yellow pines from the southern pine beetle (Kowal 1960). Imported insect pests, such as the gypsy moth, cause tree decline or death and forest composition changes (Gottschalk 1993).

Many native trees, shrubs and vines which are planted for such various uses as fiber, ornamentals, shade, or fruit may spread from plantings as competitors into native vegetation. *Pinus strobus*, very rare as a native in Middle Tennessee (Chester and Scott 1980), is commonly planted and may escape. *Pinus taeda*, native on the southern border of the state and in the western Tennessee River Valley, is now planted widely and escapes. *Magnolia grandiflora*, native on the Gulf Coastal Plain, is planted and escapes here (Shanks 1952).

In addition to facilitating the spread of native competitors, we have introduced competitors from other continents (McKnight 1993, Mooney and Drake 1986, Natural Areas Association 1992, Tennessee Exotic Plant Pest Council 1996). Seen in this study were *Broussonetia papyrifera, Albizia julibrissin, Prunus calleryanum, Celastrus orbiculatus,* and *Vinca major*; even more commonly seen were *Ailanthus altissima, Paulownia tomentosa, Ligustrum vulgare, Rosa multiflora, Lonicera japonica* and *Vinca minor* among others. Many other woody cultivars are in use and may be potential escapes.

In spite of the problems cited above, Tennessee state and county records continue to be collected. State records of native and naturalized taxa net (in Wofford and Kral 1993) a little more than 100 more taxa than those of Sharp *et al.* (1956) and Sharp *et al.* (1960). County records of woody plants (Chester *et al.* 1993, 1997) now deviate from previous range descriptions (Shanks 1952, 1953, 1954, Sharp *et al.* 1956, Sharp *et al.* 1960). With these collections, we continue to add to our knowledge of the ranges of our native and introduced taxa and of the probable migrations of some of them.

CONCLUSIONS

A relatively large effort has been expended to sample vegetation in West and Middle Tennessee–about 59% of the state's woody flora has been found. Collateral data collected will also contribute to our understanding of the plant communities–the units of landscape management. Species distribution types (floristic elements) approximate those known from previous studies.

Abundance on the Rim and in the Basin of certain limestone intolerant and tolerant taxa amplifies simple county-level distribution records.

Destruction of our natural landscape and natural vegetation has made our "old" records of species occurrence and range of increased importance. In spite of habitat fragmentation and depredation of native flora and introduced pests into the native flora, new County and State records continue to be made (records at TENN).

ACKNOWLEDGMENTS

DeSelm acknowledges the University of Tennessee, Botany Department Hesler Fund (first year), and the Austin Peay State University Center for Field Biology for travel funds (first two years). Those funds aided the study materially. Personnel at TENN, especially Dr. Vernon McNeilus and Dr. B. E. Wofford, gave freely of advice on problem plant determination. Dozens of people contacted across the area offered advice on where to see the less disturbed vegetation. Many landowners gave permission for site examinations. Without this cooperation and help, this study could not have been accomplished. Much field expense has been personal, however, and for our families' forbearance we are grateful.

LITERATURE CITED

Baker, W. L. 1972. Eastern forest insects. Misc. Publ. 1175, USDA, Washington, DC.

Beltz, R. C., N. C. Cost, N. P. Kingsley, and J. R. Peters. 1992. Timber volume distribution maps for the eastern United States. Forest Service General Technical Report WO-60, USDA, Washington, DC.

Black, C. A. 1968. Soil-plant relationships. Second ed. John Wiley and Sons, Inc. New York.

Boon, D. 1784. The adventures of Daniel Boon, formerly a hunter; containing narratives of the wars of Kentucky. pp. 324-362. *In*: George Imlay. Topographical description of the western territory of North America. Printed for J. Debrett. London.

Brady, N. C. 1974. The nature and properties of soils. Eighth Ed. MacMillan Publ. Co. New York.

Braun, E. L. 1950. Deciduous forests of eastern North America. The Blakiston Company. Philadelphia, Pennsylvania.

Bryant, W. S., W. C. McComb, and J. S. Fralish. 1993. Oak-hickory forests (Western Mesophytic/Oak-Hickory forests). pp. 143-201. *In*: W. H. Martin, S. G. Boyce and A. C. Echternacht (eds.). Biodiversity of the southeastern United States. Upland Terrestrial Communities. John Wiley and Sons, Inc. New York.

Chester, E. W. and A. F. Scott. 1980. *Pinus strobus* in Middle Tennessee: Fifty-four years after discovery. J. Tennessee Acad. Sci. 55:85-86.

Chester, E. W., B. E. Wofford, R. Kral. 1997. Atlas of Tennessee Vascular Plants. Vol. 2. Angiosperms: Dicots. Misc. Pub. No. 13. The Center for Field Biology, Austin Peay State University. Clarksville, Tennessee.

Chester, E. W., B. E. Wofford, R. Kral, H. R. DeSelm and A. M. Evans. 1993. Atlas of Tennessee vascular plants. Vol. 1. Pteridophytes, Gymnosperms, Angiosperms: Monocots. Misc. Publ. No. 9. Field Biology, Austin Peay State University. Clarksville, Tennessee.

Delcourt, P. A. and H. R. Delcourt. 1998. The influence of prehistoric human-set fires on oak-chestnut forests in the Southern Appalachians. Castanea 63:337-345.

DeSelm, H. R. 1959. A new map of the Central Basin of Tennessee. J. Tennessee Acad. Sci. 34:66-72.

DeSelm, H. R. 1989. The barrens of Tennessee. J. Tennessee Acad. Sci. 64:89-95.

DeSelm, H. R. 1989. The barrens of West Tennessee. pp. 3-27. *In*: A. F. Scott (ed.), Proceedings of the contributed paper session, second annual symposium on the natural history of lower Tennessee and Cumberland River valleys. The Center for Field Biology of Land Between the Lakes. Austin Peay State University. Clarksville, Tennessee.

DeSelm, H. R. 1994. Tennessee Barrens. Castanea 54:214-225.

DeSelm, H. R. 1994. Vegetation results from an 1807 land survey of southern Middle Tennessee. Castanea 59:51-68.

DeSelm, H. R. 1995. Characteristic native plants of Tennessee barrens. pp. 303-309. *In*: Hamilton, S. W., D. S. White, E. W. Chester and A. F. Scott. Proceedings of the sixth symposium on the natural history of the lower

Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University. Clarksville, Tennessee.
DeSelm, H. R. 1995. Preliminary results of a study of forest vegetation in West and Middle Tennessee. ASB Bull. 42:159-160 (abstract).
DeSelm, H. R. and E. E. C. Clebsch. 1991. Response types to prescribed fire in oak forest understory. pp. 22-33. *In*: Nodvin, S. C. and T. A. Waldrop (eds.). Fire and Environment: ecological and cultural perspectives. Proceedings of an International Symposium, Knoxville, Tennessee, March 20-24, 1990. Southeastern Forest Exper. Sta. Tech. Rep. SE-69. Asheville, North Carolina.
DeSelm, H. R. and N. Murdock. 1993. Grass-dominated communities. pp. 87-141. *In*: W. H. Martin, S. G. Boyce and A. C. Echternacht (eds.). Biodiversity of the southeastern United States. Upland Terrestrial Communities. John Wiley and Sons, Inc. New York.
DeSelm, H. R., B. E. Wofford, R. Kral, and E. W. Chester. 1994. An annotated list of grasses (Poaceae, Gramineae) of Tennessee. Castanea 59:338-353.
Dickson, R. R. 1960. Climate of Tennessee. Climatography of the United States 60-40. U. S. Dept. of Commerce, Weather Bureau. Washington, D. C.
Duffy, D. C. and A. J. Meier. 1992. Do Appalachian herbaceous understories ever recover from clearcutting? Conservation Biology 6:192-201.
Durham, D., R. Abernethy, D. C. Eagar, P. B. Hamel and R. P. Ford. 1988. Development of the West Tennessee Bottomland Hardwood Habitat Evaluation System Model. Processed Report. Tennessee Department of Conservation. Nashville.
Durham, D. B., R. K. Abernethy, D. C. Eagar, R. P. Ford, P. B. Hamel, L. J. O'Neil and T. M. Pullen, Jr. 1988. Application of the Habitat Evaluation System to Modeling Bottomland Hardwood Forest Communities in West Tennessee. Trans. North American Wildlife and Natural Resources Conference 53: 481-490.
Edwards, M. J., J. A. Elder and M. E. Springer. 1974. The soils of the Nashville Basin. Tennessee Agricultural Experiment Station Bull. 499.
Elder, J. A. and M. E. Springer. 1978. General soil map. Tennessee. U. S. Soil Conservation Service and Tennessee Agricultural Experiment Station. Knoxville.
Elliott, K. J. and W. T. Swank. 1994. Changes in tree species diversity after successive clearcuts in the Southern Appalachians. Vegetatio 115: 11-18.
Fenneman, N. M. 1938. Physiography of eastern United States. McGraw-Hill Book Co., Inc. New York.
Fernald, M. L. and A. C. Kinsey. 1958. Edible wild plants of eastern North America. Harper & Row, Publishers. New York.
Filson, J. 1784. The discovery and present state of Kentucky. pp. 267-323. *In*: George Imlay. Topographical description of the western territory of North America. Printed for J. Debrett. London.
Foster, S. and J. A. Duke. 1990. A field guide to medicinal plants. Houghton Mifflin Co. Boston.
Gattinger, A. 1887. The Tennessee flora; with special reference to the flora of Nashville. The author. Nashville.
Gattinger, A. 1901. The flora of Tennessee and a philosophy of botany. Gospel Advocate Publ. Co. Nashville, Tennessee.
Gleason, H. A. and A. Cronquist. 1991. Manual of vascular plants of northeastern United States and adjacent Canada. 2nd ed. New York Botanical Garden. Bronx, New York.
Goodspeed, W. A. 1887. History of Tennessee. The Goodspeed Publ. Co. Nashville, Tennessee.
Gottschalk, K. W. 1993. Silvicultural guidelines for forest stands threatened by the gypsy moth. Northeastern Forest Expt. Sta. Gen. Tech. Report NE-171.
Hardeman, W. D. 1966. Geologic map of Tennessee. Tennessee Geological Survey. Nashville, Tennessee.
Haywood, J. 1823. The civil and political history of the State of Tennessee. Printed for the author by Heiskell and Brown. Knoxville, Tennessee.
Heineke, T. N. 1987. The flora and plant communities of the Middle Mississippi River valley. Ph.D. Diss. Southern Illinois University, Carbondale.
Hepting, G. H. 1971. Diseases of forest and shade trees of the United States. Handbook 386. U. S. Dept. of Agriculture. Washington, D. C.
Hursh, C. R. and F. W. Haasis. 1931. Effects of 1925 summer drought on southern Appalachian hardwoods. Ecology 12:380-386.
Killebrew, J. B. and J. M. Safford, assisted by C. W. Carlton and H. L. Bentley. 1874. Introduction to the resources of Tennessee, 1st and 2nd reports of the Bureau of Agriculture. Tavel, Eastman and Howell Printer. Nashville, Tennessee.

Kowal, R. J. 1960. Southern pine beetle. U. S. D. A. Forest Service. Forest Pest Leaflet 49.
Lamson-Scribner, F. 1892. The grasses of Tennessee–Part I. University of Tennessee Agric. Expt. Sta. Bull. 5:29-119.
Lamson-Scribner, F. 1894. Grasses of Tennessee–Part II. Tennessee Agric. Expt. Sta. Bull. 7:1-141.
Lewis, T. M. N. and M. Kneberg. 1958. Tribes that slumber. The University of Tennessee Press. Knoxville.
Little, E. L., Jr. 1971. Atlas of United States trees. Vol. 1. Conifers and important hardwoods. U. S. D. A. Misc. Publ. No. 1146.
Little, E. L., Jr. 1977. Atlas of United States trees. Vol. 4. Minor eastern hardwoods. U. S. D. A. Misc. Publ. No. 1342.
May, D. M. 1991. Forest resources of Tennessee. Southern Forest Experiment Station Resource Bull. SO-160, Forest Service, USDA, Washington, DC.
McKnight, B. N. (ed.). 1993. Biological Pollution: The control and Impact of Invasive Exotic Species. Indiana Acad. Sci., Indianapolis.
Michaux, A. 1793-1796. Journal of Andre Michaux. *In*: R. G. Thwaites (ed.). Early Western Travels 1748-1848. Vol. 3: 27-104. A. H. Clark Company. Cleveland, Ohio.
Miller, R. A. 1974. The geologic history of Tennessee. Tennessee Division of Geology Bull. 74.
Mooney, H. A. and J. A. Drake (eds.). 1986. Ecology of biological invasions of North America and Hawaii. Springer-Verlag. New York.
Natural Areas Association. 1992. Compendium on exotic species. Natural Areas Journal. Rockford, Illinois.
Nordman, C. 1997. Rare Plant List. Division of Natural Heritage, Department of Environment and Conservation. Nashville, Tennessee.
Patterson, W. B. 1989. Vegetation and soils of the Sinking Pond area, Coffee County, Tennessee. M.S. Thesis. The University of Tennessee, Knoxville.
Phillips, H. 1985. Growing and propagating wildflowers. University of North Carolina Press, Chapel Hill.
Quarterman, E., M. P. Burbank and D. J. Shure. 1993. Rock outcrop communities: Limestone, sandstone and granite. pp. 35-86. *In*: W. H. Martin, S. G. Boyce, and A. C. Echternacht (eds.). Biodiversity of southeastern United States. Upland Terrestrial Communities. John Wiley and Sons, Inc. New York.
Ridley, H. N. 1930. The dispersal of plants throughout the world. L. Reeve and Co. Ltd. Ashford, Kent, Great Britain.
Safford, J. M. 1869. Geology of Tennessee. S. C. Mercer Printer. Nashville, Tennessee.
Safley, J. M., Jr., and W. L. Parks. 1974. Agricultural drought probabilities in Tennessee. Bull. 533. Agric. Expt. Sta., The University of Tennessee, Knoxville.
Shanks, R. E. 1952. Checklist of the woody plants of Tennessee. J. Tennessee Acad. Sci. 27:27-50.
Shanks, R. E. 1953. Woody plants of Tennessee: First supplement. J. Tennessee Acad. Sci. 28:158-159.
Shanks, R. E. 1954. Woody plants of Tennessee: Second supplement. J. Tennessee Acad. Sci. 29:234-237.
Shanks, R. E. 1958. Floristic regions of Tennessee. J. Tennessee Acad. Sci. 33: 195-210.
Sharp, A. J., R. E. Shanks, H. L. Sherman and D. H. Norris. 1960. A preliminary checklist of dicots of Tennessee. Processed report. The University of Tennessee, Knoxville.
Sharp, A. J., R. E. Shanks, J. K. Underwood and E. McGilliard. 1956. A preliminary checklist of monocots of Tennessee. Processed report. The University of Tennessee, Knoxville.
Shaver, J. M. 1954. Ferns of Tennessee with the fern allies excluded. Bureau of Publications, George Peabody College for Teachers. Nashville, Tennessee.
Skeen, J. N., P. D. Doerr, and D. H. Van Lear. 1993. Oak-hickory-pine forests. pp. 1-33. In: W. H. Martin, S. G. Boyce and A. C. Echternacht (eds.). Biodiversity of Southeastern United States. Upland Terrestrial Communities. John Wiley and Sons, Inc. New York.
Solomon, J. D. 1995. Guide to insect borers in North American broad leaf trees and shrubs. Agricultural Handbook AH-706.
Swanton, J. R. 1946. The Indians of the Southeastern United States. Smithsonian Institution Bureau of Ethnology Bull. 137.
Tennessee Exotic Pest Plant Council. 1996. Tennessee Exotic Plant Management Manual. Friends of Warner Park. Nashville.
Underwood, J. K. 1945. The genus *Carex* in Tennessee. Amer. Midl. Naturalist 33:613-643.
Vaiksnoras, J. V. 1971. Tornadoes in Tennessee (1916-1970) with reference to notable tornado disasters in the United States (1880-1970). The University of Tennessee Institute for Public Service, Knoxville.
Vaiksnoras, J. V. and W. C. Palmer. 1973. Meteorological drought in Tennessee. J. Tennessee Acad. Sci. 48:23-30.
White, P. 1982. Impacts of cultural and historical resources on natural diversity: lessons from Great Smoky Mountains National Park, North Carolina and Tennessee. pp. 119-132. *In*: J. L. Cooley and J. H. Cooley (eds.), Natural

Diversity of Forest Ecosystems. Proceedings of the Workshop Nov. 25-8, 1982. University of Georgia, Athens.
Williams, M. 1989. Americans and their forests. A historical geography. Cambridge University Press. Cambridge, England.
Williams, S. C. 1928. Early travels in the Tennessee country (1580-1800). Watauga Press. Johnson City, Tennessee.
Williams, S. C. 1930. Beginnings of West Tennessee in the land of the Chickasaws 1541-1841. The Watauga Press. Johnson City, Tennessee.
Wofford, B. E. 1989. Floristic elements of the Tennessee Blue Ridge. J. Tennessee Acad. Sci. 64:205-207.
Wofford, B. E. and A. M. Evans. 1979. Atlas of the vascular plants of Tennessee. I. Pteridophytes and Gymnosperms. J. Tennessee Acad. Sci. 54:32-38.
Wofford, B. E. and R. Kral. 1993. Checklist of the vascular plants of Tennessee. Sida Bot. Misc. No. 10.

APPENDIX: TABLE 1

Table 1. Percent presence or frequency of woody plants in West and Middle Tennessee

Taxa	West Tennessee					Basin	N.E. Rim W. Rim
	P all a	Overst F b	Subcanopy No types:F range c	Shrub layer No types:F range d	Herb layer No types:F range e	P all f	P all g
*Abelia floribunda**							0.2
Acer floridanum	x					0.2	
A. negundo	18.6	33.0	14:0 - 76.3	7:0 - 50.0	4:0 - 7.1	13.6	20.9
A. nigrum	0.3					1.0	3.2
A. rubrum	57.8	39.6	15:0 - 70.0	16:5.1 - 72.4	10:0 - 41.4	30.4	62.4
A. saccharum	47.2	0.6	1:6.7			73.9	75.7
A. saccharinum	0.6	16.0	14:0 - 66.7	8:0 - 44.4	6:0 - 14.3	1.9	2.8
Aesculus glabra	x					7.2	29.6
A. octandra						0.2	2.3
*Ailanthus altissima**	1.7					9.8	20.6
*Albizia julibrissin**	4.7					0.2	3.7
Alnus serrulata	1.0	0.3	2:0 - 6.7	6:0 - 34.6	1:11.5	1.7	2.3
Amelanchier arborea	19.3					15.6	11.7
Amorpha fruticosa						0.2	0.5
Ampelopsis arborea	1.3			3:0 - 3.4	9:0 - 28.6		0.2
A. cordata	2.7				3:0 - 55.6	3.1	3.4
Aralia spinosa	50.5					30.6	21.3
Aristolochia tomentosa	x			1:1.1		0.5	0.7
Arundinaria gigantea	10.6			9:0 - 62.5	10:0 - 85.7	8.1	11.5
A. tecta	x					0.2	
Asimina triloba	25.2		9:0 - 71.4	7:0 - 66.7	8:0 - 33.3	18.9	27.3
Berchemia scandens	10.0			1:1.7	3:0 - 14.3	4.5	0.9
Betula nigra	4.7	8.5	5:0 - 24.1	3:0 - 16.7	1:3.4	1.2	1.4
Bignonia capreolata	14.0			2:0 - 6.8	12:0 - 85.7	47.1	25.7
*Broussonetia papyrifera**	1.0					0.2	
Brunnichia cirrhosa	x			10:0 - 40.0	13:0 - 44.4	x	
Bumelia lycioides	x			3:0 - 25.0		1.4	0.2
Callicarpa americana	0.7					0.2	0.7
Calycanthus floridus						x	0.2
Calycocarpum lyoni	0.3					0.7	0.9
Campsis radicans	33.9			5:0 - 16.7	16:9.1 - 100.0	27.3	26.4
Carpinus caroliniana	23.3	29.9	15:0 - 83.9	9:0 - 50.6	4:0 - 25.0	22.5	28.2
Carya aquatica	0.3	6.8	7:0 - 55.6	1:22.2	2:0 - 11.1	x	x
C. carolinae-septentrionalis	2.0					14.4	3.0
C. cordiformis	7.0	8.0	5:0 - 37.5	1:1.1		14.8	15.8
C. glabra	81.4					68.2	60.8
C. illinoensis	1.0	7.4	2:0 - 13.6	1:1.7	1:1.7	x	x
C. laciniosa	4.3	25.1	9:0 - 83.3	6:0 - 50.0	8:0 - 50.0	1.4	x
C. ovata	52.2	0.6				52.4	60.6
C. ovalis	1.7					8.9	4.9

Taxa	West Tennessee					Basin	N.E. Rim W. Rim
	P all a	Overst F b	Subcanopy No types:F range c	Shrub layer No types:F range d	Herb layer No types:F range e	P all f	P all g
C. pallida	1.3					0.2	0.5
C. tomentosa	28.9					29.7	40.8
C. spp.	2.7		1:1.7	4:0 - 33.3	3:0 - 12.5		0.9
Castanea dentata	2.0					1.7	1.4
Catalpa speciosa	2.3				1:12.5	1.2	0.5
Ceanothus americanus	1.3					0.5	0.7
*Celastrus orbiculatus**							0.5
C. scandens	4.0					x	x
Celtis laevigatus	2.7	29.9	13:0 - 100.0	14:0 - 83.3	9:0 - 32.3	1.9	3.0
C. occidentalis	1.4		1:1.1	1:34.5		42.1	43.6
C. tenuifolia	0.6					2.4	3.0
Cephalanthus occidentalis	0.7		11:0 - 100.0	10:0 - 81.8	8:0 - 27.3	0.7	2.1
Cercis canadensis	29.6	0.3	3:0 - 6.7	1:1.1		57.9	52.5
Chionanthus virginicus						0.2	0.2
Cladastris kentukea	1.0					1.0	x
Clethra acuminata							0.2
C. alnifolia (PE)							0.2
Cocculus carolina				2:0 - 7.1	4:0 - 16.9	x	x
Cornus alternifolia						x	0.2
C. amomum	x					3.3	0.2
C. drummondii	0.1					1.7	1.8
C. florida	68.8			1:6.7		58.4	66.7
C. foemina			11:0 - 63.3	14:0 - 59.1	8:0 - 27.3	0.5	2.8
C. spp.						0.2	
Corylus americana	15.6			1:12.5		14.1	x
C. cornuta							0.2
Crataegus crusgalli	1.0		1:3.8		1:3.8	0.5	x
C. marshallii			1:12.5	1:16.7		0.2	
C. viridus		2.8	8:0 - 25.0	4:0 - 13.8	1:3.4	x	x
C. spp.	4.0					4.5	2.1
Decodon verticillatus				03:0 - 27.3		x	x
Decumaria barbata	1.3					0.7	x
*Deutsia scabra**							0.2
Dioclea multiflora					2:0 - 12.5	x	
Diospyros virginiana	16.6	18.2	10:0 - 44.4	4:0 - 20.0	2:0 - 11.1	35.9	12.8
Dirca palustris						x	0.2
*Eleagnus umbellata**						0.2	0.7
Euonymus americana	18.6			4:0 - 14.3	4:0 - 14.3	34.9	34.4
E. atropurpurea.	0.7					3.1	1.4
*E. fortunei**	0.7					1.4	1.8
E. spp.						0.2	
Fagus grandifolia	59.1	0.6	1:1.1			46.4	60.6

Taxa	West Tennessee					Basin	N.E. Rim W. Rim
	P all a	Overst F b	Subcanopy No types:F range c	Shrub layer No types:F range d	Herb layer No types:F range e	P all f	P all g
Forestiera acuminata		3.7	12:0 - 45.5	9:0 - 44.4	3:0 - 11.1	x	x
F. ligustrina						12.2	2.1
Fraxinus americana	55.8	2.0	2:0 - 4.5	1:2.3	1:1.1	77.7	72.2
F. pensylvanica	2.7	68.4	16:11.1 - 86.2	13:0 - 30.0	11:0 - 20.1	2.2	3.2
F. quadrangulata						8.9	4.4
F. spp.			2:0 - 7.1	4:0 - 25.0	2:0 - 16.7		
Gaultheria procumbens							0.2
Gaylusaccia baccata						x	2.3
G. dumosa (T)							0.5
Gelsemium sempervirens (S)						0.2	
Gleditsia aquatica	0.3						
G. triacanthos	5.0	9.4	7:0 - 30.0	1:1.7	4:0 - 22.2	11.5	5.5
Gymnocladus dioicus	1.0	1.4	2:0 - 8.5	2:0 - 16.7		x	0.5
Hamamelis virginiana						3.3	2.8
*Hedera helix**	0.7					0.5	0.2
Hibiscus laevis				6:0 - 40.0	1:11.1	x	x
H. moscheutos						x	0.7
*H. syriaca**						0.5	0.2
Hydrangea arborescens	12.6					23.9	26.8
H. discolor	x					0.2	0.5
H. quercifolia	1.3					0.7	x
H. radiata						1.0	
Hypericum densiflorum						0.7	
H. frondosum	x					4.5	0.9
H. hypericoides	31.6					6.9	6.4
H. prolificum	0.7					3.1	3.2
H. stans						0.5	1.1
H. sphaerocarpon	x					0.7	x
H. stragalum	x					9.3	17.2
H. spp.	0.3						
Ilex decidua	19.6		14:0 - 75.0	15:0 - 66.7	8:0 - 14.3	5.2	0.9
I. opaca	26.2		3:0 - 14.3	5:0 - 14.3	1:16.7	0.5	2.1
I. verticillata	1.0					0.2	x
I. spp.							0.2
Itea virginica				9:0 - 63.6	6:0 - 27.3	0	2.3
Juglans cinerea (T)	x					1.9	1.6
J. nigra	21.6	1.7				3.9	50.0
Juniperus virginiana	40.9					60.9	61.5
Kalmia latifolia	x					2.2	8.5
Ligustrum vulgare/sinense**	11.3		5:0 - 12.5	11:0 - 33.3	7:0 - 33.0	11.2	13.5
Lindera benzoin	7.6		7:0 - 42.9	7:0 - 50.0	4:0 - 50.0	15.6	23.6

Taxa	West Tennessee					Basin	N.E. Rim W. Rim
	P all a	Overst F b	Subcanopy No types:F range c	Shrub layer No types:F range d	Herb layer No types:F range e	P all f	P all g
Liquidambar styraciflua	72.1	48.4	14:0 - 83.3	7:0 - 33.3	1:3.4	26.3	36.5
Liriodendron tulipifera	65.8	2.6	2:0 - 14.3	2:0 - 1.7		55.7	72.5
*Lonicera fragrantissima**						0.2	
*L. japonica**	56.8				9:0 - 66.7	53.6	56.7
*L. mackii**						4.3	0.5
L. sempervirens	1.0					1.2	0.5
L. spp.						0.2	
Lyonia ligustrina	x						0.4
Maclura pomifera	1.7		2:0 - 1.7			4.8	4.8
Magnolia acuminata	4.0					x	8.3
M. grandiflora	0.3						
M. macrophylla	x					0.5	
M. tripetala						x	5.7
M. virginiana (T)	0.7					0.2	
Menispermum canadense	0.7			1:1.7	1:3.4	0.5	5.7
Morus rubra		14.0	10:0 - 100.0	7:0 - 16.7	3:0 - 12.5	35.9	40.8
Nyssa aquatica	0.7	20.2	11:0 - 100.0	9:0 - 54.5	9:0 - 50.0		x
N. biflora	x					0.2	0.5
N. sylvatica	78.1	14.5	9:0 - 50.0	2:0 - 14.3	5:0 - 25.0	55.3	66.1
Ostrya virginiana	47.5	0.9	2:0 - 12.5	1:12.5		55.7	33.7
Oxydendron arboreum	13.0					28.7	38.5
Pachysandra procumbens						0.2	x
Parthenocissus quinquefolia	81.1			1:2.3	7:0 - 42.9	84.7	78.7
*Paulonia tomentosa**	1.7					1.7	1.8
Philadelphus hirsutus						x	0.7
P. inodorus	1.3					x	0.5
Pinus echinata	4.7					2.2	0.7
P. strobus						0.2	0.5
P. taeda	8.0					5.3	6.0
P. virginiana	0.7					3.3	5.1
Planera aquatica		12.8	11:0 - 54.5	7:0 - 45.5	9:0 - 33.3		
Platanus occidentalis	18.9	14.5	9:0 - 33.3	3:0 - 16.7	1:3.8	22.2	25.9
Populus deltoides	2.7	4.6	3:0 - 16.7	2:0 - 16.7		1.4	1.4
P. grandidentata (S)						x	0.2
P. heterophylla	x						0.2
Prunus americana	x					0.2	0.9
P. angustifolia	x					x	0.2
*P. mahalob**	0.3					0.2	
P. serotina	73.4	0.3	3:0 - 14.3	1:1.1		42.3	61.0
P. spp.	0.3						0.7
*Pyrus alleryana**							0.2
P. angustifolia	x					1.0	x

Taxa	West Tennessee					Basin	N.E. Rim W. Rim
	P all a	Overst F b	Subcanopy No types:F range c	Shrub layer No types:F range d	Herb layer No types:F range e	P all f	P all g
P. primulifolia	x					x	2.1
P. spp.						0.2	1.2
Ptelea trifoliata	0.7					0.5	x
*Pueraria lobata**	1.0						
Quercus alba	89.4					77.3	72.9
Q. albaxmuhlenbergii							0.2
Q. bicolor	x					0.7	0.9
Q. x capesii						0.5	
Q. coccinea	43.5					29.9	29.8
Q. falcata	64.5					37.8	41.1
Q. x fontana							0.2
Q. imbricaria	1.7					5.7	2.8
Q. lyrata	1.7	33.0	14:0 - 77.8	7:0 - 20.0	10:0 - 28.6	1.2	1.8
Q. macrocarpa	x					0.5	
Q. marilandica	8.3					5.3	4.4
Q. michauxii	6.0	20.8	9:0 - 50.0	6:0 - 16.7	5:0 - 16.7	2.6	0.9
Q. muhlenbergii	20.6					47.8	37.6
Q. nigra	7.0	11.0	5:0 - 33.3	6:0 - 16.7		0.2	6.9
Q. nuttallii	0.3		2:0 - 3.9	1:14.3			
Q. pagoda	20.6	29.3	8:0 - 21.8	2:0 - 14.3	1:3.4	1.4	0.2
Q. palustris	2.7	4.6	4:0 - 16.7			1.4	3.7
Q. phellos	14.0	21.9	9:0 - 66.7	6:0 - 12.5	3:0 - 6.9	3.6	19.3
Q. prinus	4.0					19.1	12.2
Q. rubra	34.6					59.3	56.0
Q. x saulii						0.2	
Q. schumardii	3.7	0.9				31.6	15.1
Q. stellata	60.5					40.0	31.4
Q. velutina	84.4					62.7	52.5
Rhamnus caroliniana	6.0					33.7	39.7
R. lanceolata						0.2	
Rhododendron canescens	0.7					0.2	0.2
R. spp.	5.6					0.6	10.6
Rhus aromatica	1.7					11.7	1.8
R. copallina	19.6					16.5	13.3
R. glabra	8.0					2.9	4.4
Ribes odoratum						1.7	
R. cynosbati							0.2
Robinia pseudoacacia	15.9					14.6	15.8
Rosa carolina	4.7					7.9	3.0
*R. mutiflora**	10.3					11.2	21.3
R. palustris	1.7			4:0 - 23.1	1:3.4	0.5	1.4
R. setigera	2.3					3.1	2.5
R. spp.	3.3					0.7	

Taxa	West Tennessee					Basin	N.E. Rim
	P all a	Overst F b	Subcanopy No types:F range c	Shrub layer No types:F range d	Herb layer No types:F range e	Basin P all f	N.E. Rim W. Rim P all g
Rubus hispidus							0.9
R. spp.	40.9			8:0 - 16.7	6:0 - 42.3	40.4	38.7
Salix caroliniana	x				2:0 - 7.1	x	x
S. humilis	x					x	0.2
S. nigra	0.7	20.2	11:0 - 100.0	8:0 - 77.8	6:0 - 33.3	0.7	1.4
S. tristis						0.5	0.2
Sambucus canadensis	23.9			7:0 - 16.7	7:0 - 28.6	22.7	21.3
Sassafras albidum	15.9	0.3	2:0 - 7.1		2:0 - 14.3	55.3	48.2
Schisandra glabra (T)	0.7					0.2	
Smilax bona nox	8.0					23.9	14.9
S. glauca	51.9					37.3	41.7
S. hispida	0.3					0.5	2.8
S. rotundifolia	58.5					66.7	68.3
S. spp.	0.3			11:0 - 40.2	10:0 - 57.1	0.7	
*Spirea japonica**						x	0.5
S. tomentosa						x	0.2
Staphylea trifolia	3.3					7.9	5.5
Styrax americana	0.7			8:0 - 36.4	4:0 - 33.3	1.9	0.5
S. grandiflora	2.0					4.7	x
Symphoricarpos orbiculatus	19.3					63.2	35.6
Taxodium disticum	1.0	36.8	9:0 - 86.2	8:0 - 30.0	9:0 - 54.5		0.5
Tilia americana	2.7					9.8	16.7
T. heterophylla	x					1.4	0.2
Toxicodendron radicans	84.1			5:0 - 27.1	13:0 - 86.4	81.3	78.2
Trachelospermum difforme	1.3				2:0 - 9.1		x
Tsuga canadensis							4.1
Ulmus alata	71.4		3:0 - 7.1	1:12.5	1:1.1	55.5	44.0
U. americana	3.7	4.3	10:0 - 42.9	4:0 - 42.4	1:14.3	1.9	2.3
U. crassifolia (S)		1.7	2:0 - 10.2				
U. rubra	52.2	56.7	16:9.1 - 85.1	12:0 - 39.1	6:0 - 12.5	52.3	60.3
U. serotina	x					22.2	x
U. thomasii	0.3					x	2.3
Vaccinium arboreum	34.6					16.7	15.1
V. attrococcum	1.0					x	2.8
V. corymbosm	x			1:7.7		x	1.1
V. pallidum						x	1.2
V. stamineum	6.3					18.2	17.7
V. vacillans	2.3					16.5	17.9
V. spp.	2.3					2.4	1.6
Viburnum acerifolium						x	16.1
V. cassinoides	0.3						0.7

Taxa	West Tennessee					Basin	N.E. Rim
	P all a	Overst F b	Subcanopy No types:F range c	Shrub layer No types:F range d	Herb layer No types:F range e	P all f	W. Rim P all g
V. dentatum						x	0.7
V. nudum	x		2:0 - 11.5	3:0 - 23.1	1:14.3		0.5
V. prunifolium	0.7						10.3
V. rufidulum	7.6					1.4	3.4
V. spp.						0.2	0.5
*Vinca major**	0.7						
*V. minor**	0.7					2.9	1.6
Vitis cinerea and its var. *baileyana*	x					x	0.5
V. labrusca							0.2
V. rotundifolia	61.1				1:1.1	30.6	22.1
V. spp.	59.8			3:0 - 7.1	6:0 - 28.8	70.6	70.2
Wisteria frutescens	x			4:0 - 20.0	2:0 - 6.7	0.5	0.2
W. sp.	0.3					1.0	
Xanthorhiza simplicissima	x					x	0.2
Yucca filamentosa	0.3					x	0.2

Columns a, f, g - percent presence, all layers, uplands and bottoms
Columns (bottom samples only) b, F - in overstory in all samples.
Columns (bottom samples only) c in subcanopy, d in shrub layer, e in herb layer, number of vegetation types (of 16): F range among those types.
x = known to occur but not sampled in this study.
Levels of endangerment, State: T, Threatened; S, Special Concern.; PE, Proposed Endangered (Nordman 1997)
*Species with asterisk are introduced.

FLATWOODS OF THE JACKSON PURCHASE REGION, WESTERN KENTUCKY: STRUCTURE AND COMPOSITION

WILLIAM S. BRYANT

Department of Biology, Thomas More College,
Crestview Hills, KY 41017

ABSTRACT. In the Jackson Purchase Region of western Kentucky, flatwoods represents both a geographic section (Calloway and Marshall counties) and a vegetation type. Flatwoods are most conspicuous on Henry soils which are poorly drained. Flatwoods communities are dominated by three tree species: *Quercus falcata* (southern red oak), *Q. stellata* (post oak), and *Carya ovata* (shagbark hickory). On some of the wetter sites, *Q. pagodaefolia* (cherrybark oak) replaces *Q. falcata*. Current stands are highly fragmented. Tree density varied from 258-360 trees/ha and basal area from 23-26 m^2/ha. These values are similar to those reported for flatwoods communities in Illinois and Indiana.

INTRODUCTION

Over the past several years, I have reported a number of studies dealing with vegetation in the Jackson Purchase Region of western Kentucky [*i.e.* presettlement vegetation (Bryant and Martin 1988), bottomland hardwoods (Bryant 1991), mixed mesophytic forests of the loess bluffs (Bryant 1993), and swamp forests on the Mississippi alluvial plain (Bryant 1997)]. However, there are several vegetation types and geographic areas in the Jackson Purchase for which little is known. Flatwoods, both as a vegetation type and geographic subdivision, is one such type.

Vegetationally, flatwoods are forests growing on level surfaces over nearly impervious subsoil layers (Dolan and Menges 1989). They occupy sites that are wet in spring with ponded depressions, dry in summer, and typically lack a well-developed shrub layer (Aldrich and Homoya 1984, Nelson 1985). Flatwoods were reported for Calloway and Marshall counties (Loughridge 1886, 1888; Davis 1923) and for McCracken County (DeFriese 1880), but Heineke (1987, 1989) considered the Flatwoods Belt in western Kentucky and Tennessee to have been essentially destroyed by agricultural conversion. He further noted that based on current knowledge "no intact piece of this once extensive belt remains," but he did leave open the chance that with further botanical explorations an unknown piece of this belt might be discovered.

I located several remnant stands of the Flatwoods Belt in Calloway County where they were shown by Davis (1923) and in McCracken County where they were mentioned by DeFriese (1880). This paper presents the results of vegetation analyses of these flatwoods remnants.

HISTORICAL SETTING

Loughridge (1888) wrote, "It [The Flatwoods of the Jackson Purchase] is the northern termination of that long and narrow belt reaching from the central part of Alabama northwestward and north through north-east Mississippi and West Tennessee, and possessing features very similar throughout." On his map, Bennett (1921) labeled this as the Interior Flatwoods belt, but he did not show it extending across west Tennessee and into Kentucky (Figure 1). Bennett (1921) reported that post oak (*Quercus stellata*) was the dominant tree of the Interior Flatwoods.

Other early writers, *i.e.* Hilgard (1884), Loughridge (1888), and Sargent (1884), paid special attention to topography and soils when discussing flatwoods. They noted that the surface is low or "glady" so that drainage is poor, the soil stiff, whitish and "crawfishy." In the more poorly drained portions of the "glades," post oak is the dominant tree (Davis 1923). Other trees mentioned included Spanish oak (southern red oak), hickory, black oak, and white oak.

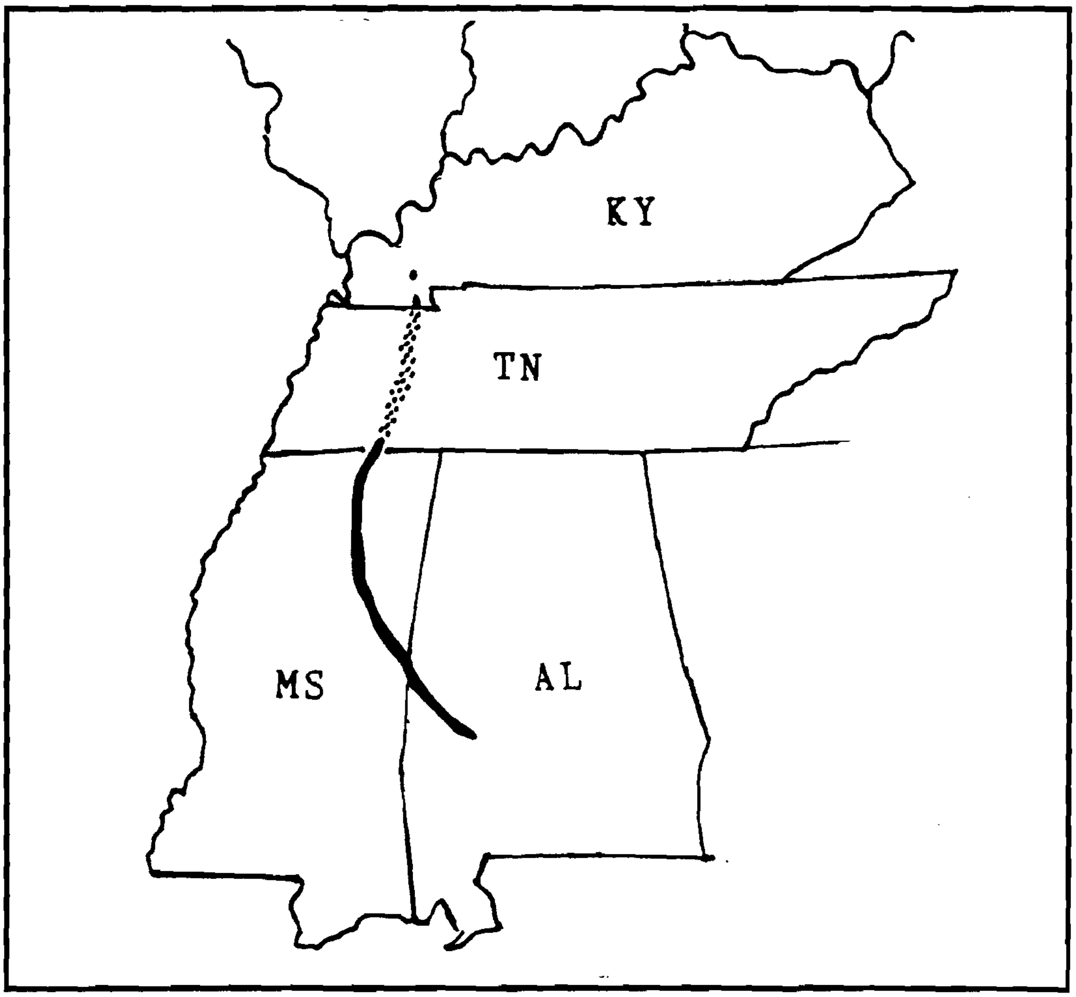


Figure 1. Map of the Interior Flatwoods Belt of Alabama, Mississippi, and extreme southwestern Tennessee (Bennett 1921); the Flatwoods Belt of West Tennessee (Heineke 1987); and the Flatwoods of the Jackson Purchase Region of Kentucky (Loughridge 1886).

METHODS

Numerous visits were made to the 38.4 km^2 area of Calloway County and the 23 km^2 area of Marshall County shown by Davis (1923). Visits also were made to McCracken County where DeFriese (1880) mentioned flatwoods sites and to other counties throughout the Jackson Purchase Region. Three stands large enough to randomly sample were located in Calloway County and three were located in McCracken County. Stands in Marshall County were too fragmented to sample.

All trees >10 cm at diameter breast height (dbh) were measured in 0.04 ha circular plots spaced at 30 m intervals through the forest stands. Because of the fragmented nature of the flatwoods sites, a minimum of five plots/stand was considered to be essential to maintain a good sample. Generally, more plots than the minimum were sampled. A total of 29 plots was taken in Calloway County and 15 in McCracken County. For each stand, relative frequency (RF), relative density (RD), relative dominance (RDo), and importance value (IV) were determined. Importance percentage (IP) also was calculated as IV/3. Density (trees/ha), basal area (m^2 /ha), H' (Shannon diversity) and J (equitability) also were determined.

RESULTS

Three flatwoods stands were sampled in the Flatwoods of Calloway County (Davis 1923) and three stands were sampled in McCracken County. Because of the clear dominance of three tree species, southern red oak (*Quercus falcata*), post oak (*Q. stellata*), and shagbark hickory (*Carya ovata*), in the Calloway County stands, data were combined (Table 1). The same was true for the McCracken County stands, but there cherrybark oak (*Q. pagodaefolia*) replaced southern red oak (Table 2). The coefficient of similarity between the combined Calloway County stands and the combined McCracken County stands was 74 per cent when southern red oak and cherrybark oak were equated. That suggests strong stand similarities, but also differences. Preliminary ordinations of 67 forest and prairie sites from the eight counties of the Jackson Purchase Region indicate that flatwoods is a distinct community type and that those in Calloway and McCracken counties segregate out as two distinct community types (Bryant and Held unpub.).

Table 1. Number/hectare (N/ha), relative frequency (RF), relative density (RD), relative dominance (RDo), importance value (IV), and importance percentage (IP) for Calloway County, Kentucky, flatwoods.

Taxa	N/ha	RF	RD	RDo	IV	IP
Quercus falcata	101.4	19.35	28.13	37.39	84.87	28.29
Quercus stellata	83.5	17.74	23.17	28.44	69.35	23.12
Carya ovata	96.2	21.77	26.71	12.09	60.57	20.19
Quercus alba	23.8	11.29	6.62	13.68	31.59	10.53
Carya glabra	17.9	8.87	4.96	3.83	17.66	5.85
Nyssa sylvatica	17.0	6.45	4.73	1.65	12.83	4.28
Quercus velutina	9.4	4.84	2.60	2.09	9.53	3.18
Ulmus alata	6.0	4.84	1.65	0.44	6.93	2.31
Acer rubrum	3.4	3.23	0.95	0.21	4.39	1.46
Prunus serotina	0.9	0.81	0.24	0.10	1.15	0.38
Quercus coccinea	0.9	0.81	0.24	0.09	1.14	0.38
Totals	360.4	100.00	100.00	100.01	300.01	99.97

Table 2. Number/hectare (N/ha), relative frequency (RF), relative density (RD), relative dominance (RDo), importance value (IV), and importance percentage (IP) for McCracken County, Kentucky flatwoods.

Taxa	N/ha	RF	RD	RDo	IV	IP
Quercus pagodaefolia	79.0	27.64	30.57	50.85	105.06	35.02
Quercus stellata	59.3	23.64	22.93	27.07	73.64	24.55
Carya ovata	70.8	23.64	27.39	17.66	68.69	22.90
Prunus serotina	19.8	10.91	7.64	1.68	20.23	6.74
Diospyros virginiana	11.5	3.64	4.46	0.70	8.80	2.93
Ulmus alata	6.6	3.64	2.55	0.29	6.48	2.16
Carya sp.	3.3	3.64	1.27	1.13	6.04	2.01
Quercus palustris	3.3	3.64	1.27	0.41	5.32	1.77
Sassafras albidum	3.3	1.82	1.27	0.14	3.23	1.08
Ulmus americana	1.6	1.82	0.64	0.08	2.54	0.85
Totals	258.5	100.03	99.99	100.01	300.03	100.01

There were 11 species in the Calloway County flatwoods stands (Table 1). Southern red oak, post oak, and shagbark hickory made up >78% of the density and nearly 78% of the basal area. There were 360 trees/ha and 23.4 m^2/ha for all species. Species diversity (H') was 2.53 and evenness or equitability 0.73. The inclusion of white oak (*Q. alba*), black oak (*Q. velutina*) and pignut hickory (*C. glabra*) may indicate that another soil type was present here.

There were 10 species in the McCracken County flatwoods stands (Table 2). Cherrybark oak, post oak, and shagbark hickory collectively accounted for 81% of the density and 95.6% of the basal area. There were 258.5 trees/ha and basal area was 26.6 m^2/ha. Species diversity was 2.43 and evenness was 0.73, the same as in the Calloway County flatwoods.

All flatwoods stands were on nearly level sites (0-2% slope) and were on Henry silt loam (Humphrey *et al.* 1973). Nearly all of the rainfall enters the soil because natural drainage channels have not penetrated these flatwoods sites. Water often stands on the soil surface and few roots penetrate the claypan subsoils (Leighty *et al.* 1945). The understory of the flatwoods stands was quite open. Only winged elm (*Ulmus alata*) and farkleberry (*Vaccinium arboreum*) were present as scattered individuals.

DISCUSSION

Although highly fragmented, flatwoods communities are present in the Jackson Purchase Region. These remnants undoubtedly have been affected by a number of past events, *i.e.* grazing, fire and its suppression, and agricultural conversion. In many ways, the Jackson Purchase flatwoods resemble flatwoods in Illinois (Fralish 1988; Coates *et al.* 1992) and Indiana (Aldrich and Homoya 1984, Dolan and Menges 1989). Post oak was the major dominant in those flatwoods and investigators stressed the importance of soils and topography in the maintenance of such communities.

A mosaic of loessial soils occupy the flat uplands of the Jackson Purchase Region. In particular, these include the Henry, Calloway, and Grenada soils. These soils differ primarily in rates of internal drainage, *i.e.* the Calloway silt loam is somewhat poorly drained and the Henry silt loam is poorly drained (Humphrey *et al.* 1973). Those latter two soils have concave surfaces. Soil forming processes are influenced by a fluctuating water table, which causes the gray colors and the brittle, slowly permeable layers to be nearer the surface in Calloway and Henry soils and to be more restrictive of air and water movement than in Grenada soils (Humphrey *et al.* 1973). Leighty *et al.* (1945) note that sites where Henry silt loam predominates are commonly called "white or glade land".

The mosaic of soils and their corresponding vegetation was perhaps first observed by DeFriese (1880) for the flatwoods sites of McCracken County. He reported that "the timbers alternate most curiously." He noted, "Here white oak is the principal, almost the only timber; two hundred yards distant, Spanish oak and black oak have succeeded the white oak; at the same distance further on, these timbers have disappeared, and only post oak and hickory is to be seen, and all this without the slightest change of level, or the apparent reason therefor." That sequence may reflect the changes from Grenada to Calloway to Henry soils as seen by observing vegetation patterns.

Post oak is generally the dominant tree species in flatwoods communities. This tree is characteristic of sites that are alternately waterlogged, and hard and dry, such as the Alabama and Mississippi flatwoods and the heavy planosols of the undissected till plains of the Central States (Bourdeau 1954). In the Jackson Purchase, it is a co-dominant with southern red oak or cherrybark oak, particularly on Henry silt loam. This soil may occur on uplands and stream terraces (Humphrey 1976). The McCracken County sites appeared to occupy old or former stream terraces. Such sites may be more favorable for cherrybark oak than for southern red oak, but have no limitation on post oak. Fralish (1988) noted two soil phases of the Wynoose soil type in the flatwoods of Illinois and their influence on local vegetation types.

Based on the 1820 General Land Office Survey of the Jackson Purchase Region, Bryant and Martin (1988) found post oak to comprise 15.64% of the trees sampled; Spanish oak or southern red oak, 1.65%; and hickory (no species designations), 11%. In the flatwoods sites, I found post oak to account for 23-36% of the density; southern red oak or cherrybark oak, 10-30%; and shagbark hickory, 4-27%. Those differences from the 1820 sample may serve to show the flatwoods communities as distinct from other forest communities of the Jackson Purchase. More investigations of these remnants are needed in Kentucky and in West Tennessee.

LITERATURE CITED

Aldrich, J.R. and M.A. Homoya. 1984. Natural barrens and post oak flatwoods in Posey and Spencer Counties, Indiana. Proc. Indiana Acad. Sci. 93:291-301.

Bennett, H.H. 1921. The soils and agriculture of the southern states. Macmillan Co., New York.

Bourdeau, P. 1954. Oak seedling ecology determining segregation of species in Piedmont oak-hickory forests. Ecol. Monogr. 24:297-320.

Bryant, W.S. 1990. Sugarberry (*Celtis occidentalis*) and its associates in the bottomland forests of the Jackson Purchase of Kentucky. Pp. 93-100 in: Hamilton, S.W. and M.T. Finley (eds.). Proc. of the Third Annual Symposium on Natural History of Lower Tennessee and Cumberland River Valleys. The Center for Field

Biology. Austin Peay State University, Clarksville, Tennessee.
Bryant, W.S. 1993. Vegetation of loess bluff ravines in the Jackson Purchase Region of Kentucky. 9th Central Hardwood Forest Conference. Lafayette, Indiana.
Bryant, W.S. 1997. Structure and composition of three swamp forests on the Mississippi Alluvial Plain of Kentucky's Jackson Purchase Region. Trans. Kentucky Acad. Sci. 58:85-91.
Bryant, W.S. and W.H. Martin. 1988. Vegetation of the Jackson Purchase of Kentucky based on the 1820 General Land Office Survey. Pp. 264-276 in: Snyder, D.H. (ed.). Proc. of the First Annual Symposium on Natural History of Lower Tennessee and Cumberland River Valleys. The Center for Field Biology. Austin Peay State University, Clarksville, Tennessee.
Coates, D.T., K.J. Lyman and J.E. Ebinger. 1992. Woody vegetation structure of a post oak flatwoods in Illinois. Castanea 57:196-201.
Davis, D.H. 1923. The geography of the Jackson Purchase. Kentucky Geol. Surv., Frankfort, KY.
DeFriese, L.H. 1880. Report on the timbers of the district west of the Tennessee River, commonly known as the Purchase District. Geol. Surv. Kentucky, n.s. 5:125-158.
Dolan, R.W. and E.S. Menges. 1989. Vegetation and environment in adjacent post oak (*Quercus stellata*) flatwoods and barrens in Indiana. Amer. Midl. Nat. 122:329-338.
Fralish, J.S. 1988. Diameter-height-biomass relationships for *Quercus* and *Carya* in Posen Woods Nature Preserve. Trans. Illinois Acad. Sci. 81:31-38.
Heineke, T.E. 1987. The flora and plant communities of the Middle Mississippi River Valley. Dissertation. Southern Illinois University. Carbondale, Illinois.
Heineke, T.H. 1989. Plant communities and flora of West Tennessee between the Loess Hills and the Tennessee River. J. Tennessee Acad. Sci. 64:117-119.
Hilgard, E.W. 1884. Cotton production in the United States. Part 1. Mississippi Valley and Southwestern States. Dept. Interior, Census Office. 924 pp.
Humphrey, M.E. 1976. Soil survey of Ballard and McCracken counties, Kentucky. U.S.D.A. Soil Cons. Service, Washington, D.C.
Humphrey, M.E., F.L. Anderson, R.A. Hayes and J.D. Sims. 1973. Soil survey of Calloway and Marshall counties, Kentucky. U.S.D.A. Soil Cons. Service, Washington, D.C..
Leighty, W.J., H.W. Higbee, W.S. Reed and C.E. Wyatt. 1945. Soil survey: Calloway County, Kentucky. U.S.D.A., Agric. Research Admin., Washington, D.C..
Loughridge, R.N. 1886. Agricultural map of the Jackson Purchase. Geological Surv. of Kentucky. Frankfort, Kentucky.
Loughridge, R.N. 1888. Report on the geological and economic features of the Jackson Purchase Region. Kentucky Geol. Survey, Frankfort, Kentucky.
Nelson, P.W. 1985. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee. Jefferson City, Missouri.
Sargent, C.S. 1884. Report on the forests of North America (exclusive of Mexico). 10th U.S. Census. Washington, D.C.

STRUCTURE OF FOREST COMMUNITIES AT TAYLOR HOLLOW NATURE PRESERVE, SUMNER COUNTY, TENNESSEE

JOE SCHIBIG

Department of Biology, Volunteer State Community College, Gallatin, TN 37066, and The Center for Field Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. Four topography-based forest communities, each including some relatively old-growth stands, were studied at Taylor Hollow Nature Preserve, a Nature Conservancy property in Sumner County, Tennessee. Systematic plot sampling and calculated importance values of seedlings (dbh <2.5 cm), saplings (dbh 2.5-10.2 cm), and large trees (dbh ≥10.2 cm) revealed a growing dominance by maples, primarily *Acer saccharum*, in all communities. The dominant species (descending IV) of the large tree class for the four communities were (1) Ridge Community: *Acer saccharum*, *Quercus prinus*, *Liriodendron tulipifera*, *Fagus grandifolia*, and *Q. velutina*; (2) South-Facing Slope Community: *Fagus grandifolia*, *Acer saccharum*, *Quercus velutina*, *Carya glabra*, and *Q. alba*; (3) North-Facing Slope Community: *Acer saccharum*, *Fagus grandifolia*, *Quercus alba*, *Carya ovata*, and *Liriodendron tulipifera*; (4) Ravine Community: *Acer saccharum*, *Juglans nigra*, *Ulmus* spp., *Carya cordiformis*, and *Carpinus caroliniana*. For all community types, *Acer saccharum* had an IV of 21.3 in the large tree class and 40.5 in the sapling class. In the seedling class, the IV for *Acer* spp. (primarily *A. saccharum*) was 22.8. The mesophytic species *Aesculus octandra*, *Magnolia acuminata*, and *Tilia americana* are rare in Middle Tennessee but were significant components at Taylor Hollow.

INTRODUCTION

The Study Area

The Taylor Hollow Preserve is a Nature Conservancy property in Sumner County, Tennessee at latitude 36° 31′25″north and longitude 86°13′45″ west. It was acquired as a 173 acre (70 ha) tract in 1978 from Betty and Clyde Henson and presently consists of 62 ha. The site is approximately 4.5 km south of Westmoreland, 23.0 km northeast of Gallatin, and 63.2 km northeast of Nashville.

The Taylor Hollow ravine is the result of dissection in the Northern Highland Rim of the Interior Low Plateau. The Rim generally is an area of flat to gently rolling topography, but near the edge of the Central Basin it is sharply dissected into narrow ridges and draws. Elevations at Taylor Hollow range from 670 to 920 feet above sea level. The slopes are steep, averaging 36%. The average aspect of the north-facing slope plots is 21° west of north while the average for the south-facing slope plots is 19° east of south. Most slopes are rocky with the lower slopes consisting mostly of steep limestone cliffs. The narrow valley floor is drained by a small permanent creek which has a spring source at the northeastern end of the property. A seasonal waterfall with a drop of about 5 m is located close to the spring.

The uppermost slopes and ridges are underlain by Fort Payne chert (Mississippian age), upper slopes by Chattanooga Shale (Devonian), and middle to lower slopes by Silurian Peagram Formation (sandstones and limestones) and the Wayne Group (dolomites) (DeSelm and Schmalzer 1982). A dominant soil at the floor of the hollow is the Ocana series, a deep alluvial, well-drained, gravelly silt loam. The Mimosa-Rock Outcrop Complex is a prevalent soil of the lower slopes; it consists of deep well drained Mimosa soil and outcrops of limestone bedrock. The steep middle and upper slopes are comprised mostly of Sulphura channery silt loam, a moderately deep and very well drained soil, which also is present on the narrow winding hilltops. Sugargrove gravelly silt loam is another well-drained soil associated with the hilltops. All soils are acidic and well-drained (U.S.D.A 1997).

Climatic data for the area are given in Schibig (1996). Perhaps one of the most serious climatic factors affecting forest composition is ice storms. Trees with shallow root systems, *e.g.*, *Acer saccharum*, *Celtis* spp., *Fagus grandifolia*, and *Prunus serotina* are especially susceptible to ice storms as well as windfall. Eichmeier (1988) reported that a severe ice storm occurred in middle Tennessee in 1957. In 1996, I observed many large dead trees at Taylor Hollow, especially on the south-facing slope, which were apparently felled by the ice storm of 1994. It appeared that large areas opened by these fallen trees provided opportunities for tree reproduction.

Vegetatively, some of the Taylor Hollow forests resemble those of the Mixed Mesophytic Forest Region of Braun (1950). Most are old-growth, but there is a stand of young forest <30 years old on a ridge in the northeastern section of the property. Alcorn (1976) was the first to realize that Taylor Hollow was of botanical significance and noted that it was the last of the mesic forests of the Northern Rim not obliterated by repeated and careless lumbering and not having the ground flora eliminated by grazing. Kral (1979) listed numerous rare plant species from there, including *Carex purpurifera, Collinsia verna, Hydrastis canadensis, Panax quinquefolium, Synandra hispidula*, and *Trillium pusillum* var. *arkansanum.* He reported 389 vascular plant taxa in 85 families. DeSelm and Schmalzer (1982) noted that the herb cover and diversity were extremely high.

The previous property owners, Betty and Clyde Henson, were interviewed in 1978 (Schibig and Burkitt 1979). According to the Hensons, who had owned the land since 1946, there was no significant cutting of timber during their ownership, but there was some cutting of firewood. They mentioned that a fire occurred in the area in 1972 or 1973. In 1978, I noticed some trees on the ridges that were fire-scarred. Baskam and Anny Carr, long-time owners of property adjacent to Taylor Hollow, recalled that there was a timber harvest in the hollow in 1928 (Schibig and Burkitt 1979). Because of the current presence of many large old trees, especially beech trees >20 cm in diameter, it appears that the cutting was selective. The Carrs recalled that there was a peach orchard on a northwest-facing slope close to the mouth of Taylor Hollow in the 1940s. Today there is a *Lirodendron tulipifera* stand (approximately 50 years old) on that site. They remembered a forest fire that occurred in the area in 1958. The Carrs stated that they used the Taylor Hollow creekbed as a wagon road in the 1920s. Despite these disturbances, most of the Taylor Hollow area appears to have been well-protected compared to other areas on the Highland Rim.

The purpose of this paper is to present quantitative analyses of the forest communities of the Taylor Hollow Nature Preserve as they were in 1996, and to compare findings with other studies of mature protected forest communities of the region, *e.g.*, Eickmeier (1988), Kettler *et al.* (1990), McGee (1986), Schibig (1996), and others.

METHODS

In the summer of 1996, 40 permanent circular plots were established. Each plot had a diameter of 16.05 m and an area of 0.02 ha, thus the total area sampled was 0.8 ha. Plots were systematically placed in a linear fashion with a distance of 30.5 m between adjacent plot centers (a few exceptions to this distance were made) and each permanently marked with a white PVC pipe, 2 cm diameter, at the plot center such that 10 cm of pipe projected above ground. A tag with the plot number, names of the samplers, and date was placed in each pipe before capping. In each plot, the identity and diameter of all stems with a dbh (diameter at 1.4 m above ground) of 2.5 cm or greater were recorded. In addition, a smaller circular plot (0.002 ha) was nested at the center of each 0.02 ha plot to obtain data on tree seedlings (dbh <2.5 cm), shrubs, and vines. For all plots with slope, the plot diameter was made horizontal by extending the radius rope in a horizontal plane from the pole at the plot center to the perimeter. Aspect and percent slope were recorded for each of the slope plots. Approximate elevation was ascertained for all plots by reference to topographic maps. Soil types were determined by reference to the Sumner County Soil Survey (U.S.D.A. 1997). Five plots were along the ridge crest north of the creek and five ran along the ridge crest south of the creek. Ten plots were at midslope along the north-facing slope and ten at midslope along the south-facing slope. Ten plots were placed along the creek, six on the south side and four on the north side of the creek.

Upon conclusion of the field work, data were entered on Quattro Pro spreadsheets for computer-assisted analyses. Density, basal area, frequency, and importance value (IV = %density + %basal area + %frequency)/3 were determined for each species with a dbh ≥2.5 cm. For tree seedlings (dbh <2.5 cm), density and frequency data were obtained and then the IV for each species was determined as (%density + %frequency)/2. Only frequency data were obtained for shrubs and vines. Nomenclature follows Wofford and Kral (1993).

RESULTS AND DISCUSSION

Ridge Community. Dominant taxa (Table 1, all tables are appended) in the large tree class were *Acer saccharum, Quercus montana, Liriodendron tulipifera, Fagus grandifolia and Q. velutina. Acer saccharum* had the greatest density and frequency, *Q. montana* had the greatest basal area, and *F. grandifolia* had the greatest average dbh. *Quercus montana* was restricted to the ridge on the north side of the hollow and *A. saccharum* and *L. tulipifera* were more important on the ridge south of the hollow. The south ridge appeared more disturbed than the north ridge as evidenced by the presence of an old wagon road and a young forest on an unsampled section of the ridge. Data for saplings (Table 2) show the absence of *Quercus montana, Q. velutina, Liriodendron tulipifera*, and *Fagus grandifolia.* These species, currently dominant in the large tree class, eventually will be replaced largely by *A. saccharum* (sapling IV = 37.98) and *A. rubrum* (sapling IV = 16.81) if the present trend continues. *Ulmus spp.* (including *U. americana, U. alata,* and *U. rubra)* (sapling IV = 12.79) is the third most important taxon. Eight shrubs and vines were sampled: *Parthenocissus quinquefolia* (in 9 of 10 plots), *Smilax spp. (S. herbacea, S. hispida*, and *S. rotundifolia)* (7), *Rhus radicans* (5), *Vitis spp.* (*V. aestivalis* and *V. vulpina)* (4), *Bignonia capreolata* (3), *Euonymus americana* (3), *Rubus argutus* (2), and *Viburnum acerifolium* (2).

South-Facing Slope Community. Dominant species of the large tree class were *Fagus grandifolia, Acer saccharum, Quercus velutina, Carya glabra*, and *Quercus alba* (Table 3). The composition was most similar to that of the north-facing slope where *F. grandifolia* and *A. saccharum* also were the chief canopy species. The canopy was opened considerably in 1994 when a severe ice storm downed many trees. This feature also was observed, but to a lesser degree, on the other topographic sites. Data for saplings (Table 4) indicate that the most important species were *Acer saccharum, Cornus florida, A. rubrum, Asimina triloba*, and *C. glabra*. Surprisingly, no *Fagus grandifolia* saplings were sampled in this community although it was the most dominant species in the large tree class. The only two oaks in the sapling class, *Quercus montana* and *Q. alba*, had comparatively low importance values. Eleven shrub and vine taxa were sampled: *Rhus radicans* (in 8 of 10 plots), *Parthenocissus quinquefolia* (6), *Smilax spp.* (3), *Bignonia capreolata* (2), *Lindera benzoin* (2), *Rubus argutus* (2), *Staphylea trifolia* (2), *Vitis spp.* (2), *Euonymus americana* (1), *Lonicera japonica* (1), and *Rosa spp.* (1).

North-Facing Slope Community. Dominant trees in the large size class were *Acer saccharum, Fagus grandifolia, Quercus alba, Carya ovata,* and *Liriodendron tulipifera* (Table 5). Also, *Acer saccharum* and *Fagus grandifolia* accounted for 64.5 % of the total IV. Table 6 shows that no oak or hickory saplings were sampled in this forest. *Acer saccharum* (including a small percentage of subspecies *nigrum*) was the most important species in both the large tree class and the sapling class in this community. *Ulmus spp.*, present as saplings, were absent from the large tree group. Only this community had *Fagus grandifolia* as a significant species in the sapling class. *Viburnum rufidulum* was observed but not sampled. Eight shrub and vine taxa were sampled: *Lindera benzoin* (in 4 of 10 plots), *Staphylea trifolia* (4), *Parthenocissus quinquefolia* (3), *Hydrangea arborescens* (2), *Bignonia capreolata* (1), *Euonymus americana* (1), *Rhus radicans* (1), and *Smilax spp.* (1).

Ravine Community. Dominant taxa were *Acer saccharum, Juglans nigra, Ulmus spp., Carya cordiformis,* and *Carpinus caroliniana* (Table 7). Although *Acer saccharum* was the most important species of the large tree category, it exhibited higher importance values on other topographic areas. Here I observed a large dead specimen of *Gymnocladus dioicus*, a rare species also reported by Kral (1979). Among the saplings of the ravine forest, *Acer saccharum* was most important, followed by *Ulmus spp., Carpinus caroliniana, Aesculus flava,* and *Tilia americana* (Table 8). The absence of *Juglans nigra* in the sapling category indicates that its dominance in the large tree class will be temporary if the area continues to be undisturbed. The greatest diversity of sampled shrubs and vines was in the ravine forest with 12 taxa: *Lindera benzoin* (7 of 10 plots), *Parthenocissus quinquefolia* (5), *Sambucus canadensis* (5), *Symphoriocarpus orbiculatus* (4), *Arundinaria gigantea* (3), *Euonymus atropurpureus* (3), *Hydrangea arborescens* (3), *Staphylea trifolia* (2), *Vitis spp.* (2), *Rhus radicans* (1), *Smilax spp.* (1), and *Viburnum acerifolium* (1).

Combined Data. The most important taxa overall (average IV's from all four communities) were *Acer saccharum* (21.3), *Fagus grandifolia* (15.8), *Quercus velutina* (6.2), *Liriodendron tulipifera* (5.9), *Carya glabra* (4.7), *Q. alba* (4.5), *Q. montana* (3.8), *A. rubrum* (3.6), *Juglans nigra* (3.4), and *Ulmus spp.* (3.2). Data for saplings (Tables 2, 4, 6, and 8) and tree seedlings (Table 9) indicate that *Acer saccharum* will become even more important at Taylor Hollow if present trends continue. The six most important seedling taxa in descending order of IV were *Acer spp.* (mostly *A. saccharum* with some *A. rubrum* and *A. negundo*), *Ulmus spp.* (*U. americana, U. rubra*, and *U. alata*), *Carya spp.* (*C. cordiformis, C. glabra, C. ovalis,* and *C. ovata*), *Quercus spp.* (*Q. alba, Q. montana, Q. muehlenbergii, Q. rubra,* and *Q. velutina*), and *Fraxinus spp.* (*F. americana* and *F. quadrangulata*), and *Cornus florida.*

Richness. In the large tree class, richness was greatest in the ravine (19 sampled taxa) and lowest on the north facing slope (13). Diversity for saplings was greatest on the south facing slope

(22 sampled taxa) and least on the north facing slope (12).

CONCLUSIONS

The Taylor Hollow Nature Preserve hosts a high diversity of plant species, some quite rare for the area. The diversity of tree species may be threatened by a growing dominance of *Acer saccharum* on all topographic sites. This study and others in Tennessee (McGee, 1986; Kettler *et al*, 1990; Eickmeier 1988; Schibig 1996) indicate that the growing importance of *A. saccharum* in protected forests is a general trend for this region. It appears that, in the protected upland forests of Tennessee, *A. saccharum* is a strong competitor against other tree species. This could be due to its shade tolerance, prolific production of wind-dispersed samaras, adaptability to various soil conditions, and its longevity. It does not succeed in the driest soils (Chester *et al.* 1998) nor in overly wet soils. Schibig (1996) found *A. saccharum* to be a dominant in all communities at Radnor Lake Natural Area, Davidson County, Tennessee, except on the wet soils of the lakeshore where *A. saccharinum* was the chief species.

The growing importance of *Acer saccharum* in protected forests seems to be a widespread phenomenon. The long-term studies of protected old growth forests by Abrell and Jackson (1977) in Indiana, Boggess and Bailey (1964) in Illinois, Parker and Leopold (1983) in Indiana, and Weaver and Ashby (1971) in Illinois, all show an increase in the dominance of *A. saccharum.* Abrahms (1992) maintains that periodic disturbance by fire permits oaks to be dominant in many upland forests of eastern North America, while Lorimer (1985) states that periodic fire should check succession in oak forests, because most later successional species such as *A. rubrum* and *A. saccharum* exhibit low resistance to fire.

ACKNOWLEGEMENTS

I extend my gratitude to Rick Schibig and Cathy Feldman for their assistance in the sampling. This project was made possible by a grant from Austin Peay State University's Center for Field Biology. I also thank officials of the Nature Conservancy for permitting me to conduct research at the Taylor Hollow Preserve.

LITERATURE CITED

Abrams, M. D. 1992. Fire and the development of oak forests. BioScience 42:346-353.

Abrell, D. B., and M. T. Jackson. 1977. A decade of change in an old-growth beech-maple forest in Indiana. Amer. Midl. Nat. 98:22-32.

Alcorn, J. 1976. The vascular flora of Sumner County, Tennessee. M.A. Thesis. Vanderbilt University. Nashville, Tennessee.

Boggess, W. R., and W. Bailey. 1964. Brownfield Woods, Illinois: woody vegetation and changes since 1925. Amer. Midl. Nat. 71:392-401.

Braun, E. L. 1950. Deciduous forests of eastern North America. Hafner Publishing Company, New York.

Chester, E. W., C. E. Harris, S. Gonzalez, and K. Denley. 1998. Characterization of the woody strata in the xeric-site chestnut oak forest community, Northwestern Highland Rim, Kentucky and Tennessee. Trans. Kentucky Acad. Sci. 59:178-184.

DeSelm, H. R., and P. A. Schmalzer. 1982. Taylor Hollow, a potential National Natural Landmark. Report provided to the Tennessee Chapter, The Nature Conservancy, Nashville, Tennessee.

Eickmeier, W. G. 1988. Ten years of forest dynamics at Radnor Lake, Tennessee. Bull. Torrey Bot. Club 115:100-107.

Kettler, S., J. Fralish, and F. Crooks. 1990. Forest succession patterns at Land Between The Lakes, Kentucky and Tennessee. Pp. 105 *in*: S. W. Hamilton and M. T. Finley (eds.). Proceedings of the third annual symposium on the natural history of lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Kral, R. 1979. Taylor Hollow master plan and inventory. Report provided to the Tennessee Chapter, The Nature Conservancy, Nashville, Tennessee.

Lorimer, C. G. 1985. The role of fire in the pertetuation of oak forests. Pp. 8-25 *in*: J. E. Johnson (ed.). Challenges in oak managemented and utilization. Cooperative Extension Service, Univ. of Wisconsin, Madison, Wisconsin.

McGee, C. E. 1986. Loss of *Quercus* spp. dominance in an undisturbed old-growth forest. J. Elisha Mitchell Sci. Soc. 102:10-15.

Parker, G. W. and D. J. Leopold. 1983. Replacement of *Ulmus americana* L. in a mature east-central Indiana woods. Bull. Torrey Bot. Club 110:482-488.

Schibig, J. 1996. Twenty years of forest change at Radnor Lake Natural Area, Davidson County, Middle Tennessee. J. Tennessee Acad. Sci. 71:57-72.

Schibig, J., and J. Burkitt. 1979. The vertebrate fauna of Taylor Hollow, Sumner County, Tennessee. Report provided to the Tennessee Chapter, The Nature Conservancy, Nashville, Tennessee.

United States Department of Agriculture. 1997. Soil survey of Sumner County, Tennessee. U. S. Government Printing Office, Washington, D.C.

Weaver, G. T., and W. C. Ashby. 1971. Composition and structure of an old growth forest remnant in unglaciated southwestern Illinois. Amer. Midl. Nat. 86:46-56.

Wofford, B. E., and R. Kral. 1993. Checklist of the vascular plants of Tennessee. Sida, Bot. Miscellany 10:1-66.

APPENDIX: TABLES 1 - 9

Table 1. Average dbh, density, basal area, occurrence (of 10 plots, 0.02 ha each), and importance value (IV) of large trees (dbh ≥10.2 cm) in the ridge forest at the Taylor Hollow Preserve in 1996.

Taxon	Average dbh cm	Density (number/ha)	Basal area (m^2/ha)	Occurrence	IV (100)
Acer saccharum	30.8	50	4.038	4	17.6
Quercus montana	41.0	35	4.815	3	15.2
Liriodendron tulipifera	51.3	20	4.106	3	12.0
Fagus grandifolia	62.3	15	4.666	2	10.8
Quercus velutina	46.9	15	2.888	3	9.7
Acer rubrum	20.8	30	1.260	2	8.6
Caya glabra	26.7	20	1.160	2	6.9
Cornus florida	15.4	10	0.183	2	4.2
Carya ovata	53.3	5	1.096	1	3.4
Quercus alba	48.2	5	0.895	1	3.1
Carya tomentosa	29.5	5	0.335	1	2.4
Oxydendrum arboreum	13.6	5	0.071	1	2.1
Carya ovalis	12.8	5	0.063	1	2.1
Nyssa sylvatica	10.3	5	0.041	1	2.0
Totals	34.6	225	25.619	27	100.0

Table 2: Average dbh, density, basal area, occurrence (of 10 plots, 0.02 ha each), and importance value (IV) of saplings (dbh 2.5 -10.2 cm) in the ridge forest at Taylor Hollow in 1996.

Taxon	Average dbh cm	Density (number/ha)	Basal area (m^2/ha)	Occurrence	IV (100)
Acer saccharum	4.4	470	0.727	10	38.0
Acer rubrum	5.6	130	0.387	6	16.8
Ulmus spp.	3.3	190	0.170	4	12.8
Cornus florida	3.8	90	0.108	7	10.6
Cercis canadensis	3.8	65	0.086	5	7.8
Nyssa sylvatica	5.4	20	0.054	3	4.1
Celtis occidentalis	4.9	20	0.037	2	3.0
Carya glabra	6.2	15	0.043	2	2.9
Fraxinus americana	4.1	5	0.006	1	1.1
Ailanthus altissima	3.8	5	0.006	1	1.1
Morus rubra	3.1	5	0.004	1	1.0
Oxydendrum arboreum	2.8	5	0.003	1	1.0
Totals	4.4	1020	1.631	43	100.0

Table 3. Average dbh, density, basal area, occurrence (of 10 plots, 0.02 ha each), and importance value (IV) of large trees (dbh > 10.2 cm) in the south-facing slope forest at Taylor Hollow in 1996.

Taxon	Average dbh cm	Density (number/ha)	Basal area (m^2/ha)	Occurrence	IV (100)
Fagus grandifolia	41.1	45	7.725	4	18.9
Acer saccharum	16.5	90	2.081	6	18.6
Quercus velutina	47.8	30	5.362	5	15.2
Carya glabra	18.7	45	1.468	2	8.9
Quercus alba	32.8	20	1.929	4	8.6
Liriodendron tulipifera	55.8	10	2.468	2	6.3
Carya ovalis	36.9	15	1.698	2	5.8
Acer rubrum	22.9	10	0.515	2	3.7
Quercus rubra	66.4	5	1.700	1	3.7
Carya cordiformis	23.1	5	0.205	1	1.8
Nyssa sylvatica	22.1	5	0.187	1	1.8
Carya ovata	20.5	5	0.162	1	1.8
Aesculus flava	16.2	5	0.101	1	1.7
Oxydendrum arboreum.	13.8	5	0.074	1	1.6
Magnolia acuminata	29.8	5	0.056	1	1.6
Totals	31.0	300	25.732	34	100.0

Table 4. Average dbh, density, basal area, occurrence (of 10 plots, 0.02 ha each), and importance value (IV) of saplings (dbh 2.5 - 10.2 cm) in the south-facing slope forest at Taylor Hollow in 1996.

Taxon	Average dbh cm	Density (number/ha)	Basal area (m^2/ha)	Occurrence	IV (100)
Acer saccharum	4.4	395	0.701	8	37.88
Cornus florida	3.8	115	0.158	8	14.04
Acer rubrum	5.6	60	0.109	4	7.78
Asimia triloba	2.8	35	0.038	3	4.44
Carya glabra	7.4	25	0.113	1	4.28
Carpinus caroliniana	3.3	20	0.019	3	3.38
Nyssa sylvatica	5.4	15	0.035	2	2.82
Amelanchier arboreum	5.9	15	0.046	1	2.36
Quercus montana	6.4	10	0.031	2	2.52
Cercis canadensins	4.4	20	0.030	1	2.22
Ulmus spp.	4.4	10	0.014	2	2.15
Fraxinus americana	4.1	10	0.013	2	2.13
Carya ovata	6.9	10	0.042	1	2.07
Quercus alba	6.4	10	0.035	1	1.91
Magnolia acuminata	8.7	5	0.029	1	1.57
Fraxinus quadrangulata	8.5	5	0.028	1	1.53
Aesculus octandra	7.7	5	0.023	1	1.43
Sassafras albidum	6.7	5	0.017	1	1.3
Carya ovalis	7.4	5	0.008	1	1.1
Hammalelis virginiana	4.6	5	0.008	1	1.1
Ostrya virginiana	3.3	5	0.004	1	1.0
Celtis occidentalis	2.8	5	0.003	1	1.0
Totals	5.5	790	1.503	47	100.0

Table 5. Average dbh, density, basal area, occurrence (of 10 plots, 0.02 ha each), and importance value (IV) of large trees (dbh $\geq$ 10.2 cm) in the north-facing slope forest at Taylor Hollow in 1996.

Taxon	Average dbh cm	Density (number/ha)	Basal area (m^2/ha)	Occurrence	IV (100)
Acer saccharum	27.2	145	10.552	10	34.3
Fagus grandifolia	48.2	75	17.490	8	30.2
Quercus alba	70.3	10	3.821	2	6.2
Carya ovata	47.4	15	2.690	2	5.8
Liriodendron tulipifera	58.5	10	2.633	2	5.2
Fraxinus quadrangulata	34.1	15	1.366	1	3.7
Carya glabra	35.1	10	0.964	1	2.9
Sassafras albidum	49.2	5	0.934	1	2.3
Acer rubrum	39.0	5	0.585	1	2.0
Fraxinus americana	33.6	5	0.435	1	1.9
Tilia americana	31.8	5	0.390	1	1.9
Magnolia acuminata	29.5	5	0.335	1	1.8
Aesculus flava	10.8	5	0.045	1	1.6
Totals	39.6	310	42.240	32	100.0

Table 6. Average dbh, density, basal area, occurrence (of 10 plots, 0.02 ha each), and importance of saplings (dbh 2.5 -10.2 cm) in the north-facing slope forest at Taylor Hollow in 1996.

Taxon	Average dbh cm	Density (number/ha)	Basal area (m^2/ha)	Occurrence	IV (100)
Acer saccharum	4.2	425	0.724	9	54.3
Aesculus flava	4.1	45	0.069	5	9.4
Ulmus spp.	3.1	75	0.052	4	9.4
Fagus grandifolia	5.9	25	0.072	4	7.6
Asimina triloba	2.9	40	0.027	3	5.8
Cornus florida	2.6	30	0.015	3	4.9
Acer rubrum	4.4	10	0.014	2	2.9
Magnolia acuminata	2.6	10	0.005	1	1.7
Carpinus caroliniana	3.1	5	0.004	1	1.4
Ostrya virginiana	2.8	5	0.003	1	1.3
Tilia americana	2.6	5	0.003	1	1.3
Totals	3.5	675	0.987	34	100.0

Table 7. Average dbh, density, basal area, occurrence (of 10 plots, 0.02 ha each), and importance value (IV) of large trees (dbh $\geq$ 10.2 cm) in the ravine forest at Taylor Hollow in 1996.

Taxon	Average dbh cm	Density (number/ha)	Basal area (m^2 /ha)	Occurrence	IV (100)
Acer saccharum	14.4	110	1.978	7	14.6
Juglans nigra	25.1	65	3.360	6	13.4
Ulmus spp.	22.6	70	3.225	5	12.9
Carya cordiformis	24.4	50	2.505	5	10.4
Carpinus caroliniana	12.8	65	0.831	7	9.8
Acer negundo	15.9	30	0.591	3	4.7
Carya laciniosa	27.4	20	1.334	2	4.7
Tilia americana	20.5	20	0.748	3	4.4
Aesculus flava	14.6	20	0.353	4	4.3
Fagus grandifolia	62.3	5	1.496	1	3.4
Fraxinus quadrangulata	33.8	10	0.926	2	3.4
Fraxinus americana	47.4	5	0.867	1	2.4
Quercus rubra	28.2	10	0.625	1	2.3
Magnolia acuminata	15.1	10	0.174	2	2.1
Cercis canadensis	11.8	10	0.109	2	2.0
Prunus serotina	37.2	5	0.533	1	1.8
Morus rubra	18.2	5	0.127	1	1.1
Celtis occidentalis	17.4	5	0.117	1	1.1
Quercus muehlenbergii	13.3	5	0.069	1	1.0
Totals	24.3	520	19.968	55	100.0

Table 8. Average dbh, density, basal area, occurrence (of 10 plots, 0.02 ha each), and importance value of saplings (dbh 2.5 -10.2 cm) in the ravine forest at Taylor Hollow in 1996.

Taxon	Average dbh cm	Density (number/ha)	Basal area (m^2 /ha)	Occurrence	IV (100)
Acer saccharum	5.4	185	0.470	9	32.9
Ulmus spp.	5.6	105	0.290	4	18.3
Carpinus caroliniana	5.6	65	0.173	6	14.3
Aesculus flava	6.2	40	0.145	4	10.1
Tilia americana	7.2	25	0.111	4	8.2
Asimina triloba	3.3	30	0.028	4	6.4
Carya cordiformis	8.2	5	0.026	1	1.9
Acer negundo	3.6	10	0.009	1	1.8
Celtis occidentalis	6.7	5	0.017	1	1.7
Ostrya virginiana	3.1	5	0.014	1	1.6
Carya laciniosa	5.6	5	0.012	1	1.6
Cercis canadensis	2.6	5	0.003	1	1.3
Totals	5.3	485	1.297	37	100.0

Table 9. Overall density, occurrence (of 40 plots, 0.002 ha each) and IV of tree seedlings (dbh < 2.5 cm) at Taylor Hollow in 1996.

Taxon	Density (number/ha)	Occurrence	IV (100)
Acer spp.	3538	36	22.8
Ulmus spp.	2613	33	18.2
Carya spp.	650	24	7.8
Quercus spp.	875	17	7.3
Fraxinus spp.	550	21	6.8
Cornus florida	675	18	6.7
Asimina triloba	688	12	5.5
Liriodendron tulipifera	450	13	4.7
Sassafras albidum	413	6	3.0
Fagus grandifolia	163	8	2.4
Celtis occidentalis	100	8	2.1
Cercis canadensis	125	6	1.8
Nyssa sylvatica	125	6	1.8
Diospyros virginiana	113	6	1.7
Morus rubra	88	6	1.6
Magnolia acuminata	75	4	1.2
Aesculus flava	50	3	0.8
Prunus serotina	50	3	0.8
Ostrya virginiana	63	2	0.7
Ailanthus altissima	25	2	0.5
Crataegus sp.	13	1	0.3
Robinia pseudoacacia	25	1	0.3
Aralia spinosa	13	1	0.3
Rhamnus caroliniana	13	1	0.3
Hammamelis virginiana	13	1	0.3
Carpinus caroliniana	25	1	0.3
Totals	11525.0	240	100.0

CHARACTERIZATION OF TWO RIPARIAN FORESTS OF HAYNES BOTTOM, MONTGOMERY COUNTY, TENNESSEE

S. JOY STEPHENS AND EDWARD W. CHESTER

The Center for Field Biology, Austin Peay State University
Clarksville, TN 37044

ABSTRACT. **Haynes Bottom, a 393-ha (971-ac) tract adjacent to and on the north side of the Cumberland River in southwestern Montgomery County, Tennessee, was purchased in 1996 by the Tennessee Wildlife Resources Agency for eventual development into a wildlife management area. From European settlement to 1996, the land was privately owned and used primarily for agriculture, including row-crops and livestock. The site now supports a variety of habitat types, including the Cumberland River and an adjacent narrow strip of riparian forest, broad alluvial bottom lands with fencerows, drainage ditches and an apparent abandoned river meander channel (slough) with associated marshes and meadows, a first-order stream (Hog Creek) with adjacent riparian forest, upland successional fields, fencerows, forests, old homesites, and several man-made ponds. This study characterizes the two major riparian forests of the property. The Hog Creek riparian forest comprises about 6 ha and lies adjacent to and west of southerly-flowing Hog Creek. It is bordered on the west by upland successional fields and forests. Plot sampling and designation of dominance, following U.S. Army Corps of Engineers methods, showed that the canopy (dbh ≥3 in) consists of 11 species, dominated (based on basal area) by *Platanus occidentalis*, *Acer negundo*, and *Ulmus rubra*. The sapling/shrub layer (dbh <3 in, height >3.2 ft) includes seven species, dominated (based on total height) by *Ulmus rubra, Cephalanthus occidentalis, Acer negundo*, and *Lindera benzoin*. Two woody vines, *Parthenocissus quinquefolia* and *Toxicodendron radicans*, are found. Dominant herbs (based on estimated percent cover) are *Microstegium vimineum*, *Aster simplex*, *Impatiens capensis*, and *Boehmeria cyclindrica*. The Cumberland River riparian forest occurs as a narrow strip (5-30 m wide) paralleling and separating the river from cultivated bottom lands. Trees and shrubs ≥2.5 cm were sampled by the Quarter Method. Canopy (dhb ≥10.0 cm) dominants (of 17 species) are *Acer saccharinum, Celtis laevigata*, and *Acer negundo*. Sapling/shrub (dbh 2.5-9.9 cm, 20 species) dominants are *Acer negundo, A. saccharinum, Celtis laevigata*, and *Ulmus rubra*. *Arundinaria gigantea* is abundant, often forming dense stands. *Aristolochia tomentosa* and *Smilax rotundifolia* are the most commonly-observed woody vines. Floristic inventories for all sites are underway.**

INTRODUCTION

Bottom land hardwood forests are one of the most extensive class of wetlands in the United States. Covering approximately 4.9 million ha in 1991, over 16 million ha have been lost to agricultural uses and other anthropogenic causes since European settlement. Bottom land hardwood forests are predominately found in the southeastern United States. Also known as riparian forests, they occupy transitional areas between streams and rivers and adjacent uplands. Generally, these wetlands are low-lying, flat, extensive flood plains with well-developed soils and with strong seasonal hydrologic pulses, resulting in extremely variable hydrology (Mitsch and Gosselink 1993). Hydroperiods range from infrequently flooded to year-round inundation. This variable moisture regime, accompanied by topographical gradients, determines the vegetative composition of the wetlands. Plant communities are typically diverse and are physiologically and morphologically adapted to anaerobic conditions (Brinson *et al.* 1995).

There are several accounts dealing with the flora and vegetation of northwestern middle Tennessee (see Chester and Ellis 1989). Also, there have been several studies of lowland communities, especially bottom land and stream-bank forests of the lower Cumberland River, even though the U.S. Army Corps of Engineers have, with high dams, inundated many wetlands, or they have been drained for agriculture (Chester and Dodson 1996). Areas studied include the Cross Creeks National Wildlife Refuge in Stewart County, TN (Chester and Schibig 1993; Joyner and Chester 1994), the Long Pond Slough Wetland Acquisition in Montgomery County, TN (Chester and Dodson 1996, 1997), and the St. Stevens Forest in Lyon County, KY (Chester and Schibig 1997). In addition, Bingham and Roberts (1994) characterized selected palustrine wetlands types in Tennessee, including forested wetlands.

This paper characterizes the two major riparian forests of Haynes Bottom, a Tennessee Wildlife Resources Agency (TWRA) Wetland Acquisition in Montgomery County, Tennessee. The data will add to existing accounts of bottom land flora and vegetation in the lower Cumberland River Basin. In addition, the data may be used by TWRA in wetland enhancement and to employ best management practices in developing Haynes Bottom into a wildlife management area. The data also will be important in future biomonitoring projects.

The Study Area

Haynes Bottom is a 393-ha (971-acre) in southwestern Montgomery County, Tennessee (Fig. 1). It is within the Western Highland Rim Subsection, Highland Rim Section, Interior Low Plateau Physiographic Province (Fenneman 1938). This Subsection is a highly dissected plateau bordered on the east by the Central Basin and on the west by the Tennessee River. The Southern Highland Rim Subsection is to the south and the Pennyroyal Plain Subsection to the north. The property is within the Deciduous Forest Formation, Western Mesophytic Forest Region of Braun (1950), where the vegetation is a mosaic of types determined by local climatic, edaphic, and topographic features. Typically, it is transitional between the more mesic Mixed Mesophytic Region to the east and the more xeric Oak-Hickory Region to the west.

Haynes Bottom was purchased in 1996 by the TWRA as part of a program to acquire wetlands across the state. TWRA plans to convert the area into a wildlife management area, especially for migratory waterfowl, by enhancing and expanding existing wetlands, constructing new ones, wildlife food plantings, and other habitat construction-manipulation, including varying water-levels in wetlands.

From European settlement until TWRA purchase, the site mostly was agricultural (row-crops, pastures, homesteads). Areas too wet, too steep, or otherwise unsuitable for crops-pastures remain in forests that have been high-graded on numerous occasions. The site now supports a variety of habitat types, including the Cumberland River and an adjacent narrow strip of riparian forest, broad alluvial bottom lands with drainage ditches, old fencerows, and an apparent abandoned river meander channel (slough) with associated marshes and meadows, a first-order stream (Hog Creek) with adjacent riparian forest, upland successional fields and forests, old homesites (one now occupied), and several man-made ponds. This study characterizes the two major riparian forests of the property.

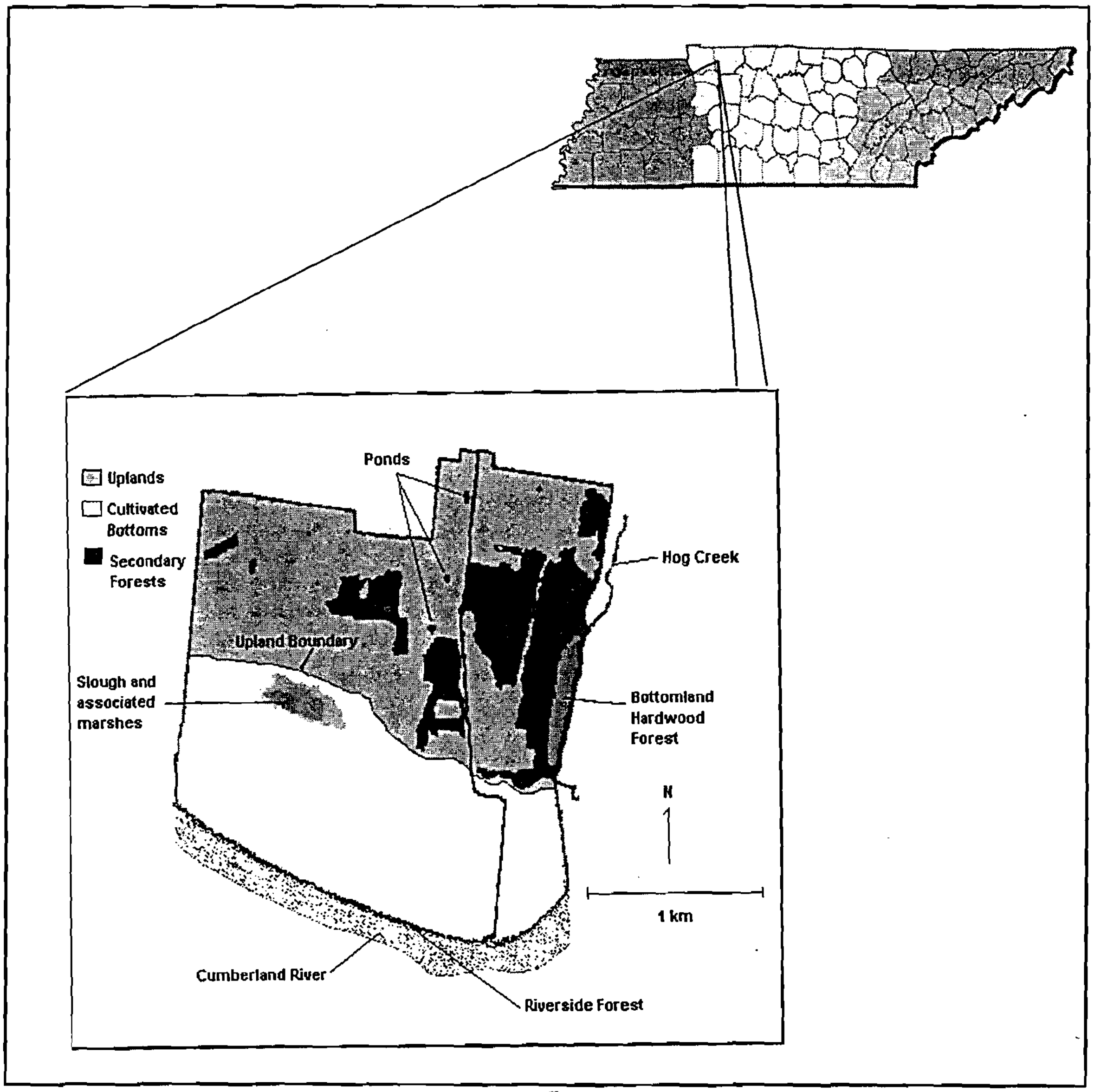


Figure 1. Location and major topographic features of Haynes Bottom, Montgomery County, Tennessee.

Hog Creek Riparian Forest

Hog Creek Forest, the larger of the riparian forests, is a 6-ha bottom land hardwood forest adjacent to and west of southerly-flowing Hog Creek (Fig. 1). Upland secondary forests and successional fields adjoin Hog Creek Forest on the west and north and cultivated bottom lands are to the south. Soils are Newark Silt Loams, somewhat poorly drained soils on flood plains and in small depressions on uplands. Most areas of this type range from 3-25 ac with 0-2% slope (U.S. Dept. Agric. 1975). This forest occurs at an average elevation of 370 ft (normal summer pool of the Cumberland River is 356 ft) (U.S. Geol. Survey, Palmyra Quadrangle, 1958, photorevised 1983). The area is flooded at depths varying from a few cm to >1-m whenever Hog Creek overflows, normally several times a year and usually in winter and spring. In addition, numerous seeps and springs on the west side at the base of the adjacent slopes result in saturated soils and some standing water, even in dry seasons.

Cumberland River Riparian Forest

A second riparian forest stretches 2.1 km (about 7000 ft or 1.33 miles) along the Cumberland River (Fig. 1) and is about 30 m at its widest point. This forest separates the river from cultivated fields, presently in corn, soybeans and wheat. Included in this community type is an eroded area of about 1-ha near the western edge of the site. Most soils of this forest are Arrington silt loam (nearly level deep soils of flood plains, <2% slope) with some Staser fine silt loam (<2% slope) on the eastern end of the area (U.S. Dept. Agric. 1975). The elevation is 360 ft above sea level, or only slightly above the normal summer pool (356 ft) of the Cumberland River (U.S. Geol. Survey, Palmyra Quadrangle, 1958, photorevised 1983). Temporary flooding of several m due to river overflow is common, especially in winter and early spring. This remnant bottom land hardwood forest is a prime example of a general reduction of wetland habitats in southeastern United States due to agricultural practices.

METHODS

Hog Creek Riparian Forest

The Corps of Engineers Wetlands Delineation Manual (U.S. Army Environmental Laboratory 1987) was used, with slight modifications, for sampling techniques and for designations of dominance. Following this Manual, results are reported in the English system. Maps of the area (U.S. Dept. Agriculture 1975; the U.S. Geol. Survey, Palmyra Quadrangle, 1958, photorevised 1983; our aerial photographs) were used to determine the size of the study area and to establish a baseline from which transects and observation points were established.

During July and August 1998, five transects approximately 200 ft apart and extending from the creek westward to the paralleled slope, were established perpendicular to Hog Creek. At each of 10 observation points systematically predetermined along the five transects, nested circular quadrats were temporarily established. Within a diameter of 60 ft, all trees with dbh ≥3 in were recorded. Within a nested diameter of 20 ft, the height of all saplings was taken (saplings are defined as woody species with a height ≥3.2 ft but with a dbh <3.0 in, exclusive of woody vines). Woody vines >3.2 ft in height were tallied by species and numbers in a nested plot of 20 ft diameter. Finally, all herbs (all nonwoody and woody species <3.2 ft in height within or with foliage extending into the plot) were tallied and percentage cover estimated within a nested plot of 3.3 ft diameter. Data were combined for all observation points and used to determine dominant species. The total basal area of each tree species was used to establish dominance. For saplings, dominance was based on total height from all plots for each species. The percent cover for herbaceous species at each observation point was summed to determine dominant herbs. Woody vine dominance was based on the total number of stems.

Cumberland River Riparian Forest

The Cumberland River Forest was sampled by the Quarter Method described by Cottam and Curtis (1956) as an adaptation of the procedure used by Federal land surveyors when they made the original land surveys of the United States. During September 1998, a transect through the forest, roughly paralleling the river, was established at approximately midpoint between the river and cropland. At distances of approximately 30 m, a point was selected and the nearest four trees with dbh ≥ 10 cm recorded by species and dbh. Four additional stems, each 2.54-9.9 cm, were likewise recorded by species and dbh. A total of 72 points was taken. Analyses for each species within the two size groupings included mean dbh and basal area, relative frequency (number of occurrences of one species as a % of the total number of occurrences of all species); relative density (number of individuals of one species as a % of the total number of individuals of all species); relative dominance (total basal area of one species as a % of the total basal area of all species). The relative values were summed to provide an importance value (maximum 300), which was converted to %IV (IV/3).

RESULTS AND DISCUSSION

Hog Creek Riparian Forest

The canopy (dbh ≥3 in), based on 199 stems sampled, consists of 11 species. Dominants are *Platanus occidentalis* (23.6% of density, 47.1% of BA), *Acer negundo* (19.1% of density, 12.2% of BA), and *Ulmus rubra* (24.1% of density, 10.8% of BA). These three taxa made up 66.8% of stems and >70% of basal area. A summary of composition and structure of the canopy is given in Table 1. Species observed but not sampled include *Juglans nigra* and *Quercus palustris*.

The sapling/shrub layer consists of seven species. Dominants are *Ulmus rubra* (72 ft total height), *Cephalanthus occidentalis* (48.8), *Acer negundo* (48), and *Lindera benzoin* (34). Other understory species are *Celtis laevigata* (26), *Fraxinus pennsylvanica* (20), and *Ilex decidua* (4). Two woody vines, *Parthenocissus quinquefolia* (63 stems sampled) and *Toxicodendron radicans* (31 stems sampled) were found.

Nineteen herbaceous species were plot-sampled. Dominants are (sum of estimated percent coverage from all plots given): *Microstegium vimineum* (305), *Aster simplex* (92.5), *Impatiens capensis* (67.5), and *Boehmeria cylindrica* (50). Only four of ten observation points are dominated by *M. vimineum*; however, dominance is great at those points (Fig. 2). No other studies of lowlands in the area (see introduction for citations) found *M. vimineum* as a dominant herb. It is possible that this invasive, shade-tolerant grass is only now migrating into regional forested areas such as Haynes Bottom. Floristic data on herbaceous species are not yet available.

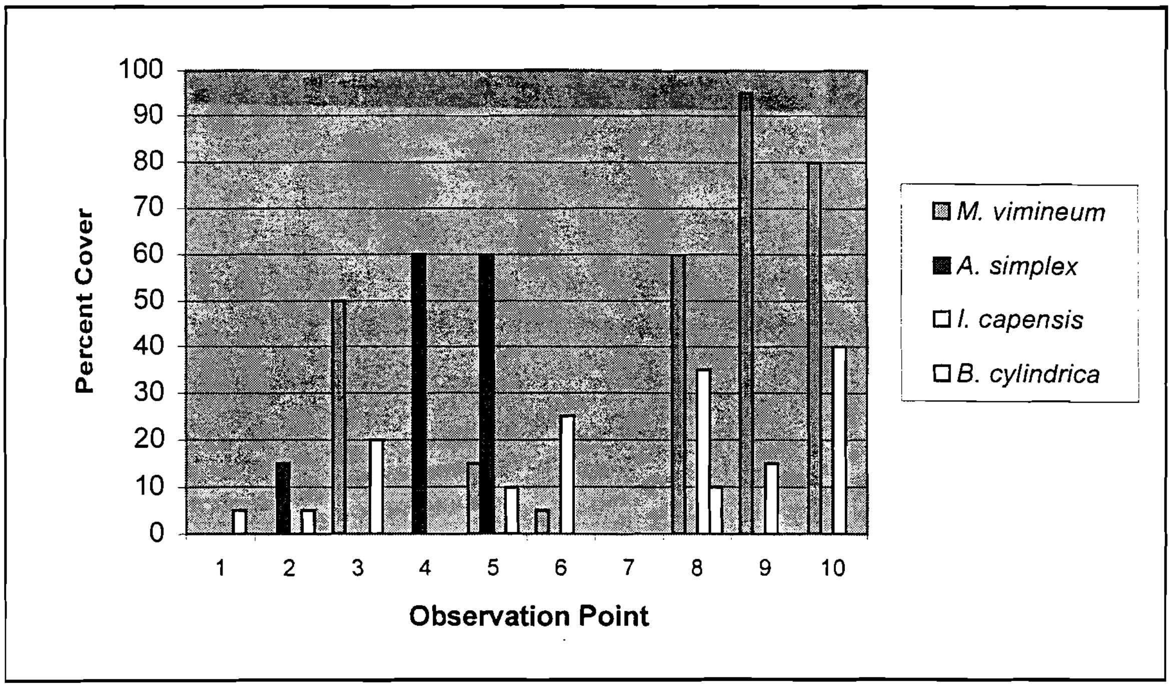


Figure 2. A comparison of the percent cover of the four dominant species of herbs at each observation point within Hog Creek Forest of Haynes Bottom, Montgomery County, Tennessee (July-August 1998).

Cumberland River Riparian Forest

Based on 288 stems sampled at 72 points, the canopy (dbh ≥10 cm) consists of 17 species dominated by *Acer saccharinum* (26.7% of density, 34.2% of BA), *Celtis laevigata* (17.0% density, 15.1% BA), and *Acer negundo* (20.1% density, 12.7% BA). These three species constitute nearly 64% of density, 62% of basal area, and 60.5% of IV (Table 2). Other species contributing significantly to canopy IV include *Ulmus rubra* (8.95% of IV), *Fraxinus pennsylvanica* (5.78%), and *Platanus occidentalis* (5.24%). Species observed but not sampled include *Crataegus viridis, Morus alba, Staphylea trifolia*, and *Tilia heterophylla*.

Table 1. Composition and structure of the canopy layer (dbh ≥3 in) in the Hog Creek riparian forest, Haynes Bottom, Montgomery County, Tennessee, based on 199 sampled stems, July-August 1998.

Taxa	No. Stems	% of Stems	No. Plots	Average dbh (in)	Total BA (ft²)	% BA
Platanus occidentalis	47	23.62	6	12.8	46.95	47.07
Acer negundo	38	19.10	9	7.0	12.18	12.21
Ulmus rubra	48	24.12	9	5.6	10.80	10.82
Acer saccharinum	16	8.04	2	9.1	8.65	8.67
Fraxinus pennsylvanica	18	9.05	9	8.2	7.87	7.89
Salix nigra	4	2.01	3	14.1	4.41	4.42
Gleditsia triacanthos	7	3.52	4	9.0	3.78	3.79
Celtis laevigata	18	9.05	4	4.9	2.50	2.51
Populus deltoides	1	0.50	1	20.2	2.23	2.24
Liquidambar styraciflua	1	0.50	1	5.9	0.19	0.19
Ilex decidua	1	0.50	1	5.9	0.19	0.19
Totals	199	100.01	-	9.34	99.75	100.00

Based on 288 stems sampled at 72 points, the saplings/small tree layer (dbh 2.5-9.9 cm) consists of 20 species dominated by *Acer negundo* (28.5% density, 33.2% BA), *Acer saccharinum* (21.5% density, 22.8% BA), and *Celtis laevigata* (20.5% density, 20.3% BA). These three species comprise 70.5% of density, >76% of basal area, and 69.6% of IV (Table 3). *Ulmus rubra* (8.9% of IV) is the only other species of significance. Species observed but not sampled include *Arundinaria gigantea* (often forming dense cane-brakes), *Hypericum frondosum*, and *Lindera benzoin.*

Woody vines were not sampled but a floristic list yielded 13 species, including: *Ampelopsis cordata, Aristolochia tomentosa, Bignonia capreolata, Calycocarpum lyoni, Clematis virginiana, Cocculus carolinus, Menispermum canadense, Parthenocissus quinquefolia, Smilax bona-nox, S. hispida, S. rotundifolia, Toxicodendron radicans,* and *Vitis vulpina.* Of these species *Aristolochia tomentosa* and *Smilax rotundifolia* were most often observed. Floristic data on the herbaceous species are not yet available.

Several differences are evident between the Hog Creek and Cumberland River forests. The mean dbh for canopy species of the Cumberland River forest is 28.0 cm, several cm greater than the 23.7 cm of canopy species in Hog Creek. Also, species diversity is much greater in the Cumberland River forest, perhaps due to a larger source of incoming propagules. Further, at least parts of the Hog Creek forest has standing water through much of the growing season. Fewer tree species can tolerate these inundated conditions as compared to the periodically flooded (normally not exceeding a few days and then drying) Cumberland River Forest.

Table 2. Species composition and structure of the canopy layer (dbh ≥10 cm) in the Cumberland River riparian forest, Haynes Bottom, Montgomery County, Tennessee; data based on 288 stems measured at 72 points, September 1998.

Taxa	No. Stems	% of Stems	Average dbh (cm)	No. of Points	Rel. Freq.	BA in M^2	% of BA	% of IV
Acer saccharinum	77	26.74	32.28	45	24.32	8.024	34.20	28.42
Celtis laevigata	49	17.01	26.69	31	16.76	3.551	15.14	16.30
Acer negundo	58	20.14	23.19	27	14.59	2.971	12.66	15.80
Ulmus rubra	28	9.72	22.50	21	11.35	1.357	5.78	8.95
Fraxinus pennsylvanica	12	4.17	29.57	10	5.41	1.823	7.77	5.78
Platanus occidentalis	11	3.82	41.31	9	4.86	1.621	6.91	5.24
Populus deltoides	11	3.82	28.93	5	2.70	0.797	3.40	3.31
Carya cordiformis	8	2.78	31.66	6	3.24	0.781	3.33	3.12
Quercus shumardii	7	2.43	26.23	7	3.78	0.538	2.29	2.83
Gleditsia triacanthos	8	2.78	25.02	6	3.24	0.517	2.20	2.74
Juglans nigra	6	2.08	30.65	6	3.24	0.501	2.14	2.49
Liquidambar styraciflua	5	1.74	33.32	4	2.16	0.614	2.62	2.17
Prunus serotina	3	1.04	24.98	3	1.62	0.171	0.73	1.13
Carya laciniosa	2	0.69	23.88	2	1.08	0.095	0.40	0.72
Quercus macrocarpa	1	0.35	25.40	1	0.54	0.051	0.22	0.37
Quercus palustris	1	0.35	16.51	1	0.54	0.021	0.09	0.33
Sassafras albidum	1	0.35	17.27	1	0.54	0.023	0.10	0.33
Totals	288	100.01	28.00	185	99.97	23.460	99.98	100.03

The data do not indicate any future change in canopy species based on understory species importance values in the Cumberland River forest. The same four species, *A. negundo, A. saccharinum, C. laevigata*, and *U. rubra*, dominate the understory and, therefore, may replace the current canopy. However, in the Hog Creek forest, *P. occidentalis*, the dominant canopy tree, was not found in the understory. *Ulmus rubra* and *A. negundo* dominate the understory and may eventually replace this canopy species.

SUMMARY

Data are presented on structure and composition of two secondary riparian forests within Haynes Bottom, a Tennessee Wildlife Resources property in Montgomery County, Tennessee. One forest occurs along a first-order stream (Hog Creek). This canopy is dominated by *Platanus occidentalis, Acer negundo*, and *Ulmus rubra.* The understory is dominated by *Ulmus rubra, Cephalanthus occidentalis, Acer negundo*, and *Lindera benzoin*. Sycamore is conspicuously missing from the understory. *Microstegium vimineum* is a common herbaceous invader, indicating the

Table 3. Species composition and structure of the sapling/small tree layer (2.5-9.9 cm dbh) in the Cumberland River riparian forest, Haynes Bottom, Montgomery County, Tennessee; data based on 288 stems measured at 72 points, September 1998.

Taxa	No. Stems	% of Stems	Average dbh (cm)	No. of Points	Freq.	BA in M^2	% of BA	% of IV
Acer negundo	82	28.47	6.20	43	26.22	0.275	33.17	29.29
Acer saccharinum	62	21.53	5.83	28	17.07	0.189	22.80	20.46
Celtis laevigata	59	20.49	5.51	31	18.90	0.168	20.27	19.88
Ulmus rubra	21	7.29	6.98	15	9.15	0.086	10.37	8.94
Carya cordiformis	10	3.47	4.88	7	4.27	0.022	2.65	3.46
Fraxinus pennsylvanica	10	3.47	4.29	8	4.88	0.016	1.93	3.43
Quercus shumardii	7	2.43	4.97	6	3.66	0.017	2.05	2.71
Asimina triloba	11	3.82	4.32	6	3.66	0.002	0.24	2.57
Cornus florida	5	1.74	6.60	3	1.83	0.019	2.29	1.95
Catalpa speciosa	3	1.04	3.56	3	1.83	0.003	0.36	1.08
Quercus muhlenbergii	3	1.04	5.25	2	1.22	0.008	0.97	1.08
Celtis occidentalis	4	1.39	3.68	2	1.22	0.005	0.60	1.07
Juglans nigra	2	0.69	6.35	2	1.22	0.007	0.84	0.92
Carpinus caroliniana	2	0.69	4.32	2	1.22	0.003	0.36	0.76
Prunus serotina	1	0.35	8.89	1	0.61	0.006	0.72	0.56
Gleditsia triacanthos	2	0.69	3.05	1	0.61	0.001	0.12	0.47
Carya laciniosa	1	0.35	3.81	1	0.61	0.001	0.12	0.36
Morus rubra	1	0.35	3.81	1	0.61	0.001	0.12	0.36
Acer saccharum	1	0.35	3.05	1	0.61	0.000	0.00	0.32
Liquidambar styraciflua	1	0.35	3.05	1	0.61	0.000	0.00	0.32
Totals	288	100.00	4.92	164	100.01	0.829	99.98	99.99

disturbed nature of this forest. The more-diverse Cumberland River riparian forest canopy is dominated by *Acer saccharinum, Celtis laevigata*, and *Acer negundo*; the same species dominate the understory.

These data add to existing information on bottom land forests of the lower Cumberland River. Specifically, the data contribute to a data base of information that the Tennessee Wildlife Resources Agency will be able to use as they develop the site into a wildlife management area. Once wetland habitats are enhanced, hydrologic conditions may change for the two riparian forests and this data base will allow for monitoring as changes occur, or as the forests mature without agricultural disturbances.

ACKNOWLEDGMENTS

The senior author expresses sincere appreciation to her mentor professor in this project, Dr. Edward W. Chester. His guidance, knowledge, and ability to share that knowledge were invaluable. Mark Stephens and Richard Riddick kindly provided technical support on the project. We thank the Tennessee Wildlife Resources Agency and The Center for Field Biology at Austin Peay State University for financial support.

LITERATURE CITED

Bingham, B.W., and T.H. Roberts. 1994. A characterization of selected types of palustrine wetlands in Tennessee. Tennessee Wetlands Conservation Strategy. Technical Report Series.

Braun, E.L. 1950. Deciduous forests of eastern North Amercia. The Blakiston Publishing Co., Philadelphia, Pennsylvania.

Brinson, M.M., R.D. Rheinhardt, F.R. Hauer, L.C. Lee, W.L. Nutter, R.D. Smith, and D. Whigham. 1995. A guidebook for application of hydrogeomorphic assessments to riverine wetlands. Wetlands Research Program, U.S. Army Corps of Engineers, Washington D.C. Technical Report WRP-DE-11.

Chester, E.W., and J. Schibig. 1993. Characterization of some remnant bottomland land forests of the lower CumberlandRiver in Tennessee and Kentucky: 1. Introduction and the Cross Creeks site in Stewart County, Tennessee. Pp. 65-75 in: S.W. Hamilton, E.W. Chester, and A.F. Scott (eds.). Proceedings of the fifth annual symposium on the natural history of lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Chester, E.W., and J. Schibig. 1997. Characterization of some remnant bottomland land forests of the lower Cumberland River in Tennessee and Kentucky: 2. The St. Stevens site in Lyon County, Kentucky. Pp. 175-185 in: S.W. Hamilton, E.W. Chester, and A.F. Scott (eds.). Proceedings of the seventh annual symposium on the natural history of lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Chester, E.W., and F.E. Dodson. 1996. Vascular flora of Long Pond Slough, Montgomery County, Tennessee. J. Tennessee Acad. Sci. 71:81-89.

Chester, E.W., and F. E. Dodson. 1997. Characterization of some remnant bottomland land forests of the lower Cumberland River in Tennessee and Kentucky: 3. The Long Pond Slough site in Montgomery County, Tennessee. Pp. 186-192 in: S.W. Hamilton, E.W. Chester, and A.F. Scott (eds.). Proceedings of the seventh annual symposium on the natural history of lower Tennessee and Cumberland River valleys. The Center for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Chester, E.W., and W.H. Ellis. 1989. Plant communities of northwestern middle Tennessee. J. Tennessee Acad. Sci. 64:75-78.

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

Fenneman, N.M. 1938. Physiography of eastern United States. McGraw-Hill Book Co., New York.

Joyner, J.M., and E.W. Chester. 1994. The vascular flora of Cross Creeks National Wildlife Refuge, Stewart County, Tennessee. Castanea 59:127-145.

Mitsch, W.J., and J.G. Gosselink. 1993. Wetlands, 2nd ed. Van Nostrand Reinhold, New York.

U.S. Army Environmental Laboratory. 1987. Corps of Engineers Wetlands Delineation Manual. Wetlands Research Program, U.S. Army Corps of Engineers, Washington D.C. Technical Report Y-87-1.

U.S. Department of Agriculture, Soil Conservation Service. 1975. Soil Survey of Montgomery County, Tennessee. Washington D.C.

COMPARISON OF THE MORPHOLOGY, FLOWERING PHENOLOGY, AND LIFE CYCLE TYPE IN *GRINDELIA LANCEOLATA* NUTT. (ASTERACEAE) FROM TENNESSEE AND ALABAMA GROWN IN A COMMON GARDEN

CHRISTOPHER A. ADAMS[1], JERRY M. BASKIN[1], AND CAROL C. BASKIN[2]

[1]School of Biological Sciences, The University of Kentucky, Lexington, KY 40506
[2]School of Biological Sciences and Department of Agronomy,
The University of Kentucky, Lexington, KY 40506

ABSTRACT. *Grindelia lanceolata* Nutt. is an herbaceous plant species that ranges from central Tennessee and northern Alabama to the Ozarks and southeastern Kansas, south to Louisiana, Texas, and Nuevo Leon, Mexico. The species also is known from a single locality in southeastern Ohio. It is reported to be a biennial, a short-lived monocarpic perennial, and a (presumably polycarpic) perennial in the (mostly taxonomic) literature. The purpose of this study was to grow Tennessee and Alabama plants from seed in a common environment and compare their morphology, flowering phenology, and life cycle type. Morphological differences between Tennessee and Alabama plants included sizes of both basal rosette and stem leaves, number of secondary stems, stem height, number of capitula per plant, number of ray and disk flowers per capitulum, diameter of capitulum, ray flower corolla length, length of involucral bracts, and length of disk achenes. Tennessee plants began flowering about one month earlier than Alabama plants, and Alabama plants produced basal rosettes after they flowered (potentially at least dicarpic), whereas Tennessee plants did not (strictly monocarpic). This study strongly indicates that there are genetic differences in vegetative and floral morphology, flowering phenology, and life cycle type between Tennessee and Alabama plants of *G. lanceolata*.

EFFECT OF BURIAL UNDER FLOODED AND NONFLOODED CONDITIONS ON THE ANNUAL DORMANCY CYCLE OF *SCHOENOPLECTUS PURSHIANUS* (CYPERACEAE) SEEDS

CAROL C. BASKIN[1,2], JERRY M. BASKIN[2,3] AND EDWARD W. CHESTER[2]

[1,2]School of Biological Sciences and Department of Agronomy,
The University of Kentucky, Lexington, KY 40506
[2]Center for Field Biology, Austin Peay State University, Clarksville, TN 37044
[2,3]School of Biological Sciences, The University of Kentucky, Lexington, KY 40506

ABSTRACT. **Seeds of the summer annual *Schoenoplectus purshianus* (Fern.) Strong (= *Scirpus purshianus* Fern.) were dormant at maturity in mid-September and consequently did not germinate in light or in darkness at 12/12 h daily alternating temperature regimes of 15/6, 20/10, 25/15, 30/15 or 35/20°C. Seeds were placed in fine-mesh polyester cloth bags and buried in either flooded or nonflooded soil and exposed to natural seasonal temperature changes for 32 months. At monthly intervals, flooded and nonflooded seeds were exhumed and tested over the range of thermoperiods in light under flooded (*i.e.*, submerged 9 cm in 250 ml glass jars filled with distilled water) and nonflooded (*i.e.*, on wet sand in Petri dishes) conditions and in darkness under nonflooded conditions. Seeds buried in flooded or in nonflooded soil exhibited an annual dormancy/nondormancy cycle each year when tested in light under flooded or under nonflooded conditions. That is, dormancy loss occurred during autumn and winter, and seeds germinated to high percentages in spring. Seeds did not germinate while buried in soil, and by summer they had re-entered dormancy (secondary dormancy), thus losing the ability to germinate at all thermoperiods. Seeds buried in flooded soil and tested in darkness on wet sand also exhibited an annual dormancy/nondormancy cycle. However, seeds buried in nonflooded soil and tested in darkness on wet sand never germinated to more than 2%. The best habitat conditions for high year-to-year germination of *S. purshianus* are a regime of nonflooding in winter and flooding in spring.**

ECOLOGICAL LIFE HISTORY OF *POLYMNIA CANADENSIS* L. (ASTERACEAE) - I

MARTIN H. BENDER[1,2], JERRY M. BASKIN[1], AND CAROL C. BASKIN[3]

[1]School of Biological Sciences, The University of Kentucky, Lexington, KY 40506
[2]Present address: The Land Institute, 2440 E. Water Well Road, Salina, KS 67401
[3]School of Biological Sciences and Department of Agronomy,
The University of Kentucky, Lexington, KY 40506

ABSTRACT. *Polymnia canadensis* is an herbaceous plant species that grows in mesic to dry woods throughout a large portion of the Eastern Deciduous Forest, *i.e.*, from Vermont west to southern Minnesota and south to eastern Oklahoma, central Alabama, and western North Carolina. Although heretofore reported (mostly in taxonomic works) to be a (presumably polycarpic) perennial, it primarily is a short-lived monocarp. The majority of plants of this species grown in common garden and greenhouse experiments in Lexington, Kentucky, from seeds collected in Alabama, Kentucky, Missouri, Ohio, and Virginia died after they flowered once. Winter annual, biennial, triennial, and dicarpic and tricarpic perennial life histories occurred within populations in both common garden and reciprocal transplant (*i.e.*, between mesic and dry population study sites in central Kentucky) experiments; most plants were either biennials (most common) or winter annuals (second most common). Genetic differentiation among populations for timing of reproduction was negligible compared to phenotypic plasticity for this character.

Anthesis date was earlier, and mean plant height at maturity taller, at dry- than at mesic field sites; however, common garden experiments showed that these were due to environmental, and not to genetic effects. Lack of a significant source x site interaction for these characters indicated that sources did not differ in their plastic responses. Further, most annual germination occurred in autumn at the dry sites and in spring at the mesic sites; reciprocal seed transplant experiments also showed that the cause of these differences was environmental. Lack of germination in autumn at the mesic sites was not due to tree canopy-filtered light or to the thick leaf litter cover. Exposing seeds to a high FR/R photon ratio or covering them with a thick layer of leaf litter did not inhibit germination. Like seeds of many weedy facultative biennials, those of *P. canadensis* (1) germinate to higher percentages after cold stratification, (2) germinate better in light than in darkness, and (3) form a persistent seed bank.

ECOLOGICAL LIFE HISTORY OF *POLYMNIA CANADENSIS* L. (ASTERACEAE) - II

MARTIN H. BENDER[1,2], JERRY M. BASKIN[1], AND CAROL C. BASKIN[3]

[1]School of Biological Sciences, The University of Kentucky, Lexington, KY 40506
[2]Present address: The Land Institute, 2440 E. Water Well Road, Salina, KS 67401
[3]School of Biological Sciences and Department of Agronomy,
The University of Kentucky, Lexington, KY 40506

ABSTRACT. More than 96% of the 23,063 plants of the woodland facultative biennial *Polymnia canadensis* monitored in undisturbed plots from seed germination until death at study sites in central Kentucky, died without flowering; the majority of the 796 plants that reproduced were biennials. Weekly cohorts of *P. canadensis* generally exhibited a Deevey Type III survivorship. Life tables revealed variation in survivorship among seasonal cohorts. Highest mortality occurred in summer and was associated with low soil moisture. Population structure (proportion of juveniles and of adults) varied among years, seasons, and study sites; at two study plots, a 2-year flowering cycle persisted for 4 years. Mass seedling and senescence was documented in several study plots. In field, greenhouse, and transplant garden experiments, small individuals of *P. canadensis* died in competition with large ones, suggesting that intraspecific competition could result in mass flowering and senescence when the large age-class(es) matured and thus play a role in population cycling.

Unlike many weedy facultative biennials, *P. canadensis* does not require open habitat or disturbance to persist at population sites. Disturbance treatments did not increase germination, survivorship, or number of reproductive individuals either in a treefall gap or under a tree canopy. Further, 4-year population growth was 1.6 and 2.1 at undisturbed mesic and dry population sites, respectively.

***Polymnia canadensis* has a vernalization requirement for flowering, and even very small plants can be vernalized; vernalized plants can flower under both LDs and SDs. However, to flower plants must attain a minimum postvernalization size. Vernalized plants exposed to high temperatures can be devernalized; these must be re-vernalized in order to flower. Plants that do not die after they flower once require a second period of vernalization to flower again. These size and vernalization requirements for flowering of *P. canadensis* help explain how this species can have winter annual, biennial, triennial, and dicarpic, tricarpic, and polycarpic perennial life histories.**

SEED DORMANCY AND GERMINATION OF TWO NORTH AMERICAN AND ONE EURASIAN SPECIES OF *SAMBUCUS* (CAPRIFOLIACEAE)

SITI N. HIDAYATI[1], JERRY M. BASKIN[1], AND CAROL C. BASKIN[2]

[1]School of Biological Sciences, The University of Kentucky, Lexington, KY 40506
[2]School of Biological Sciences and Department of Agronomy,
The University of Kentucky, Lexington, KY 40506

ABSTRACT. Temperature requirements for dormancy-break, germination, and embryo growth were determined for freshly matured seeds of the North American species *Sambucus canadensis* and *S. pubens*, and of the European species *S. racemosa*. All three species have linear embryos that are about 70% fully developed at seed maturity.

Fresh seeds of *S. canadensis* incubated at 15/6, 20/10, 25/15, 30/15, and 35/20°C did not germinate during 2 wk of incubation in light. Seeds given a 12-wk warm stratification period at 25/15°C in light followed by a 12-wk cold stratification period at 5°C in light germinated to 55-76% at 15/6-30/15°C and to 37% at 35/20°C, whereas those given a 12-wk cold stratification period only germinated to 12-51% over the range of thermoperiods. Warm stratification in light for 12 wk did not break dormancy in this species, *i.e.* 0% germination. Embryo length in fresh seeds incubated for 12 wk in light at 5°C and 25/15°C increased 33 and 22%, respectively. Gibberellic acid was only partially effective in overcoming dormancy, *i.e.* 55% of seeds incubated in light for 12 wk on 1000 mg l^{-1} GA_3 germinated at 25/15°C compared to 0% in the distilled-water control. Although a few seeds sown in a nonheated greenhouse on 14 September 1997 germinated in late October and early November 1997, peak germination occurred between 15 and 21 February 1998, when mean weekly maximum and minimum temperatures were 11.7 and 7.1°C, respectively.

Zero percent of fresh *S. pubens* seeds germinated during 2 wk of incubation in light at 15/6-35/20°C. Seeds given 6 wk of warm stratification in light followed by 12 wk of cold stratification in light germinated to 76-87% in light over the range of thermoperiods, whereas those seeds given a 12-wk cold stratification period only germinated to 27-76%; no seeds given only a 12-wk warm stratification period germinated. Embryo length in fresh seeds incubated for 12 wk in light at both 5 and 25/15°C increased about 7%. A few seeds sown in the greenhouse on 14 September 1997 germinated in late October and early November 1997; however, peak germination occurred between 22 and 28 February 1998, when mean maximum and minimum temperatures were 14.7 and 7.2°C, respectively.

No fresh seeds of *S. racemosa* germinated in light during 2 wk of incubation at 15/6-35/20°C. Seeds given a 12-wk cold stratification period only in light germinated to 77-100%, whereas none of those given only a 12-wk warm stratification period germinated. Embryo length in fresh seeds incubated for 12 wk in light at 5°C increased 40%, while those incubated in light at 25/15°C increased only 4%. Gibberellic acid was effective in overcoming dormancy, *i.e.* 78 and 100% of seeds incubated for 12 wk on 100 and 1000 mg l^{-1} GA_3, respectively, germinated in light at 25/15°C.

Seeds of the three *Sambucus* species have morphophysiological dormancy. Dormancy break in seeds of *S. canadensis* and of *S. pubens* required a warm + cold stratification treatment, whereas those of *S. racemosa* required a cold stratification period only.

DEVELOPMENTAL SEQUENCE OF PHOTOSYSTEM II CONSTRUCTION

JEFFERSON G. LEBKUECHER, KURT A. HALDEMAN, CHRISTINE E. HARRIS, SONIA L. HOLZ, SARY A. JOUDAH, AND DARCY A. MINTON

Department of Biology, Austin Peay State University, Clarksville, TN 37044

ABSTRACT. Light-induced development of Photosystem (PS) II was followed during irradiance of etiolated *Helianthus annuus* L. (sunflower) cotyledons using chlorophyll *a* fluorescence. Cotyledons from seedlings grown in continuous darkness for 6 days were exposed to 100 μmol photons·m^{-2}·s^{-1} for time periods of 1 h, 3 h, 6 h, and 12 h. Associated with increased time of irradiance-exposure were significant: (1) increases in concentration of PS II, (2) increases in quantum efficiency of PS II, (3) decreases in the ratio of PS II quinone$_B$ (Q_B)-nonreducing centers to total PS-II centers beginning during the 1-h to 3-h irradiance period, and (4) decreases in the ratio of slow PS II Q_B-reducing centers to total PS II Q_B-reducing centers following 3 h of irradiance. The results indicate that during development of PS II, PS II Q_B-nonreducing centers are assembled first, followed by their conversion to PS II Q_B-reducing centers, followed by the addition of the water-oxidation complex.

ANATOMY OF TWO MECHANISMS OF BREAKING PHYSICAL DORMANCY BY EXPERIMENTAL TREATMENTS IN SEEDS OF TWO NORTH AMERICAN *RHUS* SPECIES (ANACARDIACEAE)

XIAOJIE LI[1], JERRY M. BASKIN[1], AND CAROL C. BASKIN[2]

[1]School of Biological Sciences, The University of Kentucky, Lexington, KY 40506
[2]School of Biological Sciences and Department of Agronomy, The University of Kentucky, Lexington, KY 40506

ABSTRACT. Anatomy of the endocarp was studied in relation to the physical dormancy-breaking mechanisms in experimentally-treated *Rhus aromatica* Ait. (var. *aromatica*) and *R. glabra* L. germination units, which include seed plus endocarp (hereafter seeds). The endocarp has three distinct layers, with brachysclereids on the outside, osteosclereids in the middle, and macrosclereids on the inside. Brachysclereids in the pseudomicropyle region (i.e., region immediately adjacent to the integumentary micropyle) are shorter than those in other parts of the endocarp, and the macrosclereids in this region are not elongated. Thus, a weak point is formed in the endocarp. Concentrated sulfuric acid broke seed dormancy in *R. aromatica* by eroding the brachysclereids and osteosclereids in the pseudomicropyle region, whereas boiling-water broke dormancy in seeds of *R. glabra* by inducing a blister adjacent to the pseudomicropyle.

THE EFFECTS OF SHELTERWOOD CUTTINGS ON HERBACEOUS AND WOODY UNDERSTORIES AT LAND BETWEEN THE LAKES, KENTUCKY AND TENNESSEE

STEVEN GLICKAUF AND JAMES FRALISH

Department of Forestry, Southern Illinois University, Carbondale, IL 62901

ABSTRACT. The objectives of this research on shelterwood cut forests at Land Between The Lakes, Kentucky and Tennessee, were to determine herbaceous species composition and density across a range of sites from xeric to mesic, and to determine if herbaceous species richness and cover in shelterwood cut stands differ from that of uncut stands on analogous site types. Five three to twelve year old oak-hickory shelterwood cut forest stands were studied. A total of 29 sampling units were established with each sampling unit being composed of a 0.04 ha plot and four systematically placed nested 0.003 ha and 0.006 ha quadrats. Each sampling unit was required to contain at least one stump and an overstory canopy gap. On the 0.04 ha circular plot, species and diameter were recorded for trees >9 cm while seedling (stems <1.0 cm diameter) and sapling numbers were recorded by species on the 0.003 ha and 0.006 ha plots respectively. Absolute percent cover was recorded for each herbaceous species within 10 systematically located 1.4 x 1.4 m (2m2) quadrats. Within each quadrat, litter was collected from a randomly located 0.25 m^2 microplot. Soil and topographic data also were collected.

Data indicated that the herbaceous species in the shelterwood cut forests of LBL sort out along a soil moisture gradient. Compared to the results of Close (1996), shelterwood cutting allows xerophytic herbaceous species to become established on more mesic sites, and to a lesser extent mesic herbaceous species moved to more xeric sites. Herbaceous richness and cover were greater in shelterwood cut stands. Opening of the canopy apparently decreased competition, increased available light and allowed herbs to flourish.

Comparisons of shelterwood cut sites at LBL and disturbed forests of the Shawnee Hills (Harty 1978), in southern Illinois, provide evidence that excessive and severe past disturbances have greatly affected number of herbaceous taxa at LBL. For each site type, disturbed forests of Shawnee Hills have higher numbers of herbaceous species than that of the shelterwood cut forests of LBL. It appears that the heavy disturbances and length of disturbance associated with LBL has caused a decrease in herbaceous richness. **This research was supported by the Center for Field Biology, Austin Peay State University, Clarksville, TN and the Department of Forestry, Southern Illinois University, Carbondale, IL.**

CHARACTERISTICS OF GERMINATION IN *AGERATINA ALTISSIMA*

JOANN M. LAU AND DAVID L. ROBINSON

Department of Biology, Bellarmine College, Louisville, KY 40205

ABSTRACT. White snakeroot [*Ageratina altissima* (L.) King & Robinson = *Eupatorium rugosum* Houtt.] is a perennial commonly found in the shaded margins of woodlands and waterways. Achenes of this species typically germinate in the spring with plants blooming from early to late autumn. Achene dormancy and germination in *Ageratina altissima* were examined using genetic, physiological, and cytochemical techniques.

To study the genetic basis of germination a single population of approximately 2000 achenes was sown onto a large tray and incubated at 21°C. These achenes had been collected in Louisville, Kentucky, then after-ripened and stored for 18 months at 4°C. Within 17 d, 1539 achenes (77%) had germinated. The first achenes to sprout (4 d after sowing) were transplanted into pots and grown to maturity in a nursery. At 17 d after sowing, the ungerminated achenes were given a cold treatment (56 h; 4°C) followed by another long incubation at 21°C. Thirty-four achenes germinated and were transplanted into the same nursery. This procedure was continued for a total of nine cycles. After each cycle, germinated achenes were planted, grown to maturity in the nursery, and allowed to reproduce in order to evaluate progeny. These next-generation achenes will be evaluated for germination characteristics in the spring.

A second germination experiment (with achenes from the same source) showed that additional cold treatments may not have been necessary if adequate time had been given for them to germinate. Results from this study showed no statistically significant differences in achene germination when exposed to continuous 4°C vs. fluctuating cycles of 4/21°C vs. continuous 21°C.

In a third experiment, however, freshly-harvested achenes (harvested Oct. 10, 1998; planted 7 d later) showed 26% germination after being exposed to 60 h of 4°C. There was significantly less germination (17%) in achenes exposed to the same duration of cold, but in five 12-hour increments ($P<0.05$). Only treatment with gibberellic acid, a plant hormone known to enhance germination in the dormant seeds of many plant species, induced full germination.

In a fourth experiment, germinating seedlings were cytochemically stained for the presence of oxalate oxidase (EC 1.2.3.4). Recent studies indicate that oxalate oxidase, a member of a group of proteins referred to as "germins, " may play a role in germination during times of biotic and abiotic stress. In this experiment, germinating seedlings from two monocot species, barley (*Hordeum vulgare*), and tall fescue (*Festuca arundinacea*) and two dicot species, white snakeroot and black medic (*Medicago lupulina*) were compared for oxalate oxidase activity after 8 h exposure to different environmental stresses. These environmental treatments were: 5°C, 23°C, 37°C, 50°C, 0.2 M NaCl, acidic conditions (pH=3.6), basic conditions (pH=10.4), or exposure to *Pythium irregulare* (the fungus that causes damping-off disease). While this enzyme stained positively in the monocot species, no staining was observed in the two dicots. In the monocot seedlings, the staining was exclusively localized to the roots.

SEED GERMINATION ECOPHYSIOLOGY OF *THALICTRUM MIRABILE* (RANUNCULACEAE)

JEFFREY L. WALCK[1,3], CAROL C. BASKIN[1,2], AND JERRY M. BASKIN[1]

[1]School of Biological Sciences, University of Kentucky, Lexington, KY 40506
[2]Department of Agronomy, University of Kentucky, Lexington, KY 40506
[3]Present address: Department of Evolution, Ecology, and Organismal Biology, The Ohio State University, Columbus, OH 43210

ABSTRACT. *Thalictrum mirabile* Small is an herbaceous perennial that occurs from Kentucky to North Carolina and Alabama; it grows in rockhouses and on rock cliffs. Freshly-matured seeds (achenes) of this species were collected each September 1994-1996 in eastern Kentucky. Longitudinal sections of fresh seeds showed that they had underdeveloped (linear) embryos.

Fresh seeds collected in 1995 did not germinate during 2 weeks of incubation in light (14 h daily photoperiod, *ca.* 20 µmol m^{-2} s^{-1}, 400-700 nm) or in darkness at 15/6, 20/10, and 25/15°C. Seeds incubated on moist sand in light and in darkness at 1°C for 12 weeks (cold stratification) and those incubated on moist sand in light and in darkness at 25/15°C for 6 weeks and then at 1°C for 12 weeks (warm + cold stratification) germinated to 84-100% during 2 weeks of incubation in light and in darkness at 15/6, 20/10, and 25/15°C. Mean (± SE) embryo length in fresh seeds was 0.54 (± 0.01) mm long; their critical length for germination was ca. 2.0 mm. Embryos in seeds grew to only 0.79 and 0.70 mm in length during cold stratification and during warm + cold stratification, respectively. Thus, most of the embryo growth occurred at simulated spring temperatures after cold stratification was completed. Gibberellic acid substituted for cold stratification. Seeds collected in 1996 germinated to 0, 6, 51, and 98% on filter paper moistened with 0, 10, 100, and 1000 mg L^{-1} GA_3, respectively, during 12 weeks of incubation in light at 25/15°C. Thus, seeds of *T. mirabile* have nondeep simple morphophysiological dormancy: (1) cold stratification and GA_3 effectively break physiological dormancy, and (2) embryos grow at warm temperatures after dormancy is broken.

Seeds collected in 1996 were placed in a nylon bag and kept on moist soil in a nonheated greenhouse in Lexington, Kentucky. Seeds retrieved from the greenhouse at 2-week intervals between 15 September 1996 and 15 January 1997 germinated to 0-14% when incubated in light at 25/15°C for 2 weeks, whereas those retrieved on 1 and 15 February 1997 germinated to 94-100%. However, embryos in seeds kept in the greenhouse had grown to only 0.77 mm in length by 15 February 1997. Seeds began germinating in the greenhouse between 24 February and 3 March 1997, when mean maximum and minimum weekly temperatures were 15.8 and 7.3°C, respectively, and peak germination occurred between 3 and 10 March 1997, when temperatures were 13.5 and 6.0°C, respectively.

***Thalictrum mirabile* seeds exposed to natural temperatures remained viable until the second germination season, and thus they have the capacity to form a short-lived persistent soil seed bank. Of 900 seeds collected and sown in 1994 in the greenhouse, 61% of them germinated during spring 1995 and 11% during spring 1996. No additional seeds had germinated when the study was terminated on 1 June 1998. Similarly, seedlings were observed in bags of 1994 seeds buried in soil in the greenhouse in 1994 and exhumed in April 1995 and in April 1996, but none was observed in bags exhumed in June 1995, September 1995, or January 1996. After incubation in light at 25/15°C for 2 weeks, nongerminated seeds in bags exhumed in April 1995 and in April 1996 germinated to 100%, and those exhumed in January 1996 germinated to 57%. None of the seeds exhumed in June 1995 and September 1995 germinated during incubation. Thus, seeds of *T. mirabile* apparently go through an annual dormancy/nondormancy cycle.**