PROCEEDINGS OF THE

13^{TH} SYMPOSIUM

ON

THE NATURAL HISTORY OF

LOWER TENNESSEE AND CUMBERLAND RIVER VALLEYS

BRANDON SPRING GROUP CAMP

LAND BETWEEN THE LAKES

APRIL 3 AND 4, 2009

SPONSORED BY

AUSTIN PEAY STATE UNIVERSITY

THE CENTER OF EXCELLENCE FOR FIELD BIOLOGY

AND

MURRAY STATE UNIVERSITY

WATERSHED STUDIES INSTITUTE

AND

U.S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE

LAND BETWEEN THE LAKES NATIONAL RECREATION AREA

Austin Peay State University

Center of Excellence for Field Biology

PROCEEDINGS OF THE 13^{TH} SYMPOSIUM ON THE NATURAL HISTORY OF LOWER TENNESSEE AND CUMBERLAND RIVER VALLEYS

HELD AT BRANDON SPRING GROUP CAMP
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Sponsored by:

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

and

The Center for Reservoir Research
Murray State University, Murray, Kentucky

and

U.S. Department of Agriculture, Forest Service
Land Between The Lakes National Recreation Area
Golden Pond, Kentucky

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EDITED BY:

Steven W. Hamilton, A. Floyd Scott and L. Dwayne Estes

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

Price: $5.00

SUGGESTED CITATION

Hamilton, S.W., A.F. Scott and L.D. Estes. 2010. Proceedings of the 13th Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys. The Center of Excellence for Field Biology, Austin Peay State University, Clarksville, Tennessee.

Published
June 2010

PREFACE

At 1:30 p.m. on May 3, 2009, the 13th Symposium on the Natural History of Lower Tennessee and Cumberland River Valleys was convened at the Land Between The Lakes' Brandon Spring Group Camp by Dr. Steven W. Hamilton, Director of the Center of Excellence for Field Biology. Following welcoming remarks by Dr. Hamilton on behalf of the Center and Austin Peay State University, Dr. Howard H. Whiteman, Director of the Watershed Studies Institute, welcomed guests on behalf of the Institute and Murray State University. Dr. Whiteman explained the renaming of the Center for Reservoir Research with which many of us are long familiar. Mr. Steve Bloemer, Wildlife Program Manager, offered welcoming remarks on behalf of Dr. Bill Lisowski, USDA-Forest Service Areas Supervisor for the Land Between The Lakes National Recreation Area and updated the attendees on recent activities at LBL.

Following welcoming remarks from each of the sponsoring institutions, Dr. Hamilton opened the Invited Papers Session. The theme of this session was "Taking the Long View: The Role of Long-term Monitoring in Understanding Ecosystem Impacts of Global Climate Change." The first speaker was Dr. Gregory S. Butcher, Director of Bird Conservation for the National Audubon Society. His paper, coauthored by Daniel K. Niven and G. Thomas Bancroft, was entitled "Northward Shifts in the Abundance of Tennessee and Kentucky Birds in Early Winter: A Response to Warmer Winter Temperatures?" After a short break, Dr. David W. Inouye, Professor of Biology and Director of the graduate program in Sustainable Development and Conservation Biology at the University of Maryland, College Park spoke. His paper asked "How Does Natural History Become Science, and What Can It Tell Us About Climate Change?" The final speaker for the afternoon was Dr. David S. White, who presented "Lakes, Reservoirs, and Their Landscapes as Environmental Sentinels: The Value of Real-time and Long-term Monitoring," a paper coauthored with Susan P. Hendricks. Dr. White is a Professor of Biological Sciences and Director of the Hancock Biological Station at Murray State University and holds a Commonwealth Endowed Chair for Ecosystem Studies. Full manuscripts for each of these presentations are published here. Dr. Hamilton served as editor for the invited papers.

The Saturday morning contributed paper sessions convened at 7:55 a.m. with two concurrent sessions. Session I, Botany, was moderated by Dr. Dwayne Estes, Assistant Professor of Biology and Principal Investigator in the Center for Field Biology at Austin Peay State University. Dr. Estes, served as editor of this session, which included 15 papers, two published here as full manuscripts. The remaining botany presentations are published as abstracts. Session II, Aquatic Biology and Zoology, was moderated by Dr. Andrew N. Barrass, Associate Professor of Biology and Principal Investigator in the Center for Field Biology. Session II had 14 presentations, one of which is published as a full manuscript here and the remaining 13 are published as abstracts. Dr. A. Floyd Scott, Professor of Biology and Principal Investigator in the Center for Field Biology served as editor for this session.

Editing and publishing of these proceedings follow the format of the prior twelve proceedings published by the Center of Excellence for Field Biology. Contributed papers and abstracts were reviewed by Center staff for style, content and scientific merit. On occasion, external reviewers were asked to comment and critique contributed papers. Invited papers were reviewed by the session editor for style and content. Also, each manuscript was reviewed by one outside reviewer who could offer critical evaluation its scientific merits. Thanks are extended to the external reviewers for their assistance and to all contributors for their fine work and patience while the proceedings were being completed. We hope the results are satisfactory both for the authors and for other readers. We apologize in advance for any oversights in the editing and publishing process.

ACKNOWLEDGMENTS

Jean Langley, Technical Clerk for the Center of Excellence for Field Biology, has been a critical component in the organization and execution of the meeting as well as the publication of these proceedings. Without her diligent assistance and organizational skills, these results would be much diminished. We must also acknowledge the many undergraduate and graduate students who helped us prepare, set-up, operate and tear-down the symposium. Lastly, we thank Richard Lomax and his staff at the Brandon Spring Group Camp for the help and hospitality during this biennial event.

SYMPOSIUM REGISTRANTS

Following, in alphabetical order, is a list of those individuals who registered at the 2009 symposium. Institutional affiliation (when available), city (of the person's institution or home), and state are also given.

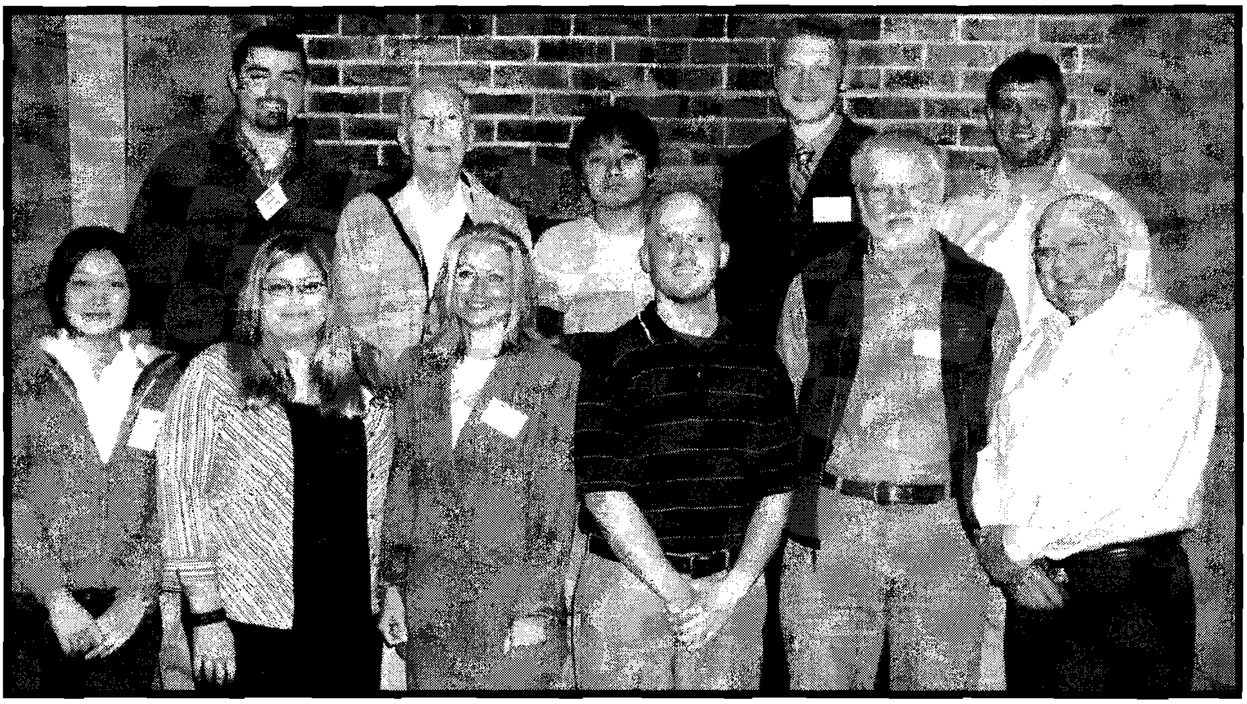
Tom Anderson – Murray State University, Murray, KY; Catherine Aubee – Murray State University, Murray, KY; Claude Bailey – Jackson State Community College, Jackson, TN; Sandra Bann – Austin Peay State University, Clarksville, TN; Andrew N. Barrass – Austin Peay State University, Clarksville, TN; Julianna Bejma – Belmont University, Nashville, TN; Steve Bloemer – USDA Forest Service, Golden Pond, KY; Matt Bruton – Austin Peay State University, Clarksville, TN; Gregory Butcher – National Audubon, Washington, DC; Edward W. Chester – Austin Peay State University, Clarksville, TN; Todd Crabtree – TDEC, Nashville, TN; Richard Connors – Tennessee State Parks, Nashville, TN; Hal De Selm – University of Tennessee, Knoxville, TN; Kathy DeWein – Austin Peay State University, Clarksville, TN; Tianita D. Duke – Austin Peay State University, Clarksville, TN; Dereck Eison – Austin Peay State University, Clarksville, TN; Dwayne Estes – University of Tennessee, Knoxville, TN; Ashlie Farmer – Austin Peay State University, Clarksville, TN; Sarah Farmer – Murray State University, Murray, KY; Robert Ferree – Austin Peay State University, Clarksville, TN; James Fralish – Southern Illinois University, Carbondale, IL; Michael Fuinn – Murray State University, Murray, KY; Karen Golinskie – Nashville, TN; Tema Goochberg – Austin Peay State University, Clarksville, TN; Debbie Hamilton – Allensville, KY; Steven W. Hamilton – Austin Peay State University, Clarksville, TN; Sunny Hart – Austin Peay State University, Clarksville, TN; Kate He – Murray State University, Murray, KY; Susan Hendricks – Murray State University, Murray, KY; Hao Jiang – Murray State University, Murray, KY; Eric Johansen – Austin Peay State University, Clarksville, TN; Dianna Johnson – Murray State University, Murray, KY; Brittny Jones – Austin Peay State University, Clarksville, TN; John Koons – Jackson State Community College, Jackson, TN; Morgan Kurz – Austin Peay State University, Clarksville, TN; Jean Langley – Austin Peay State University, Clarksville, TN; Jeff Lebkuecher – Austin Peay State University, Clarksville, TN; Todd Levine – Murray State University, Murray, KY; Bill Lisowski – LBL, Golden Pond, KY; Dongjiao Liu – Murray State University, Murray, KY; Bommanna Loganathan – Murray State University, Murray, KY; Seth McCormick – Austin Peay State University, Clarksville, TN; Travis McDonald – USDA Forest Service, Cadiz, KY; Steve Murphree – Belmont University, Nashville, TN; Chris O'Bryan – Austin Peay State University, Clarksville, TN; Darlene Panvini – Belmont University, Nashville, TN; Nathan Parker – Austin Peay State University, Clarksville, TN; Rachel Peacher – Austin Peay State University, Clarksville, TN; David Pitts – University of Tennessee at Martin, Martin, TN; Marion Pitts – Martin, TN; Elizabeth Raikes – USDA Forest Service, Murray, KY; Michelle Rogers – Austin Peay State University, Clarksville, TN; Joe Schibig – Volunteer State Community College, Gallatin, TN; Joe Schiller – Austin Peay State University, Clarksville, TN; A. Floyd Scott – Austin Peay State University, Clarksville, TN; Jimmy R. Smith – TWRA, Nashville, TN; Nathalie Smith – Austin Peay State University, Clarksville, TN; Donald L. Sudbrink – Austin Peay State University, Clarksville, TN; Jason Thiele – USDA Forest Service, Golden Pond, KY; Sarah Thomason – Murray State University, Murray, KY; Tom Timmons – Murray State University, Murray, KY; Jack Torkelson – Greenbrier, TN; Robert Tokosh – Murray State University, Murray, KY; April Tummins – Belmont University, Nashville, TN; Subhadra Vemu – Murray State University, Murray, KY; Rita Venable – Tennessee State Parks, Nashville, TN; Lindsay Walker – Belmont University, Nashville, TN; Brenda H. Webb – Florence, AL; David H. Webb – TVA, Florence, AL; David White – Hancock Station, Murray, KY; Howard Whiteman – WSI, Murray, KY; Amanda Whitley – Austin Peay State University, Clarksville, TN; Andy Wicke – Belmont University, Nashville, TN; David Withers – TWRA, Nashville, TN.

SYMPOSIUM SPEAKERS

Invited Speakers

David S. White	**Gregory S. Butcher**	**David Inouye**
Hancock Biological Station	National Audubon Society	University of Maryland
Murray State University	Washington, DC	College Park, MD
Murray, KY		

Contributed Papers



Session I: Botany – (from left) Dongjiao Liu, Dwayne Estes, April Tummins, Hal De Selm, Dianna Johnson, Hao Jiang, Matt S. Bruton, Robert Tokosh, Joe Schibig, Jonathan McQuaide, Edward W. Chester.

Session II: Aquatic Biology and Zoology – (from left) Dereck Eison, Joseph R. Schiller, Morgan E. Kurz, T. David Pitts, R. Seth McCormick, Bommanna Loganathan, Nathalie Smith, Rita Venable, Amanda L. Whitley, Sarah Thomason, Richard Conners, Sarah Farmer, C. Stephen Murphree, Subhadra Vemu, Andrew N. Barrass

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TAKING THE LONG VIEW: THE ROLE OF LONG-TERM MONITORING IN UNDERSTANDING ECOSYSTEM IMPACTS OF GLOBAL CLIMATE CHANGE

Friday, April 3, 2009

Moderated by:

Steven W. Hamilton
The Center of Excellence for Field Biology
Austin Peay State University

TENNESSEE AND KENTUCKY BIRDS ON CHRISTMAS BIRD COUNTS: NORTHWARD SHIFTS IN EARLY WINTER ABUNDANCE

Daniel K. Niven[1], Gregory S. Butcher[2] and G. Thomas Bancroft[2]

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ABSTRACT. Of the 142 species that regularly occurred on Christmas Bird Counts in Tennessee (116 of these also occurred in Kentucky), 96 (68%) moved significantly north, 30 (21%) moved significantly south, and 16 (11%) showed no significant movement in either direction. Waterbirds, woodland birds, shrubland birds, and generalists all had a majority of the species shifting northward, but grassland birds did not. A number of species are being seen less in Tennessee and Kentucky, although their populations are stable or increasing continentally, especially to the north. Other species are increasing much more in Tennessee and Kentucky that they are continentally, especially to the south. All these results and others are correlated with the warmer January weather experienced in the contiguous 48 states over the past 40 years. There is no evidence that the species moving north are suffering population declines related to those moves, but if winters continue to warm, bird habitats and food supplies may not be able to track the warmer weather as effectively as many birds can.

INTRODUCTION

Bird ranges are dynamic. The ornithological literature is filled with details of range expansions and contractions. Changes in bird ranges can be caused by a wide variety of factors, including disease, competition, predation, human intervention, and habitat changes. In the face of growing concern about rapid global changes in climatic conditions, much of it due at least in part to human activities (IPCC 2007), we decided to test the influence of winter temperature changes on winter bird distributions in North America, focusing for this paper on Tennessee and Kentucky. Previous studies have suggested that the northern ranges of birds especially should often be determined by climatic variables such as winter temperature (Root 1988a, b, c).

We have more information about bird distribution and its changes than we do for any other type of organism. Birds are generally easy to detect, identify, and count relative to other organisms. They are widely distributed both geographically and among habitats. They include both widespread and geographically restricted species, habitat specialists and generalists, and both sedentary species with little ability to disperse and migrants whose individual movements may span ten thousand kilometers. As a result, they are an ideal class of organisms with which to study range dynamics and their causes.

We have especially good information about the range and population dynamics of North American birds because of two continental-scale bird surveys – the Breeding Bird Survey, which is run in the United States by the U.S. Geological Survey, and the Christmas Bird Count, which is run in the United States by the National Audubon Society. The present study is based on 40 years of data from the Christmas Bird Count.

The focus of this paper is to report on changes in the ranges of birds over the past 40 years both continentally and in Tennessee and to compare those range changes with winter temperature changes. We looked at the range dynamics of all species that commonly occurred on the Christmas Bird Count during the 40 years of the study.

METHODS

Climate Data and Analysis

Monthly average temperature estimates were available for each of the lower forty-eight contiguous states and the continental aggregate of these states (NOAA, National Climatic Data Center 2009). For each month we used least squares regression to assess the extent and significance of change in continental temperatures over a 40-year time period from 1966 through 2005. For January temperatures, which we found to exhibit the greatest national change during the study period, we assessed the 40-year rates of change for each U.S. state; and we used the slope coefficients from this analysis to assess geographic patterns of change in temperature.

Avian Data, Survey Area, and Time Period Covered

The Christmas Bird Count is the oldest and largest wildlife survey for any class of animals in the world. Currently, more than 2,000 counts are conducted annually during a three-week period between mid-December and early January, with the participation of more than 50,000 volunteer observers (http://www.audubon.org/bird/cbc/index.html).

Each local count is conducted once annually during a 24-hour period in a 15-mile-diameter circle. A variable number of observers divide into separate field parties that each survey a different region of the circle and tally the total number of individuals of each species detected. An attempt is made to detect all species, but cryptic and/or rare species, as well as some nocturnal species, may be under-sampled. Nonetheless, the CBC is applicable to assess continental change in the abundance and distribution of most species of relatively common birds in the continental U.S. and southern Canada.

We based our analysis on the 40-year time period from the winter of 1966-67 through the winter of 2005-06. Although the CBC began in 1900, we choose 1966-67 as a starting point because by that year the CBC survey methods had become standardized; and sample sizes, particularly small in the interior west of the survey area, were sufficient for statistical analyses.

The survey area was defined as the contiguous lower 48 U.S. states and the southern portions of Alaska and the Canadian provinces. The northern portions of Alaska and the Canadian provinces were too poorly covered to provide meaningful data; therefore, the northern extent of coverage was defined based on the ecological boundaries of Bird Conservation Regions 5, 10, 11, 12, and 14 as defined by the North American Bird Conservation Initiative (NABCI 2000).

The primary sampling units (strata) for our analyses are the portions of the 55 states and provinces occurring within the survey area as defined above. In all analyses, Rhode Island was merged with Connecticut; Washington D.C. and Delaware were merged with Maryland; Prince Edwards Island was merged with Nova Scotia; and the small portion of the Yukon was merged with British Columbia. Thirty-nine CBC locations were included in this study from Tennessee and 25 from Kentucky.

Preliminary Data Analysis and Choice of Species

For 305 North American species and for 142 in Tennessee (116 of which also occurred in Kentucky), 40-year population trends and annual indices of abundance were estimated, both continentally and for each state and province (strata), with hierarchical models in a Bayesian analysis using Markov chain Monte Carlo techniques (Sauer et al. 2010, Link et al. 2006, Niven et al. 2004, Sauer et al. 2004, Link and Sauer 2002, Sauer and Link 2002). Because the number of observers and amount of time devoted to each survey varies among CBCs, differences in effort among circles were accounted for in the model based on the number of party-hours devoted to each survey (Link & Sauer 1999a, b). This method estimates the best non-linear effort adjustment appropriate for each species in each stratum and applies those adjustments to each circle in the strata.

To address the deficiencies in the reliability of the estimates for some species, the 305 species included in these analyses all met the following criteria: the minimum number of CBC circles in the analysis was at least 25, the precision estimate was sufficient that a trend of 10% per year or greater would be statistically significant, the mean relative abundance was at least 0.01 (approximately equal to the average number of birds detected per circle with the average amount of effort), and the percentage of the species' hemispheric early-winter range included within the CBC survey area was at least 1.0%. In addition, to assure that each species was sufficiently widespread in our survey area to detect distributional change by use of our methods, no species was included in the analysis unless the species met minimum criteria in at least five strata: occurred in at least five CBC circles, had a relative abundance of at least 0.01, and showed sufficient precision so that a trend of 10% per year would be statistically significant.

Definitions of Guilds and Other Classifications Used

Each of the 305 species was classified into one of the following ecological guilds based on their distribution and habitat use during early winter:

Coastal birds – species whose distributions are largely restricted to the immediate coast or offshore waters.

Waterbirds – species primarily dependent on aquatic habitats for feeding and/or roosting that are not restricted to coastal habitats. This guild includes some species found only in freshwater habitats and others that use both fresh and saltwater.

Landbirds – species primarily dependent upon terrestrial habitats. Because landbirds represent a large and diverse guild, we further subdivided them into additional habitat guilds as follows:

- Grassland birds – occurring primarily in natural or artificial grassland habitats in winter
- Shrubland birds – occupying natural shrubland or rangeland habitat, as well as species characteristic of edge and young second-growth habitats
- Woodland birds – species characteristic of mature or late-successional deciduous or coniferous forests, savannahs, open woodlands, or gallery or riparian woodlands.
- Generalists – species not easily classified within one of the other guilds due to approximately equal use of two or more habitat types during winter. We also included in this guild species often associated with urban or suburban environments.

We further subdivided landbirds based on their use of supplemental food provided at feeding stations. Our classification generally follows that of Dunn and Tessaglia-Hymes (2001), but has been expanded and modified based on our personal experience and consideration of species accounts from the Birds of North America series (Poole 2005) as follows:

Regular feeder users – species that make regular use of human-supplemented food, and as a result may at times become partially reliant upon these food sources

Occasional feeder users – Species that may use supplemental food sources when they are available, but are unlikely to develop any dependence upon these sources

Non-feeder users – Species that rarely or never visit feeding stations

Estimation of Annual Change in Latitudinal Center of Abundance

Year-specific latitudinal centers of abundance within our survey area were estimated for each species as the mean centroid latitude among all strata (states and provinces) included in the analysis, weighted by the species' strata-specific indices of abundance and the area (in km^2) of each stratum.

To facilitate the comparison of annual changes in latitudinal distribution among species, for each species we subtracted the estimated value of the centroid latitude in year one (winter 1966-67) from each of the 40 yearly estimates. This defined the 'change in latitude' value as zero for year one (1966-67) and all subsequent years reflected a change from this standard starting point. For each species, and for the median aggregate values among all species in each guild of interest, standard least squares linear regression was used to determine if the change in center of abundance over 40 years differed significantly from zero.

Estimation of Geographic Variation in Population Trends

To explore geographic variation in population trends, for each species and each stratum in which it occurred, we calculated the deviation of the stratum-specific population trend from the continental population trend by subtracting the 40-year continental population trend estimate from the 40-year stratum population trend estimate. For simplicity we will refer to these differences as the "stratum trend deviations". A positive stratum trend deviation indicates that the 40-year population trend in that state or province was higher than the overall continental average and vice versa. For each guild of interest we estimated the median stratum trend deviation among all the species that met sample size requirements within each stratum. We then regressed the median stratum trend deviations against the latitudinal center of each stratum using least squares regression to assess the relationship between strata trend deviation and latitude.

RESULTS

Temperature Patterns

Nationally, from 1895 through 2008, the coldest two Januarys were in 1977 and 1979; the warmest January was in 2006 (Fig. 1). In Tennessee, there is no evidence of a warming trend in January temperatures (Fig. 2). January of 1977 was the coldest, and January of 2006 was relatively warm, but there were at least four warmer Januarys - 1907, 1932, 1937, and 1950 (NOAA National Climatic Data Center 2009).

The average monthly temperatures across the lower 48 states increased significantly for six of the 12 months during the 40-year study period from 1966-2005. The greatest rate of change occurred in January, and the average January temperature increased more than 4.5 degrees Fahrenheit over this period (Fig. 3). The rate of change in average January temperatures during the 40 years of this study was significantly greater at higher latitudes. In Tennessee and Kentucky from 1966-2005, there is evidence of a slight increase in January temperatures during the years of this study (Fig. 4), but it is much less than the national trend, and the past three winters have reverted to the mean.

All 305 North American Species

Among the 305 bird species in our study, there was a strong northern shift in latitudinal center of abundance over the past 40 years (Niven et al. 2009a, Niven et al. in prep.). Of the 305 species in the analysis, 177 (58.0%) showed a significant shift north and 79 (25.9%) showed a significant shift south. Overall, the average latitudinal center of abundance significantly shifted to the north by a distance of 34.8 miles based on regression analysis. Among the 177 species that shifted north, the average change in latitudinal center of abundance was 98.6 miles.

The latitudinal center of abundance differed considerably from year to year, so there was not a steady march north (Fig. 5). However, when the residuals from the estimated annual distance moved were compared to the residuals from the estimated annual change in temperature for the November/December period preceding and during the CBC survey period, the relationship was significant. This analysis shows that in warm early winters, birds were found further north than in cold early winters.

Tennessee and Kentucky

Of the 142 species that regularly occurred on CBCs in Tennessee (116 also occurred in Kentucky), 96 (68%) moved significantly north, 30 (21%) moved significantly south, and 16 (11%) showed no significant movement in either direction (Table 1, Appendix).

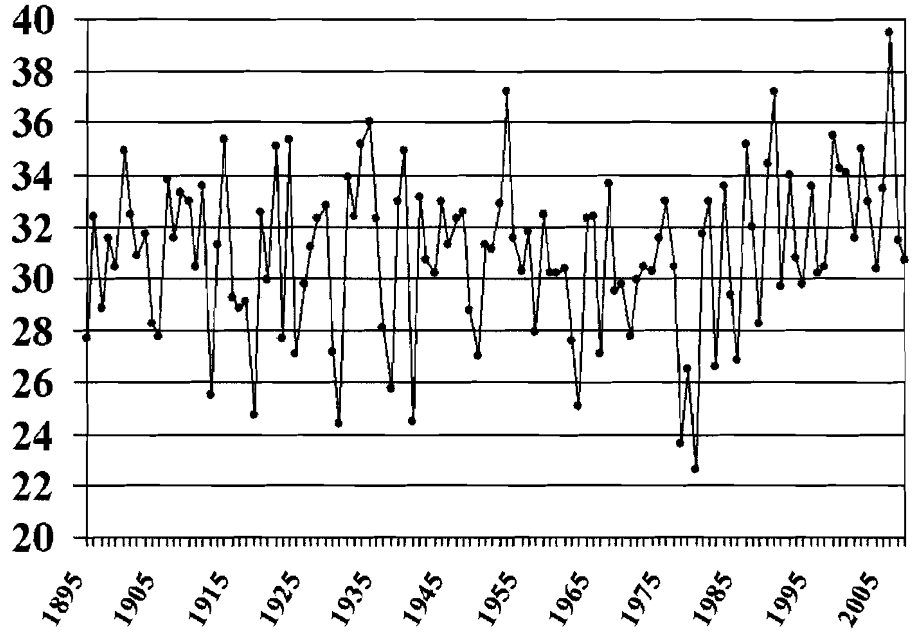

Figure 1. Average January temperatures in the contiguous United States, 1895-2008

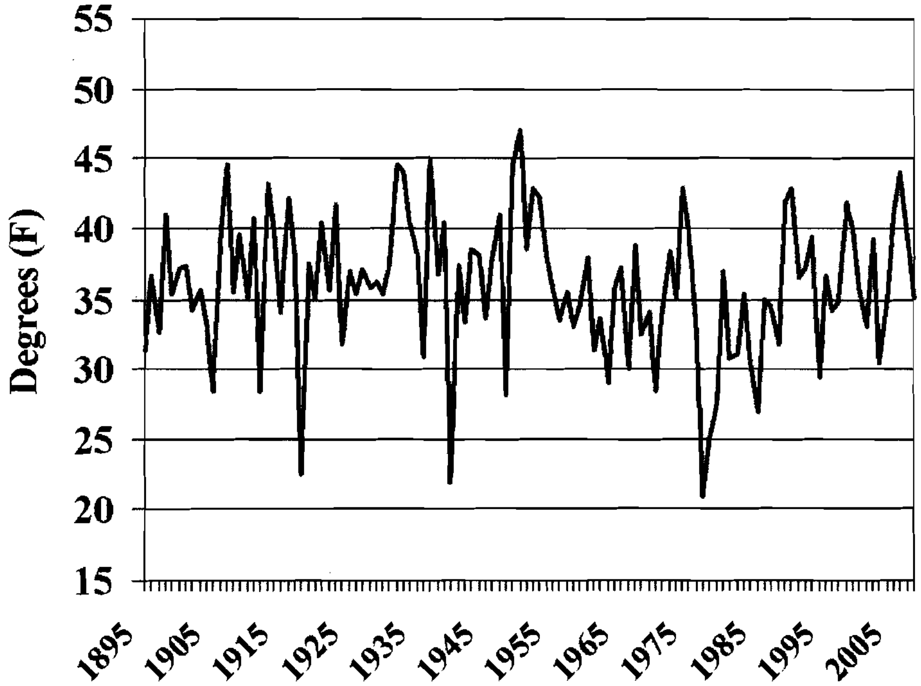

Figure 2. Average January temperatures in KY & TN, 1895-2008.

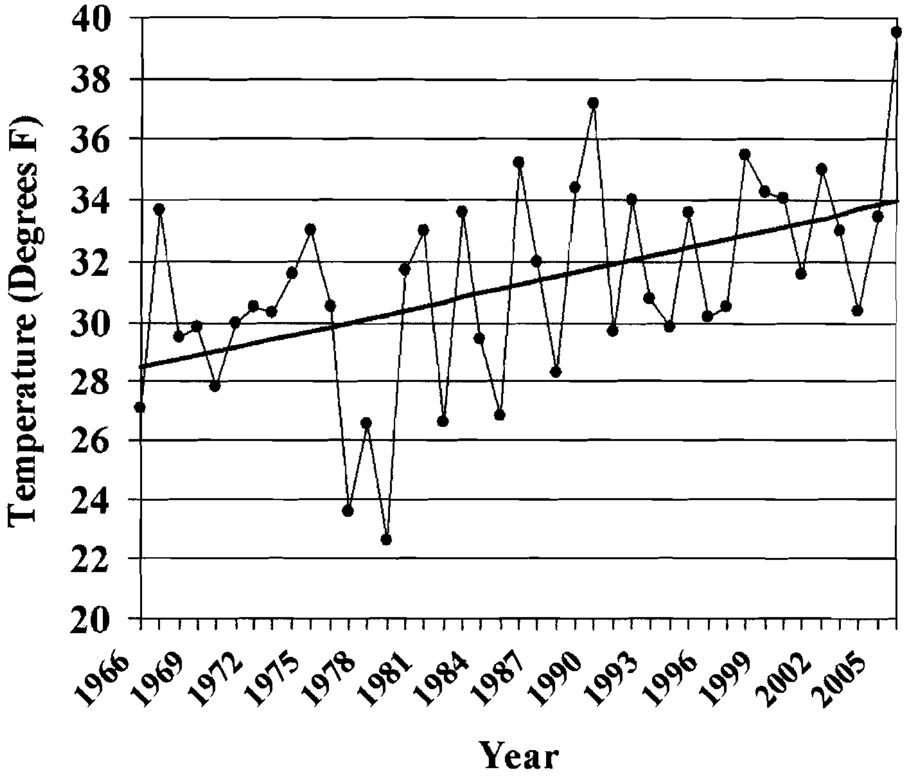

Figure 3. Changes in average January temperature across the contiguous 48 states.

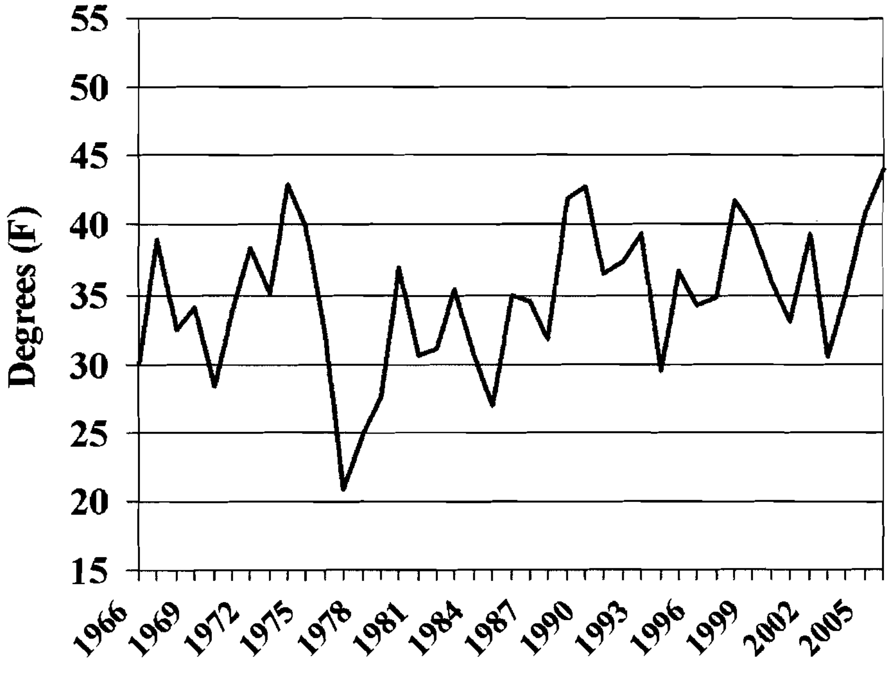

Figure 4. Average January temperatures in KY & TN.

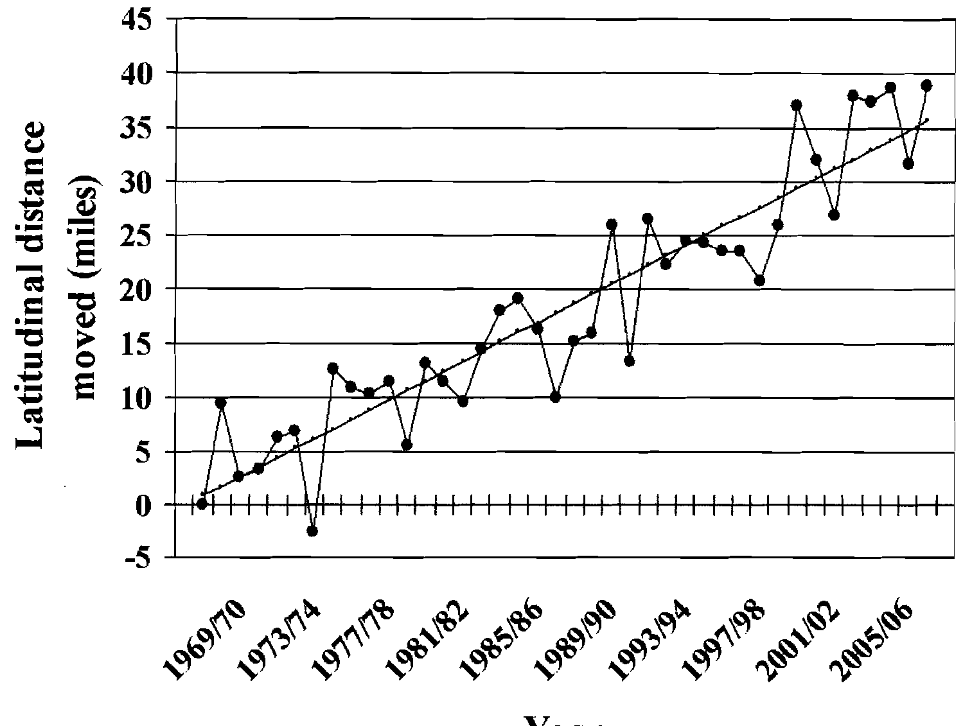

Figure 5. Change in mean latitude center of abundance among 305 widespread bird species in North America.

Five of the six guilds were found in Tennessee and Kentucky: waterbirds (53 species), woodland birds (46 species), shrubland birds (16 species), grassland birds (11 species), and generalists (16 species; Table 1, Appendix). The majority of birds in four of the five groups moved significantly north, but only 5 of the 11 grassland birds (45%) moved significantly north, while 4 (36%) shifted significantly south, the highest proportion of any group. Among the Tennessee and Kentucky waterbirds, 33 (62%) moved north; among woodland birds, 35 (76%) shifted north; among shrubland birds, 13 (81%) moved north; and among the generalists, 10 (62%) shifted north (Table 1, Appendix).

Feeder Use Among Landbirds

We divided the national landbird guild into those that regularly, occasionally, or rarely/never use supplemental food provided at bird feeders. All three of these groups of landbirds shifted their centers of abundance significantly to the north (Niven et al. 2009b); however, regular feeder users shifted north more than occasional feeder users or non-feeder users. Among the Tennessee and Kentucky landbirds, 40 regularly use feeders, 27 occasionally use feeders, and 22 rarely or never use feeders (Table 1, Appendix). Among the regular feeder users, 33 (82%) moved significantly north; among the occasional feeder users, 16 (59%) moved north; and among the species that rarely or never used feeders, 14 (64%) shifted north.

Because feeder users and woodland landbirds both are among the groups with the strongest patterns of northward shifts and many of the feeder users are also woodland birds, we divided woodland birds by feeder use status. Each group of woodland species showed highly significant northward shifts in the center of their ranges (Niven et al. 2009b). Therefore, the northward shifts in the distribution of woodland birds occurred independently of their feeder-use. In Tennessee and Kentucky, half the woodland species in the study regularly use feeders (23 of 46). Among the regular feeder users, 20 (87%) moved significantly north; among the occasional feeder users, 9 (60%) of 15 shifted north; and among the species that rarely or never use feeders, 6 (75%) of 8 moved north (Table 1, Appendix).

Table 1. Proportion of species in Tennessee and Kentucky that shifted their centers of abundance

	Total	Shifted north		No significant movement		Shifted south	
		n	%	n	%	n	%
All birds	142	96	68%	16	11%	30	21%
Waterbirds	53	33	62%	7	13%	13	25%
Woodland birds	46	35	76%	5	11%	6	13%
Shrubland birds	16	13	81%	1	6%	2	12%
Grassland birds	11	5	45%	2	18%	4	36%
Generalists	16	10	62%	1	6%	5	31%
All feederbirds	40	33	82%	1	2%	6	15%
Occasional feederbirds	27	16	59%	5	19%	6	22%
Non-feeder birds	22	14	64%	3	14%	5	23%
Woodland feederbirds	23	20	87%	1	4%	2	9%
Woodland occasional feederbirds	15	9	60%	3	20%	3	20%
Woodland non-feederbirds	8	6	75%	1	12%	1	12%

Species Less Common in Kentucky and Tennessee

Fifty-one of the 142 species have their centers of abundance north of Tennessee; 21 of those (41.2%) show a lower population trend in Tennessee than continentally. Ninety-one species have their centers of abundance near Tennessee or farther south; 17 of those (only 18.7%) show a lower population trend in Tennessee than continentally. Several bird species are shifting their ranges northward in winter, have centers of abundance north of Kentucky and Tennessee, are decreasing in population in Kentucky or Tennessee over the past 40 years, but are stable or increasing continentally (Tables 2 and 3). Common Merganser, American Black Duck, and Dark-eyed Junco made the list for both states. In Kentucky, Rough-legged Hawk, Red-breasted Merganser, Hairy Woodpecker, American Crow, and Pine Siskin are less common now even though they are stable or increasing in population continentally.

Species More Common in Kentucky and Tennessee

Of the 91 species that have their centers of abundance near Tennessee or farther south; 74 of them (81.3%) show a more positive population trend in Tennessee than nationally. Of the 51 species with centers of abundance north of Tennessee, 29 (only 56.9%) show a more positive trend in Tennessee than nationally. Several species are shifting their winter ranges northward, have a center of abundance south of Kentucky and Tennessee, are more common now in Kentucky or Tennessee than they were 40 years ago, and are increasing more in these states than they are continentally (Tables 2 and 3). Five species make this list for both states: Northern Shoveler, Eastern Phoebe, House Wren, Hermit Thrush, and Chipping Sparrow. In Kentucky, the following additional species are increasing more in state than they are continentally: Ruddy Duck, American Woodcock, Cedar Waxwing, American Robin, and White-throated Sparrow. Additional species that are increasing more than average in Tennessee include Snow Goose, Black Vulture, Sandhill Crane, Brown-headed Nuthatch, and Brown Thrasher.

Overall, the last 40 years have been good for the 142 widespread species that winter in Tennessee. Of the 142 species, 103 species (72.5%) are doing better in Tennessee than continentally; 38 are doing worse; and one has the same trend nationally and in Tennessee.

Table 2. Species that increased or decreased in Tennessee relative to the continental average.

Species	Distance moved to north continentally over 40-yrs (miles)	Center of abundance is North or South of state	40-yr State cumulative population change	40-yr Continental cumulative population change	State trend relative to continental trend
Common Merganser*	105.6	North	-92.9%	158.2%	lower
American Black Duck*	182.0	North	-81.0%	8.3%	lower
Dark-eyed Junco*	116.1	North	-38.8%	-4.7%	lower
Brown Thrasher	34.3	South	32.2%	-62.9%	higher
Black Vulture	51.9	South	4425.9%	1238.4%	higher
Snow Goose	217.1	South	5947.7%	1574.9%	higher
Northern Shoveler*	78.5	South	3279.9%	818.3%	higher
Eastern Phoebe*	47.9	South	1238.4%	226.2%	higher
Hermit Thrush*	91.4	South	689.1%	67.6%	higher
House Wren*	34.1	South	1843.7%	32.2%	higher
Chipping Sparrow*	11.4	South	15742.9%	438.7%	higher
Brown-headed Nuthatch	23.0	South	23201.5%	32.2%	higher
Sandhill Crane	37.8	South	17861150.6%	481.6%	higher

*Also in Kentucky table

Table 3. Species that increased or decreased in Kentucky relative to the continental average.

Species	Distance moved to north continentally over 40-yrs (miles)	Center of abundance is North or South of state	40-yr State cumulative population change	40-yr Continental cumulative population change	State trend relative to continental trend
Common Merganser*	105.6	North	-84.5%	158.2%	lower
American Black Duck*	182.0	North	-91.9%	8.3%	lower
Rough-legged Hawk	178.7	North	-86.7%	-2.4%	lower
American Crow	88.8	North	-57.2%	158.2%	lower
Red-breasted Merganser	316.9	North	-66.8%	-3.5%	lower
Pine Siskin	288.2	North	-24.2%	48.9%	lower
Dark-eyed Junco*	116.1	North	-48.8%	-4.7%	lower
Hairy Woodpecker	135.2	North	-31.2%	22.1%	lower
White-throated Sparrow	109.1	South	138.8%	-6.6%	higher
Northern Shoveler*	78.5	South	2611.4%	818.3%	higher
American Woodcock	52.7	South	129.6%	-32.8%	higher
American Robin	206.0	South	311.5%	22.1%	higher
Hermit Thrush*	91.4	South	504.3%	67.6%	higher
Cedar Waxwing	189.2	South	968.1%	158.2%	higher
Eastern Phoebe*	47.9	South	1397.4%	226.2%	higher
House Wren*	34.1	South	527.9%	32.2%	higher
Chipping Sparrow*	11.4	South	3158.3%	438.7%	higher
Ruddy Duck	13.5	South	928.6%	17.3%	higher

*Also in Tennessee table

DISCUSSION

Tennessee and Kentucky were unusual among the 48 contiguous states in the last 40 years because January temperatures rose only slightly, whereas January temperatures rose significantly in the 48 states as a whole during that time period. Not surprisingly, a majority of the common and widespread bird species shifted to the north on the Christmas Bird Count during this period of warmer weather. We found strong evidence that the northward shifts in winter range are caused by the warmer temperatures: 1) Annual variation in latitudinal centers of avian abundance is correlated with annual variation in temperature. 2) Among the lower 48 states, rates of population change are correlated with rates of temperature change, independent of latitude. 3) Northward movements were found among almost all types of birds, indicating that a general factor such as temperature must be responsible, rather than anything specific to a particular habitat or guild (Niven et al. in prep.). Our results support the findings of LaSorte and Thompson (2007) and Hitch and Leberg (2007). In all three of these studies (including ours) the average yearly shift north was approximately 1 mile per year. Additionally, in our study the average distance moved by only those species that shifted significantly to the north was 98.6 miles, or 2.5 miles per year.

Evidence from well studied species such as the Carolina Wren supports this claim as well, since there is strong evidence that range expansions to the north have been reversed during harsh winters (Mehlman 1997).

Our study has shown that birds are good indicators of warming winter weather. The results do not suggest that the birds that moved over the past 40 years have suffered because of that movement; in fact, 106 of the 142 widespread species (74.6%) had positive trends over the past 40 years in Tennessee. The major explanation for differences in population change over the last 40 years appears to be habitat type: waterbirds, woodland birds, and generalists are all increasing, while shrubland and grassland birds are declining (comparison of means in the Appendix). However, within those groups, birds that shifted significantly north did better than species that did not (Appendix).

If current levels of winter temperatures were expected to continue, then there would be no reason for concern for the future of most of the bird species included in this study. However, the IPCC (2007) has predicted that global warming will continue indefinitely unless humans act to curb the release of greenhouse gases into the atmosphere. If that happens, then many of the species doing well over the past 40 years may not do so well in the future. For example, most plants and many animals are not able to respond to warmer winters as quickly as birds can; thus, bird habitats and food supply may not be sufficient in the future to support northern birds even if winter temperatures are warm enough.

Our study showed that bird species varied greatly in the rate of northward movement (Appendix). Non-avian species will also vary greatly, with many moving much more slowly. Such differences in the rate of movement may lead to ecological disruption of natural communities (Niven et al. 2009). And many species that are dependent on specialized habitats (such as salt marshes) or non-migratory species restricted to oceanic islands or habitat islands (such as mountaintop habitats) may not possess the ability to disperse to new areas as conditions change and may be severely affected by climatic changes.

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APPENDIX

KEY TO APPENDIX:

Migration Codes

TM =Temperate (short-distance) migrant
NM =Neotropical (long-distance) migrant
PR =Permanent resident (non-migrant)
EX =Exotic (introduced, non-native species)

Feeder use

O =occasional

Species 40-yr mean latitude =the average latitudinal center of abundance for the species over the 40-year period of the study (in degrees of latitude)

Latitude compared to Tennessee

N =North
S =South
Close =within 2 degrees latitude of Tennessee's mean latitude

Latitude yr40 – Latitude yr1 (in miles)

Shift in the center of abundance from the beginning of the study to the end

Estimated lat yr40 and Estimated lat yr1

Center of abundance at the beginning and end of the study as determined by regression analysis of the center abundance during each year of the study

Stratum median trend

Median annual population trend calculated for Tennessee for the 40 years of the study (percent change per year)

Continental median trend

Median annual population trend calculated for North America for the 40 years of the study (percent change per year)

Stratum trend minus Continental trend

The difference between the species trend for Tennessee and for North America

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NOTE: Both Canada Goose and Northern Oriole are listed as lumped. Currently, Canada and Cackling Goose are considered separate species as are Baltimore and Bullock's Orioles. However, in the recent past the two geese were lumped together under the name Canada Goose, and the two orioles were lumped as Northern Oriole. Because all four species can occur in Kentucky and Tennessee and the data were not recorded separately for many years, we report information on these species as though they were still lumped

Species	States	Migration code	Feeder use	Urban	Species 40-yr mean latitude - Tennessee's mean latitude	Species 40-yr mean latitude compared to Tennessee	Species 40-yr mean latitude	Tennessee's mean latitude	Latitude yr40 - Latitude yr1	Latitude yr40 GT Latitude yr1	Estimated lat yr40	Estimated lat yr1	TRENDS	Stratum trend minus Cont trend	Stratum trend GT Cont trend	Stratum median trend	Stratum median trend > 0	Cont median trend	Cont median trend > 0
WATERBIRDS																			
Moved north:																			
Ring-billed Gull	Both	TM	no	yes	-1.84	S	34.02	35.85	**355.8**	1	36.59	31.44		6.90	1	10.50	1	3.60	1
Red-breasted Merganser	Both	TM	no		6.53	N	42.38	35.85	**316.9**	1	44.68	40.09		2.19	1	2.10	1	-0.09	
Virginia Rail	TN	TM	no		2.57	N	38.43	35.85	**231.6**	1	40.10	36.75		-3.00		0.00		3.00	1
Ring-necked Duck	Both	TM	no		-0.08	S	35.78	35.85	**219.2**	1	37.36	34.19		-0.70		3.40	1	4.10	1
Snow Goose	Both	TM	no		-2.72	S	33.14	35.85	**217.1**	1	34.71	31.56		3.50	1	10.80	1	7.30	1
American Black Duck	Both	TM	no		6.94	N	42.80	35.85	**182.0**	1	44.12	41.48		-4.27		-4.07		0.20	1
Green-winged Teal	Both	TM	no		0.70	Close	36.56	35.85	**157.2**	1	37.70	35.42		1.70	1	2.80	1	1.10	1
Gadwall	Both	TM	no		-1.94	S	33.91	35.85	**148.9**	1	34.99	32.84		2.60	1	7.70	1	5.10	1
Sora	TN	NM	no		-2.17	S	33.69	35.85	**130.7**	1	34.64	32.74		-1.41		-0.41		1.00	1
Tundra Swan	TN	TM	no		5.38	N	41.24	35.85	**129.1**	1	42.17	40.30		3.81	1	3.40	1	-0.41	
"Canada" Goose (lumped)	Both	TM	o	yes	5.18	N	41.03	35.85	**119.9**	1	41.90	40.16		-0.50		10.50	1	11.00	1
Double-crested Cormorant	Both	TM	no		-3.94	S	31.92	35.85	**117.4**	1	32.77	31.07		13.20	1	20.10	1	6.90	1
Great Egret	TN	NM	no		-5.04	S	30.81	35.85	**109.8**	1	31.61	30.02		0.60	1	5.80	1	5.20	1
Common Merganser	Both	TM	no		9.99	N	45.85	35.85	**105.6**	1	46.61	45.08		-8.81		-6.41		2.40	1
Rusty Blackbird	Both	TM	no		-0.79	S	35.06	35.85	**100.9**	1	35.79	34.33		1.71	1	-3.75		-5.46	
Belted Kingfisher	Both	TM	no		1.05	Close	36.90	35.85	**98.2**	1	37.61	36.19		0.30	1	1.10	1	0.80	1
Northern Pintail	Both	TM	no		0.76	Close	36.61	35.85	**91.0**	1	37.27	35.95		4.29	1	1.90	1	-2.39	
Northern Shoveler	Both	TM	no		-1.82	S	34.03	35.85	**78.5**	1	34.60	33.47		3.50	1	9.20	1	5.70	1
Dunlin	Both	TM	no		8.02	N	43.87	35.85	**71.1**	1	44.39	43.36		0.71	1	-0.07		-0.78	
Redhead	Both	TM	no		-0.17	S	35.68	35.85	**68.1**	1	36.18	35.19		-4.16		-2.16		2.00	1
Pied-billed Grebe	Both	TM	no		-1.40	S	34.45	35.85	**63.6**	1	34.91	33.99		0.40	1	1.60	1	1.20	1
Green Heron	TN	NM	no		-4.06	S	31.79	35.85	**61.9**	1	32.24	31.34		-2.54		-3.05		-0.51	
Least Sandpiper	TN	NM	no		-1.63	S	34.22	35.85	**57.4**	1	34.64	33.81		7.32	1	7.10	1	-0.22	
American Woodcock	Both	TM	no		-2.60	S	33.26	35.85	**52.7**	1	33.64	32.88		2.49	1	1.50	1	-0.99	

Species	States	Migration code	Feeder use	Urban	Species 40-yr mean latitude - Tennessee's mean latitude	Species 40-yr mean latitude compared to Tennessee	Species 40-yr mean latitude	Tennessee's mean latitude	Latitude yr40 - Latitude yr1	Latitude yr40 GT Latitude yr1	Estimated lat yr40	Estimated lat yr1	TRENDS	Stratum trend minus Cont trend	Stratum trend GT Cont trend	Stratum median trend	Stratum median trend > 0	Cont median trend	Cont median trend > 0
Horned Grebe	Both	TM	no		11.55	N	47.40	35.85	**50.5**	1	47.77	47.04		1.48	1	0.30	1	-1.18	
Dunlin	TN	NM	no		-5.02	S	30.83	35.85	**45.0**	1	31.16	30.51		8.97	1	8.60	1	-0.37	
Sandhill Crane	TN	TM	no		-3.84	S	32.02	35.85	**37.8**	1	32.29	31.74		30.80	1	35.30	1	4.50	1
Wood Duck	Both	TM	no		-2.07	S	33.79	35.85	**37.1**	1	34.06	33.52		-1.70		2.00	1	3.70	1
Marsh Wren	TN	TM	no		1.60	Close	37.45	35.85	**25.2**	1	37.64	37.27		4.60	1	6.30	1	1.70	1
Herring Gull	Both	TM	no	yes	7.54	N	43.40	35.85	**23.8**	1	43.57	43.22		-1.01		-1.62		-0.61	
Fish Crow	TN	PR	no	yes	-6.19	S	29.66	35.85	**15.1**	1	29.77	29.55		-6.24		-5.14		1.10	1
Ruddy Duck	Both	TM	no		0.50	Close	36.35	35.85	**13.5**	1	36.45	36.26		5.80	1	6.20	1	0.40	1
Osprey	Both	NM	no		-5.86	S	29.99	35.85	**10.7**	1	30.07	29.91		-5.00		1.70	1	6.70	1
MEAN					**0.46**				**107.4**					**2.05**		**4.04**		**1.99**	
N=33; SUM										**33**					**21**		**23**		**22**
Moved South:																			
Le Conte's Sparrow	TN	TM	no		-3.08	S	32.78	35.85	**-25.6**		32.59	32.96		2.60	1	3.10	1	0.50	1
Black-crowned Night-Heron	Both	TM	no		-1.89	S	33.96	35.85	**-34.1**		33.71	34.21		7.00	1	10.00	1	3.00	1
Spotted Sandpiper	TN	NM	no		-2.48	S	33.38	35.85	**-34.3**		33.13	33.62		1.70	1	2.60	1	0.90	1
Bald Eagle	Both	TM	no		11.97	N	47.83	35.85	**-47.1**		47.49	48.17		-1.90		4.10	1	6.00	1
American Wigeon	Both	TM	no		6.16	N	42.02	35.85	**-70.7**		41.50	42.53		-1.48		-0.48		1.00	1
Canvasback	Both	TM	no		0.83	Close	36.68	35.85	**-74.4**		36.14	37.22		3.26	1	0.80	1	-2.46	
Hooded Merganser	Both	TM	no		2.90	N	38.76	35.85	**-93.4**		38.08	39.43		0.30	1	6.00	1	5.70	1
Common Loon	Both	TM	no		9.08	N	44.93	35.85	**-95.4**		44.24	45.62		2.20	1	3.20	1	1.00	1
Common Goldeneye	Both	TM	no		10.80	N	46.65	35.85	**-122.7**		45.76	47.54		-7.95		-6.65		1.30	1
Mute Swan	TN	EX	no	yes	7.67	N	43.52	35.85	**-122.9**		42.63	44.41		2.10	1	10.90	1	8.80	1
Greater Scaup	Both	TM	no		14.83	N	50.69	35.85	**-135.7**		49.71	51.67		8.98	1	7.00	1	-1.98	
Bonaparte's Gull	Both	TM	no		1.06	Close	36.91	35.85	**-238.2**		35.19	38.64		12.50	1	14.40	1	1.90	1
Bufflehead	Both	TM	no		10.08	N	45.93	35.85	**-267.4**		44.00	47.87		0.50	1	3.50	1	3.00	1
MEAN					**5.23**				**-104.7**					**2.29**		**4.50**		**2.20**	
N=13; SUM										**0**					**10**		**11**		**11**

Species	States	Migration code	Feeder use	Urban	Species 40-yr mean latitude - Tennessee's mean latitude	Species 40-yr mean latitude compared to Tennessee	Species 40-yr mean latitude	Tennessee's mean latitude	Latitude yr40 - Latitude yr1	Latitude yr40 GT Latitude yr1	Estimated lat yr40	Estimated lat yr1	TRENDS	Stratum trend minus Cont trend	Stratum trend GT Cont trend	Stratum median trend	Stratum median trend > 0	Cont median trend	Cont median trend > 0
No significant movement:																			
Lesser Scaup	Both	TM	no		-1.41	S	34.44	35.85	**61.0**	1	34.89	34.00		-0.89		-0.49		0.40	1
Wilson's Snipe	Both	TM	no		-0.37	S	35.48	35.85	**18.0**	1	35.61	35.35		0.80	1	-0.63		-1.43	
American Coot	Both	TM	no		-0.33	S	35.52	35.85	**12.4**	1	35.61	35.43		0.55	1	0.50	1	-0.05	
Sedge Wren	TN	TM	no		-4.26	S	31.60	35.85	**5.1**	1	31.64	31.56		2.30	1	4.10	1	1.80	1
Great Blue Heron	Both	TM	no		0.17	Close	36.02	35.85	**-1.5**		36.01	36.03		3.60	1	6.20	1	2.60	1
Swamp Sparrow	Both	TM	o		-2.42	S	33.44	35.85	**-1.7**		33.42	33.45		1.13	1	1.10	1	-0.03	
Blue-winged Teal	Both	NM	no		-5.15	S	30.71	35.85	**-4.2**		30.68	30.74		-0.20		2.50	1	2.70	1
MEAN					**-1.97**				**12.7**					**1.04**		**1.90**		**0.86**	
N=7; SUM										4					**5**		**5**		4
WOODLAND BIRDS																			
Moved North:																			
Purple Finch	Both	TM	y		4.26	N	40.11	35.85	**433.0**	1	43.25	36.98		1.35	1	-0.92		-2.27	
Wild Turkey	Both	PR	o		4.20	N	40.05	35.85	**407.6**	1	43.01	37.10		3.90	1	18.20	1	14.30	1
Pine Siskin	Both	TM	y		10.71	N	46.56	35.85	**288.2**	1	48.65	44.48		2.30	1	3.30	1	1.00	1
Red-breasted Nuthatch	Both	TM	y		8.98	N	44.84	35.85	**244.4**	1	46.61	43.07		-0.80		2.90	1	3.70	1
American Robin	Both	TM	o	yes	-0.26	S	35.59	35.85	**206.0**	1	37.09	34.10		6.20	1	6.70	1	0.50	1
Northern Flicker	Both	TM	y		2.60	N	38.45	35.85	**192.5**	1	39.84	37.06		0.64	1	0.40	1	-0.24	
Cedar Waxwing	Both	TM	o	yes	0.15	Close	36.00	35.85	**189.2**	1	37.37	34.63		7.20	1	9.60	1	2.40	1
Winter Wren	Both	TM	o		7.80	N	43.65	35.85	**138.8**	1	44.66	42.65		0.60	1	2.00	1	1.40	1
Hairy Woodpecker	Both	PR	y		7.29	N	43.14	35.85	**135.2**	1	44.12	42.16		0.00		0.50	1	0.50	1
Pileated Woodpecker	Both	PR	y		1.51	Close	37.36	35.85	**125.3**	1	38.27	36.45		-0.80		0.70	1	1.50	1
Dark-eyed Junco	Both	TM	y		3.57	N	39.43	35.85	**116.1**	1	40.27	38.59		-1.10		-1.22		-0.12	
Eastern Bluebird	Both	TM	y		-0.73	S	35.13	35.85	**114.5**	1	35.96	34.30		1.90	1	5.50	1	3.60	1
White-throated Sparrow	Both	TM	y		-0.96	S	34.89	35.85	**109.1**	1	35.68	34.10		1.27	1	1.10	1	-0.17	
Barred Owl	Both	PR	no		0.37	Close	36.23	35.85	**103.8**	1	36.98	35.48		1.70	1	3.20	1	1.50	1
Brown Creeper	Both	TM	y		4.93	N	40.79	35.85	**103.8**	1	41.54	40.03		0.20	1	0.60	1	0.40	1

Species	States	Migration code	Feeder use	Urban	Species 40-yr mean latitude - Tennessee's mean latitude	Species 40-yr mean latitude compared to Tennessee	Species 40-yr mean latitude	Tennessee's mean latitude	Latitude yr40 - Latitude yr1	Latitude yr40 GT Latitude yr1	Estimated lat yr40	Estimated lat yr1	TRENDS	Stratum trend minus Cont trend	Stratum trend GT Cont trend	Stratum median trend	Stratum median trend > 0	Cont median trend	Cont median trend > 0
Hermit Thrush	Both	TM	o		-1.24	S	34.61	35.85	**91.4**	1	35.28	33.95		4.00	1	5.30	1	1.30	1
Black-capped Chickadee	TN	PR	y		9.51	N	45.36	35.85	**90.3**	1	46.01	44.71		-1.60		0.50	1	2.10	1
Blue Jay	Both	TM	y		3.69	N	39.55	35.85	**89.1**	1	40.19	38.90		-0.40		0.20	1	0.60	1
Golden-crowned Kinglet	Both	TM	o		7.02	N	42.88	35.85	**87.3**	1	43.51	42.25		1.60	1	2.80	1	1.20	1
Red-tailed Hawk	Both	TM	no	yes	2.00	Close	37.86	35.85	**82.4**	1	38.45	37.26		0.30	1	2.70	1	2.40	1
Red-shouldered Hawk	Both	TM	no		-2.69	S	33.17	35.85	**76.2**	1	33.72	32.61		1.00	1	4.00	1	3.00	1
Eastern Screech-Owl	Both	PR	no		1.85	Close	37.70	35.85	**75.2**	1	38.25	37.16		0.70	1	2.00	1	1.30	1
Red-bellied Woodpecker	Both	PR	y		0.34	Close	36.19	35.85	**59.7**	1	36.62	35.76		-0.20		1.60	1	1.80	1
Carolina Wren	Both	PR	y		-1.31	S	34.55	35.85	**57.0**	1	34.96	34.13		0.80	1	3.00	1	2.20	1
Yellow-bellied Sapsucker	Both	TM	y		-1.61	S	34.25	35.85	**50.1**	1	34.61	33.89		1.90	1	2.10	1	0.20	1
Eastern Phoebe	Both	TM	no		-3.89	S	31.97	35.85	**47.9**	1	32.32	31.62		3.70	1	6.70	1	3.00	1
Ruby-crowned Kinglet	Both	TM	y		-1.62	S	34.23	35.85	**45.0**	1	34.56	33.90		1.90	1	3.00	1	1.10	1
Sharp-shinned Hawk	Both	TM	y	yes	2.88	N	38.74	35.85	**37.6**	1	39.01	38.47		1.80	1	4.80	1	3.00	1
House Wren	Both	TM	o		-3.89	S	31.97	35.85	**34.1**	1	32.21	31.72		7.00	1	7.70	1	0.70	1
Downy Woodpecker	Both	PR	y		5.00	N	40.86	35.85	**29.3**	1	41.07	40.64		-0.10		0.90	1	1.00	1
Tufted Titmouse	Both	PR	y		0.99	Close	36.84	35.85	**27.0**	1	37.04	36.65		0.10	1	0.90	1	0.80	1
Brown-headed Nuthatch	TN	PR	y		-2.64	S	33.22	35.85	**23.0**	1	33.38	33.05		13.90	1	14.60	1	0.70	1
"Northern" Oriole (lumped)	TN	NM	o	yes	-1.43	S	34.42	35.85	**21.1**	1	34.57	34.27		1.31	1	-1.41		-2.72	
Blue-headed Vireo	TN	TM	no		-4.32	S	31.54	35.85	**19.4**	1	31.68	31.40		5.60	1	9.10	1	3.50	1
Chipping Sparrow	Both	TM	o	yes	-3.13	S	32.72	35.85	**11.4**	1	32.80	32.64		9.20	1	13.50	1	4.30	1
MEAN					**1.71**				**113.2**					**2.20**		**3.90**		**1.70**	
N=35; SUM										**35**					**27**		**32**		**30**
Moved South:																			
Carolina Chickadee	Both	PR	y		-0.72	S	35.13	35.85	**-14.4**		35.03	35.24		0.70	1	1.50	1	0.80	1
White-breasted Nuthatch	Both	PR	y		5.97	N	41.83	35.85	**-16.8**		41.70	41.95		1.70	1	3.50	1	1.80	1
Pine Warbler	Both	TM	o		-3.43	S	32.42	35.85	**-32.3**		32.19	32.65		3.60	1	6.80	1	3.20	1
Great Horned Owl	Both	PR	no		4.53	N	40.38	35.85	**-43.1**		40.07	40.69		3.10	1	3.50	1	0.40	1

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Merlin	Both	TM	o	yes	6.47	N	42.32	35.85	**-81.5**		41.73	42.91		6.30	1	9.60	1	3.30	1
Red-headed Woodpecker	Both	TM	o		1.15	Close	37.00	35.85	**-170.3**		35.77	38.24		1.35	1	0.10	1	-1.25	
MEAN					**2.33**				**-59.7**					**2.79**		**4.17**		**1.38**	
N=6; SUM										**0**					**6**		**6**		**5**
No significant movement:																			
Red Crossbill	TN	TM	o		13.08	N	48.94	35.85	**38.8**	1	49.22	48.66		-0.64		-2.15		-1.51	
Yellow-rumped Warbler	Both	TM	o		-3.09	S	32.76	35.85	**6.7**	1	32.81	32.71		6.60	1	9.10	1	2.50	1
Ruffed Grouse	Both	PR	o		11.01	N	46.87	35.85	**4.7**	1	46.90	46.83		2.07	1	-0.47		-2.54	
Cooper's Hawk	Both	TM	y	yes	2.60	N	38.46	35.85	**-3.0**		38.43	38.48		2.00	1	5.60	1	3.60	1
Blue-gray Gnatcatcher	TN	TM	no		-5.70	S	30.16	35.85	**-8.7**		30.10	30.22		4.70	1	5.90	1	1.20	1
MEAN					**3.58**				**7.7**					**2.95**		**3.60**		**0.65**	
N=5; SUM										**3**					**4**		**3**		**3**
SHRUBLAND BIRDS																			
Moved North:																			
Fox Sparrow	Both	TM	y		3.28	N	39.13	35.85	**286.8**	1	41.21	37.05		0.47	1	0.10	1	-0.37	
Eastern Towhee	Both	TM	o		0.31	Close	36.16	35.85	**215.0**	1	37.72	34.60		0.27	1	-0.78		-1.05	
Lincoln's Sparrow	TN	TM	o		-2.17	S	33.69	35.85	**165.3**	1	34.88	32.49		4.08	1	4.00	1	-0.08	
Common Yellowthroat	TN	TM	no		-4.77	S	31.08	35.85	**109.3**	1	31.87	30.29		1.52	1	1.30	1	-0.22	
Northern Bobwhite	Both	PR	o		0.46	Close	36.31	35.85	**85.7**	1	36.93	35.69		-2.42		-9.94		-7.52	
Song Sparrow	Both	TM	y		2.46	N	38.32	35.85	**74.5**	1	38.85	37.78		1.20	1	1.60	1	0.40	1
Northern Cardinal	Both	PR	y	yes	0.74	Close	36.60	35.85	**58.9**	1	37.02	36.17		-0.21		-0.29		-0.08	
Bewick's Wren	Both	PR	y		1.82	Close	37.68	35.85	**54.8**	1	38.07	37.28		-13.01		-13.01		0.00	
American Tree Sparrow	Both	TM	y		5.17	N	41.03	35.85	**54.3**	1	41.42	40.63		0.34	1	-1.82		-2.16	
Brown Thrasher	Both	TM	o		-2.95	S	32.91	35.85	**34.3**	1	33.15	32.66		3.15	1	0.70	1	-2.45	
White-crowned Sparrow	Both	TM	y		0.47	Close	36.33	35.85	**21.7**	1	36.48	36.17		2.98	1	2.50	1	-0.48	
Gray Catbird	Both	TM	o		-5.51	S	30.34	35.85	**21.2**	1	30.49	30.19		2.00	1	3.10	1	1.10	1

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Northern Mockingbird	Both	PR	o	yes	-2.48	S	33.37	35.85	**13.5**	1	33.47	33.27		0.37	1	-0.24		-0.61	
MEAN					**-0.24**				**91.9**					**0.06**		**-0.98**		**-1.04**	
N=13; SUM										**13**					**10**		**7**		**2**
Moved South:																			
Loggerhead Shrike	Both	TM	o		-2.86	S	33.00	35.85	**-46.5**		32.66	33.34		-3.67		-6.37		-2.70	
Harris's Sparrow	TN	TM	y		2.31	N	38.17	35.85	**-49.7**		37.81	38.53		3.73	1	1.60	1	-2.13	
MEAN					**-0.27**				**-48.1**					**0.03**		**-2.39**		**-2.42**	
N=2; SUM										**0**					**1**		**1**		**0**
No significant movement:																			
Field Sparrow	Both	TM	o		-1.21	S	34.65	35.85	**11.7**	1	34.73	34.56		1.49	1	-1.67		-3.16	
GRASSLAND BIRDS																			
Moved North:																			
Rough-legged Hawk	Both	TM	no		7.02	N	42.88	35.85	**178.7**	1	44.17	41.58		-0.72		-0.78		-0.06	
Barn Owl	Both	TM	no		1.48	Close	37.34	35.85	**107.1**	1	38.11	36.56		2.20	1	3.20	1	1.00	1
Northern Harrier	Both	TM	no		1.30	Close	37.15	35.85	**76.8**	1	37.71	36.59		1.60	1	1.70	1	0.10	1
Golden Eagle	Both	TM	no		5.48	N	41.33	35.85	**58.3**	1	41.76	40.91		-2.92		-3.12		-0.20	
American Kestrel	Both	TM	no	yes	0.55	Close	36.40	35.85	**54.5**	1	36.79	36.00		1.10	1	1.40	1	0.30	1
MEAN					**3.17**				**95.1**					**0.25**		**0.48**		**0.23**	
N=5; SUM										**5**					**3**		**3**		**3**
Moved South:																			
Savannah Sparrow	Both	TM	o		-2.80	S	33.05	35.85	**-32.1**		32.82	33.28		3.50	1	4.80	1	1.30	1
Eastern Meadowlark	Both	TM	o		-2.01	S	33.85	35.85	**-34.1**		33.60	34.10		0.62	1	-2.65		-3.27	
American Pipit	Both	TM	no		-1.16	S	34.69	35.85	**-86.2**		34.07	35.31		12.87	1	11.90	1	-0.97	
Short-eared Owl	Both	TM	no		7.37	N	43.23	35.85	**-207.4**		41.72	44.73		8.06	1	4.60	1	-3.46	
MEAN					**0.35**				**-90.0**					**6.26**		**4.66**		**-1.60**	
N=4; SUM										**0**					**4**		**3**		**1**
No significant movement:																			

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Horned Lark	Both	TM	o		3.71	N	39.57	35.85	**4.8**	1	39.60	39.53		-2.19		-4.99		-2.80	
Vesper Sparrow	Both	TM	no		-3.31	S	32.55	35.85	**-8.3**		32.49	32.61		4.63	1	2.60	1	-2.03	
MEAN					**0.20**				**-1.7**					**1.22**		**-1.20**		**-2.42**	
N=2; SUM										**1**					**1**		**1**		**0**
GENERALISTS																			
Moved North:																			
American Goldfinch	Both	TM	y		2.71	N	38.56	35.85	**219.1**	1	40.15	36.98		-1.10		0.40	1	1.50	1
Mourning Dove	Both	TM	y	yes	0.83	Close	36.68	35.85	**147.3**	1	37.75	35.62		0.10	1	2.60	1	2.50	1
Red-winged Blackbird	Both	TM	y		-1.79	S	34.06	35.85	**99.3**	1	34.78	33.35		-2.41		-2.31		0.10	1
American Crow	Both	TM	y	yes	3.56	N	39.41	35.85	**88.8**	1	40.05	38.77		-1.40		1.00	1	2.40	1
European Starling	Both	EX	y	yes	3.70	N	39.56	35.85	**85.6**	1	40.18	38.94		-1.97		-1.27		0.70	1
House Sparrow	Both	EX	y	yes	6.49	N	42.34	35.85	**77.4**	1	42.90	41.78		-0.70		-2.91		-2.21	
Turkey Vulture	Both	NM	no		-4.03	S	31.83	35.85	**53.2**	1	32.21	31.44		2.00	1	6.90	1	4.90	1
Black Vulture	Both	PR	no		-3.97	S	31.89	35.85	**51.9**	1	32.26	31.51		3.30	1	10.00	1	6.70	1
Orange-crowned Warbler	TN	TM	o		-3.75	S	32.11	35.85	**32.2**	1	32.34	31.87		6.70	1	9.40	1	2.70	1
Brewer's Blackbird	Both	TM	y	yes	1.84	Close	37.69	35.85	**13.6**	1	37.79	37.59		4.26	1	1.80	1	-2.46	
MEAN					**0.56**				**86.9**					**0.88**		**2.56**		**1.68**	
N=10; SUM										**10**					**5**		**6**		**8**
Moved South:																			
Brown-headed Cowbird	Both	TM	y		-2.99	S	32.86	35.85	**-18.5**		32.73	32.99		-0.36		-3.41		-3.05	
Common Grackle	Both	TM	y	yes	-2.74	S	33.12	35.85	**-46.3**		32.78	33.45		1.01	1	-3.23		-4.24	
Killdeer	Both	TM	no	yes	-2.09	S	33.77	35.85	**-78.0**		33.20	34.33		2.84	1	2.70	1	-0.14	
Common Raven	TN	PR	y	yes	10.89	N	46.74	35.85	**-135.7**		45.76	47.73		1.00	1	4.90	1	3.90	1
Peregrine Falcon	Both	NM	no	yes	5.02	N	40.87	35.85	**-189.6**		39.50	42.24		0.90	1	5.80	1	4.90	1
MEAN					**1.62**				**-93.6**					**1.08**		**1.35**		**0.27**	
N=5; SUM										**0**					**4**		**3**		**2**
No significant movement:																			
Palm Warbler	Both	NM	no		-6.66	S	29.19	35.85	4.8	1	29.22	29.16		7.30	1	8.90	1	1.60	1

HOW DOES NATURAL HISTORY BECOME SCIENCE, AND WHAT CAN IT TELL US ABOUT CLIMATE CHANGE?

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Abstract. Natural history observations have been important to humans for as long as there have been hunter-gatherer and agricultural societies. They help to prepare for changes in seasons, and in the efficiency of resource gathering. Recognition of the scientific value of natural history and phenological observations is more recent in the USA. For example, it was only last year when the USA National Phenology Network (USA-NPN) became an official effort of the US Geological Survey. I illustrate the use of long-term data on phenology, both plant an animal, to gain insights into how the changing climate is affecting wildflowers and small mammals at high altitudes in the Colorado Rocky Mountains. Emergence times from hibernation by three species of small mammals are changing, but not uniformly among species, and a recent increase in the frequency of frost damage to wildflowers is resulting in a declining population of at least one species. There is a growing appreciation among the general public of the interesting insights that phenological observations can provide in this era of climate change. As they generate, collect, and archive data, the transition from natural history to science occurs, and the data become a valuable resource for scientific studies of the consequences of a changing environment.

There is a long tradition of natural history observations by non-scientists in the southeastern United States and elsewhere. The incentive for making such observations has its roots in agriculture, hunting, fishing, and general interest in nature. Observations of animal behavior are one component of this interest, to answer questions such as how to improve your chances to harvest a turkey, deer, or shad, but another major component of natural history observations is recording the phenology (timing of seasonal events, such as migration, or flowering (Post and Inouye 2008) of species of economic interest. This information could provide guidance, for example, for when is the best time to plant particular crops ("plant corn when oak or maple leaves are the size of squirrel ears"), or shear sheep in the Rocky Mountain region ("when spring sown grain begins to carpet the fields in green") (Smith 1920).

Historical information about phenology could also allow knowledgeable hunters to estimate when the migratory or hibernating game species would appear or disappear, or when anadromous fish would arrive. For example, flowering of *Amelanchier canadensis* was a good cue to when the shad would arrive in rivers along the Atlantic coast, giving rise to its common name "shad bush" (Smith 1920). Another common name for the same plant, in areas not associated with shad, is "service berry", apparently a reference to the fact that it flowered about the time the ground thawed sufficiently for the burial of those who had died during the winter.

Much of the rich tradition of natural history in North America is related to phenological observations. For example, Henry David Thoreau wrote in his journal in 1856 "I soon found myself observing when plants first blossomed and leafed, and I followed it up early and late, far and near, several years in succession, running to different sides of the town and into the neighboring towns, often between twenty and thirty miles in a day" (Thoreau 1962). He listed the first flowering dates for several hundred species of plants in the Concord, MA area. Inspired by Thoreau's work, a shopkeeper named Alfred Hosmer collected similar data on first flowering dates in 1878 and then again from 1888 to 1902 for more than 700 plant species in the Concord area (Hosmer 1899, cited in Miller-Rushing and Primack 2008).

Boston University botanist Richard Primack and his graduate student Abe Miller-Rushing took advantage of these historical data from the Concord area as an opportunity to see how flowering dates had changed since the 19^{th} Century. They collected data from 2005 – 2007 in many of the same sites where Thoreau and Hosmer had made observations (Miller-Rushing and Primack 2008). They found that for the great majority of species flowering was earlier than it had been, and that some species had disappeared from the area. These species losses could be in part due to the changing climate, as phenology was significantly correlated with temperature, which has been warming, with early spring flowers being most strongly affected. However, there also seem to be phylogenetic components (Willis et al. 2008).

Another famous natural historian who collected phenological data of historical interest was Aldo Leopold. From 1936 to 1947 he kept records of a wide range of ecologically important seasonal events at his "Shack" in Sauk County, Wisconsin. The property remained in his family, and his observations were continued by his daughter Nina Leopold Bradley at the same farm from 1976 to 1998, extending the phenological record for a span of 61 years. Their data revealed two different categories of responses, those that changed significantly in response to the changing environment (the majority) and those whose seasonal activity remained constant (Bradley et al. 1999).

At what point did these observations, collected by both non-scientists (e.g., Thoreau and Hosmer) and scientists (e.g., Primack, Miller-Rushing, Leopold), make the transition from natural history to scientific data? Certainly if the data such as Hosmer's had not been rescued from obscurity by scientists, they would never have left the realm of natural history, despite the fact that they had been collected carefully over a long period. The shorter study by Primack and Miller-Rushing could probably have been counted as science from the inception, given the intent of using the data to gain insight into the quantitative relationship between flowering and the changing environment.

Long-term phenological observations related to agriculture (viticulture in particular) have been used recently to gain insight into historical climate. For example, Chuine et al. (2004) used historical records of the dates of French grape harvests in Burgundy to reconstruct spring and summer temperatures from 1370 to 2003 by using a process-based model developed for Pinot Noir grapes. They found that although temperatures as high as those reached in the 1990s had occurred several times since 1370 in Burgundy, the summer of 2003 was probably warmer than any year since 1370. Meier et al. (2007) did a similar reconstruction back to1480 of April to August temperature for Switzerland by using records of grape harvests. But the length of these phenological records, much longer than any available in North America, is still dwarfed by the 1200 year record from Kyoto, Japan, of the flowering of cherry trees (Arakawa 1955, Aono and Omoto 1994, Aono and Kazui 2008), that was used to reconstruct spring temperature history back to the 9th Century.

A more recent example of a natural historian whose data have made the transition from observation to science is work by Billy Barr, a year-round resident of a high-altitude biological research station in Colorado, the Rocky Mountain Biological Laboratory. Since the early 1970s he has collected phenological information on the dates of first sightings of a variety of spring events, including the emergence of small mammals from hibernation, arrival of migratory birds, and first sightings of insects and flowers. (Inouye et al. 2000). For example, Figure 1 shows Barr's data on the first date that he saw a chipmunk (*Tamias minimus*) each year from 1974 – 2008. There is a lot of variation (range from 6 April – 12 May), and these data can make the transition from natural history to science if we use them in a statistical analysis to determine what environmental variables might help to explain this variation in emergence date.

Figure 2 shows the relationship between date of first sighting of a chipmunk and the date that the last snow melted each spring at a permanent snow measurement station that Barr has monitored daily for decades. Although this is a statistically significant relationship, average April temperature (measured at the NOAA weather station in nearby Crested Butte, CO) does a somewhat better job (Figure 3), as does using April heating degree days (Figure 4). It remains to be seen how these correlations translate to causation, which will probably require a better understanding of chipmunk physiology and behavior.

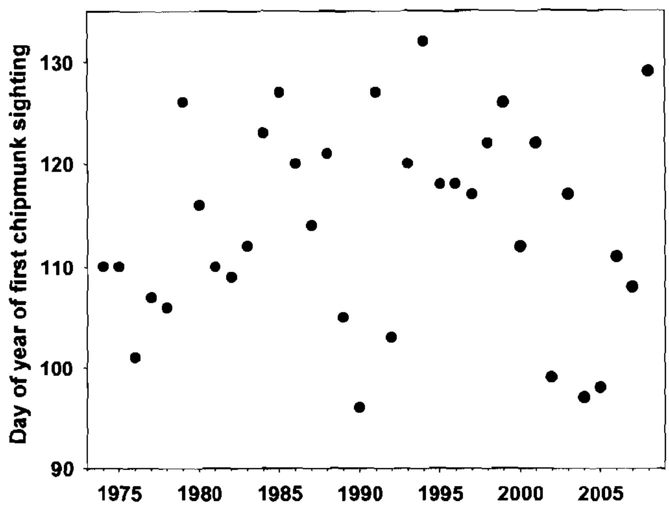

Figure 1. Day of year of the first sighting of a chipmunk (*Tamias minimus*) at the Rocky Mountain Biological Laboratory. Earliest date is 6 April, latest date is 12 May. Data from Billy Barr.

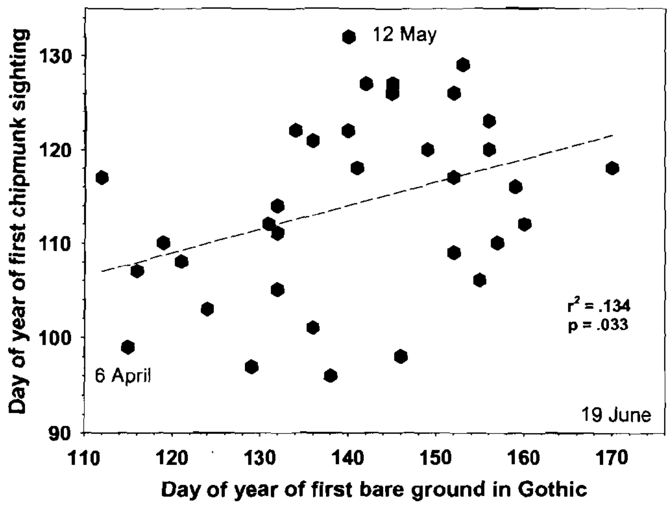

Figure 2. Day of year of the first sighting of a chipmunk at the Rocky Mountain Biological Laboratory, plotted against the date that snow melted at a permanent snow measurement station. Data from Billy Barr. Snowmelt dates ranged from 22 April – 19 June.

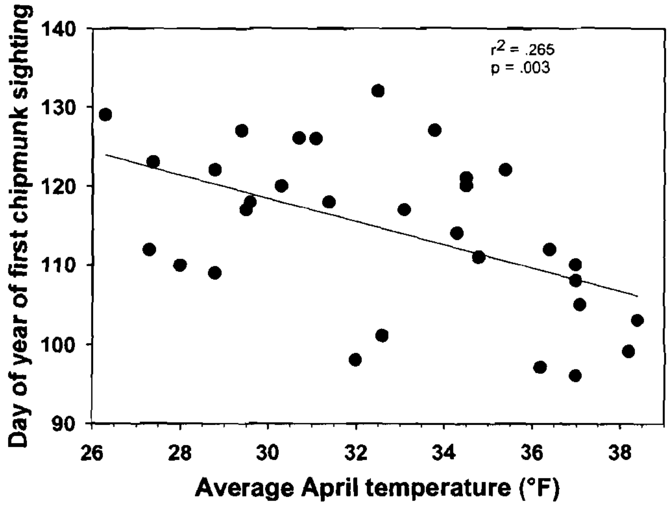

Figure 3. Day of year of the first sighting of a chipmunk at the Rocky Mountain Biological Laboratory, plotted against the average April temperature at the Crested Butte, Colorado, NOAA weather station.

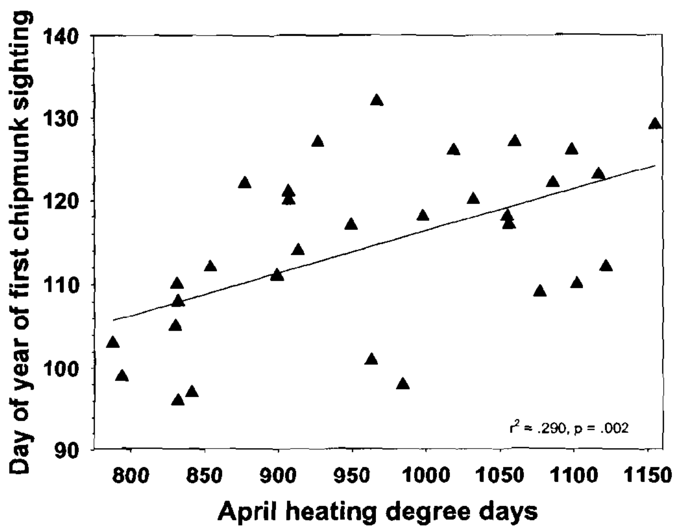

Figure 4. Day of year of the first sighting of a chipmunk at the Rocky Mountain Biological Laboratory, plotted against heating degree days, measured at the Crested Butte, Colorado, NOAA weather station.

Not all small mammals are responding the same way to the changing environment. Figure 5 shows marmots (*Marmota flaviventris*) are emerging about a month earlier than they used to, and responding in a much more linear fashion over the decades than chipmunks (Inouye et al. 2000). The responses of ground squirrels (*Spermophilus lateralis*) differ from both of the other species, although they are more similar to the marmots (Figure 6). Again, a better understanding of the physiology and behavior of these species will be required to understand the causation behind the natural history observations. The fact that the phenology of plants and animals may not be responding similarly to the changing environment also suggests that there may be significant reorganization of ecological communities in the future as the component species change their seasons at different rates. For example, Figure 7 shows that the flowering phenology (mean date of first flower) of *Mertensia fusiformis* and the dates of first sightings of ground squirrels are not changing at the same rate (there is a significant slope to the line relating these two categories of observations).

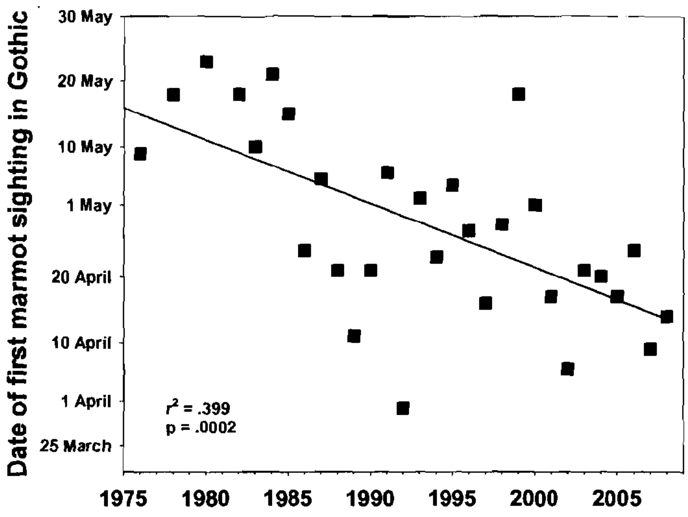

Figure 5. Day of year of the first sighting of a marmot at the Rocky Mountain Biological Laboratory. Data from Billy Barr.

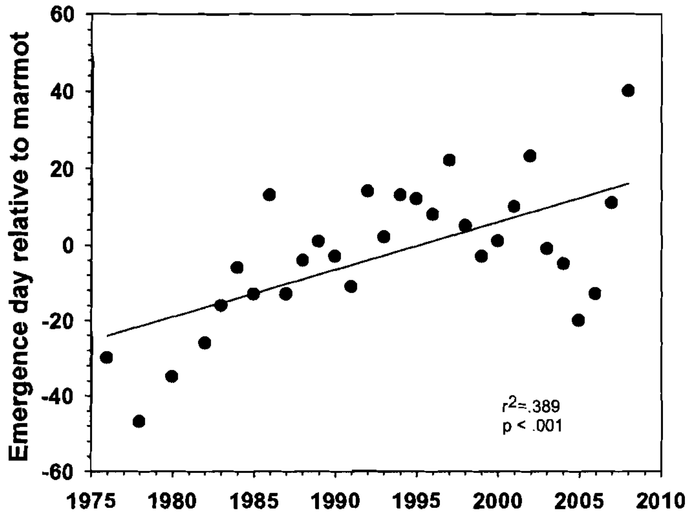

Figure 6. Day of year of the first sighting of a ground squirrel at the Rocky Mountain Biological Laboratory, relative to the day of year of the first sighting of a marmot. Data from Billy Barr.

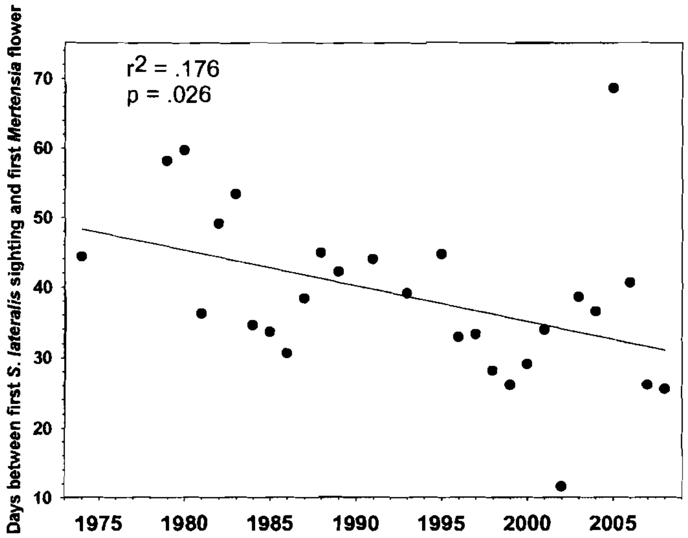

Figure 7. The number of days between the first sighting of a ground squirrel at the Rocky Mountain Biological Laboratory and the mean date of first flowering by *Mertensia fusiformis* at the same field site.

Some of my own work could potentially be classified either as natural history observation or scientific data collection. Since 1974 I have made an annual count of the number of flower heads of the aspen sunflower (*Helianthella quinquenervis*) in two permanent plots at the Rocky Mountain Biological Laboratory. The large range (Figure 8) is explained in part by the occurrence of late spring (early June) frosts, which can kill most or all of the developing flower heads in some years (Figure 9). Much of this variation in frost damage is explained by when the snow melts. In years with early snowmelt, the growing season starts early but there can still be late frosts until early to mid June, while later snowmelt delays development until after the last frost, thereby protecting the heads (Inouye 2008) (Figure 10). The lack of seed production that results from the frost damage is resulting in a declining population of plants (Figure 11).

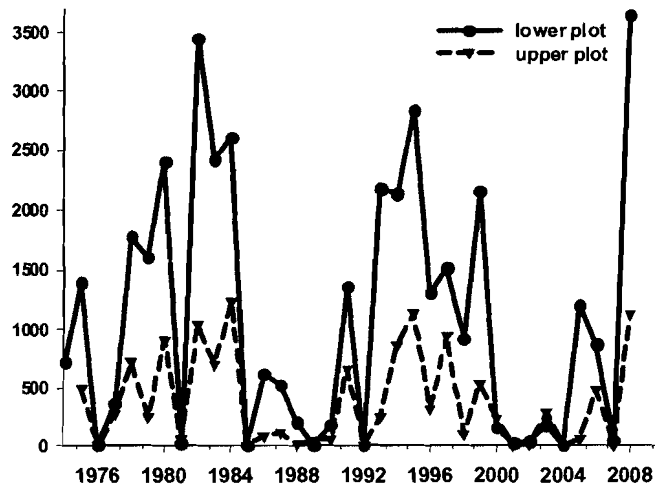

Figure 8. The number of flower heads of *Helianthella quinquenervis* (aspen sunflower) in two plots at the Rocky Mountain Biological Laboratory.

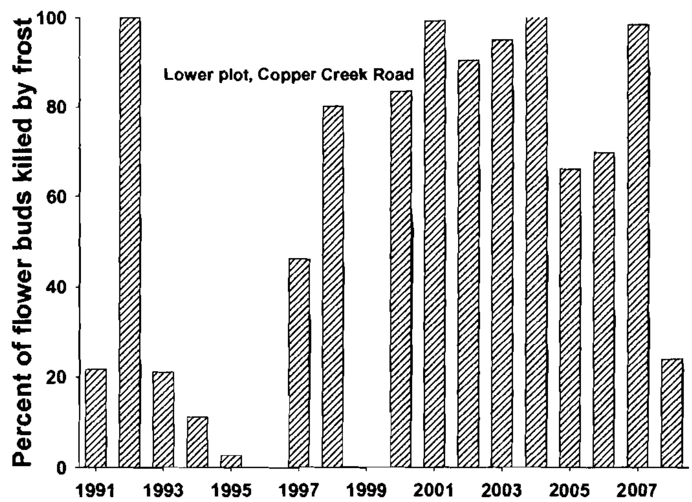

Figure 9. The percent of flower buds of *Helianthella quinquenervis* produced each year from 1991-2008 that have been killed by frost.

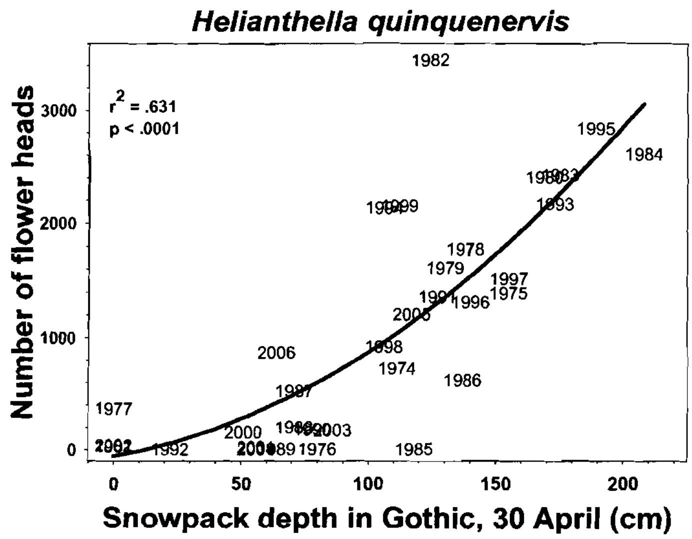

Figure 10. The relationship between number of flower heads of the aspen sunflower and the amount of snow remaining on the ground on 30 April (a good indicator of when snowmelt will occur and the growing season will begin).

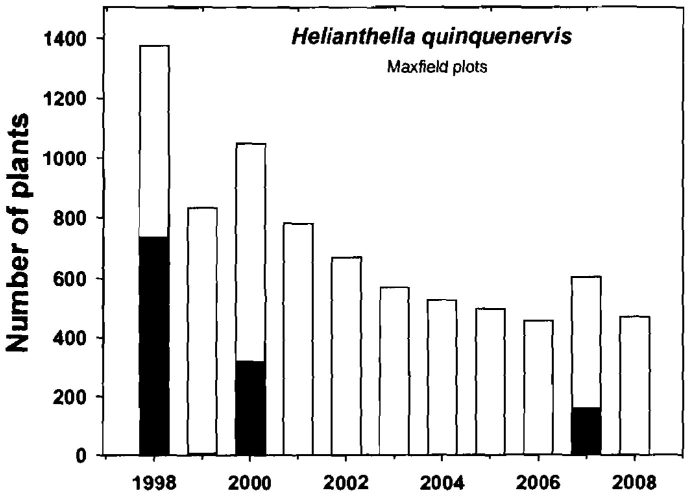

Figure 11. The number of plants of *Helianthella quinquenervis* in six permanent plots near the Rocky Mountain Biological Laboratory. The black sections indicate the number of seedlings, which have only been produced in 4 years.

DISCUSSION

The phenology of both animals and plants is changing at high altitudes, apparently in response to changes in environmental variables including snowpack, snowmelt, and temperature. The fact that the phenological responses are not uniform among species means that there may be significant changes in ecological communities, as the seasonal patterns of activity of plants, herbivores, and pollinators break historical norms. Demographic changes that may result in the loss of some plant and animal species will also result in alternations of historical community ecology.

Although the value of phenological data was readily recognized by those dependent on nature to provide food, the recognition of the scientific value of phenological observations is more recent. For example, it was only last year when the USA National Phenology Network (USA-NPN) became an official effort of the US Geological Survey. The scientific value of these data lies in large part in the insights that they provide into the effects of the changing climate on plant and animal ecology.

There is a growing appreciation among the general public of the interesting insights that phenological observations can provide in this era of climate change. For example, efforts such as the lilac phenology network, Project Budburst, and the USA-NPN have received much attention in the past few years, and a growing network of participants is collecting and contributing data. As these data are generated, collected, and archived, the transition from natural history to science occurs, and they become a valuable resource for scientific studies of the consequences of a changing environment. One effort of the USA-NPN is to discover the long-term data collected by natural historians, gardeners, bird watchers, fishermen, etc., in order to preserve them and take advantage of the information they can provide about the effects of climate on phenology. As our society considers how best to adapt to the new environment being shaped by global climate change, this kind of information will be important to scientists and policy makers.

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LAKES AND RESERVOIRS AS SENSORS OF ENVIRONMENTAL CHANGE: THE VALUE OF LONG-TERM AND HIGH-FREQUENCY MONITORING

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ABSTRACT. Lakes and reservoirs represent the lowest points in their landscapes making them integrators of watershed processes and thus potential sentinels and sensors of long and short-term water quality conditions resulting from climate and land-use changes. While natural lakes are relatively well-studied, much less is known about how reservoirs respond to their landscapes. Kentucky Lake (Tennessee River) and Lake Barkley (Cumberland River) are two of the largest reservoirs in the U.S. Both reservoirs are the farthest downstream water bodies within their respective watersheds, but there is little understanding of how they integrate extremely variable land-use and lateral tributary processes. The Hancock Biological Station/Center for Reservoir Research established a 16-day interval long-term monitoring program on Kentucky Lake in 1988. The value of the long-term monitoring data is apparent by examining physicochemical and biological changes occurring over large spatial and temporal scales. While the 16-day interval provides a wealth of descriptive information, the data often cannot assess cause and effect or the environmental drivers that may function on hourly or daily intervals. Hence, the need arises for collection of real-time or near real-time, high-frequency data using 21st century cyberinfrastructure. Sensors placed on buoys can measure environmental variables at close high-frequency temporal intervals meaningful for forecasting effects on water quality at larger spatial (e.g., continental, global) and temporal (decades, centuries) scales. High resolution, high-frequency data collection and storage are very useful for calibration of predictive models. Instrumentation of our local reservoirs with networks of sensors and cyberinfrastructure enables us to predict and compare with greater accuracy any changes in these sentinel ecosystems that may occur from human activities and to provide data for a variety of other uses to governmental agencies and local citizens.

INTRODUCTION

Freshwater has long been recognized as a critical human resource (e.g., Forbes 1887); however, only within the past few decades have both the scientific and governmental communities begun to examine the connectivity and relationships among lakes, reservoirs, streams, landscapes, and human activity (e.g., Thornton et al. 1990, Jones and Mulholland 2000, Wetzel 2001, Brooks et al. 2003, Magnuson et al. 2005). Very few freshwater habitats remain unaltered or unaffected by human activity (Bates et al. 2008). For example, only one major river in the Ohio River basin, the Wabash, does not have a large dam or lock, but the influences of agriculture, urban development, and species invasions occur throughout its basin (White et al. 2005). Similar analogies can be made for most other lake and river systems around the world (Wetzel 2001). Although the era of major reservoir construction in the United States ended nearly 30 years ago (White 1990), reservoir construction continues in much of the world, with numbers reaching or exceeding 600,000 (Wetzel 2001). How large reservoirs alter their landscapes and watershed processes remains largely unstudied (White 1990, Wetzel 2001). Most research has focused solely on their management for flood control, hydroelectric power, or recreation. Conversely, a similar lack of knowledge occurs for how reservoirs integrate land use changes, climate change, or species invasions. Annual physical, chemical, and biological patterns are well known for natural lakes and somewhat less known for reservoirs (Thornton et al. 1990, Wetzel 2001). The effects of pollution, land-use changes, and altered water budgets on patterns have been extensively documented for some individual systems leading Williamson et al. (2008) to speculate on the ability of lakes and rivers to act as environmental sentinels (also see Mulholland et al. 1997 for southeastern ecosystems).

Reservoirs are the result of impounding streams and rivers, and their surface areas usually represent a much lower fraction of watershed dimensions than do natural lakes. "Reservoirs" range from farm and small millponds with water residence times in months to large mainstem impoundments with residence times usually in days. Small reservoirs are expected to be more lake-like in functions, while mainstem impounds would be more river like (Thornton et al. 1990, Wetzel 2001). Further, because reservoirs of all sizes occupy much less of their watersheds than do natural lakes, watershed processes are expected to have a greater influence on their limnology. Today, superimposed upon in-basin changes, the impending effect of global climate change on reservoir/lake/river structure and function must also be considered (Bates et al. 2008). Other drivers that can alter reservoir/lake structure and function include land-use change and exotic species invasions. These effects on reservoirs are not well-studied to date but can be examined qualitatively and quantitatively using both long-term and high-frequency monitoring systems.

The purpose of this paper is 1) to examine the value of long-term monitoring programs using reservoirs and lakes as sentinels and sensors of environmental change and 2) to examine the value of automated, real-time, high-frequency monitoring to assess the effects of continental/global scale climate change, land-use change, and exotic species invasions. The first uses long-term monitoring programs that compile data on precipitation, water budgets, water chemistry, and biology collected at time intervals of days, weeks, or months, whereas the second requires data collected at much more frequent intervals (e.g., minutes, hours) for predictive model integration and calibration. Outcomes from combinations of both monitoring strategies coupled with other legacy data should result in greater forecasting powers needed for better management of water resources.

DISCUSSION

As the lowest points in the landscape, reservoirs are integrators of environmental change occurring upstream, sentinels of terrestrial and aquatic processes occurring in their basins, and sensors of both long- and short-term disturbances at multiple scales that have not been well studied. They are "canaries in the landscape" of temporal and spatial water and watershed change resulting from human activities and ultimately deserve wise, science-based resource management.

We wish to take the opportunity to discuss the situation with climate change and the potential effects on lakes and reservoirs in the 21st century. Based on decades of observations and more recent modeling efforts, several "conclusions" have been summarized in the recent IPCC Technical Paper on Climate Change and Water (Bates et al. 2008). The following conclusions have been put forth by the IPCC with a high degree of confidence. First, past is not necessarily prologue. Rather, climate change subverts the traditional assumption that past hydrological experience provides a good guide to future conditions. A degree of uncertainty still exists with predictions and forecasting of effects on water resources. Although we are already feeling the effects of climate change globally, it is difficult to predict exactly what the local impacts will be to our own reservoir, to our own 'canary' in the landscape. The negative effects of future climate change on global freshwater systems are expected to outweigh any benefits. Higher water temperatures and changes in extreme events such as floods and droughts are projected to affect water quality and quantity and to make many forms of water pollution even more severe (e.g., sediments, nutrients, dissolved organic matter, pathogens, pesticides and salt, and thermal pollution). In spite of a wealth of observational data from the past half century, we have little experimental information as to exactly how changing climatic conditions would affect reservoir and lake processes. Changes in water quality and quantity due to climate change are expected to affect food availability, economic stability, and access to and distribution of energy. Climate change will affect the function and operation of existing water infrastructure (e.g., hydropower, structural flood defenses, drainage, irrigation systems, and water management practices).

Forecasting and predicting the impact of climate change on water require a variety of types of observational data coupled with cause and effect experiments, yet the availability of needed observations and networks is currently decreasing due to federal, state, and local budgetary constraints. An example is the loss of critical stream gauging data as the US Geological Survey is forced to cut back. The IPCC report provides a rationale for investing in monitoring of our lakes, reservoirs, streams, and their watersheds. We argue that long-term monitoring (legacy) data provide the historical context within which automated high-frequency data can be used to observe rapid, episodic, and subtle changes that might otherwise go undetected.

Past, Present, and Future Monitoring Programs

Many lakes, rivers, and streams have seen some level of monitoring for decades, particularly in conjunction with USGS, USEPA, and National Science Foundation (NSF) Long Term Ecological Research programs (e.g., Magnuson et al. 2006). Beyond a few simple measurements, similar long-term studies on reservoirs are rare, often based on operational management needs, and only rarely ecological (White et al. 2007).

Over the past two decades, there have been many attempts to provide comparative environmental and ecological monitoring covering much larger landscapes, many of which attempt to address water issues. Notable are the NSF-funded CUAHSI (Consortium of Universities for the Advancement of Hydrologic Science), WATERS (WATer and Engineering Research System network), NEON (National Ecological Observatory Network), and GLEON (Global Lake Ecological Observatory Network) research platforms. CUAHSI (www.cuahsi.org) consists of 33 member universities, each with common interests in understanding the water cycle. WATERS (www.watersnet.org) is an offshoot of CUAHSI with the mission of "creating a national capability to better predict and manage the behavior of water—and its nutrients, contaminants, and sediments—*everywhere* in the U.S." Presently there are 10 test bed sites ranging from 4th order watersheds to large rivers and bays. NEON (www.neoninc.org) is perhaps the most ambitious of the monitoring exercises. There will be 20 US domains, each with one primary and two secondary sites with the goal of creating a "continental-scale research platform" to understanding the effects of climate change, land-use change, and invasive species on ecosystem ecology. At least in the immediate future, NEON will focus largely on the terrestrial environment. There is, however, a comparative aquatic experiment within the NEON program (STREON - STReam Ecological Observatory Network) that will examine nitrogen dynamics in small streams in each domain. At this date, Major Research Facility funding for NEON is awaiting U. S. congressional approval and for WATERS is still a ways down the road.

The one effort that is the most relevant to lakes and reservoirs is GLEON (www.gleon.org). Even though there is base support from NSF, GLEON is an effort in which member sites self-identify. GLEON describes itself as a "Grassroots network of limnologists, ecologists, information technology experts, and engineers who have a common goal of building a scalable, persistent network of lake ecology observatories." At present there are 28 member lakes including sites in North and South America, Europe, Asia, Australia, and New Zealand. Six of these are reservoirs including Kentucky Lake. One objective of GLEON is to have similarly instrumented platforms in each lake with the goals of understanding the effects climate change on carbon cycling, productivity, and lake metabolism among lakes world-wide. Data will be available in near real-time through web portals to permit computations based on high-frequency data. Research collaborations among members for the purposes of cross-system, global lake comparisons are highly desirable and encouraged.

How to monitor lakes and reservoirs and why

Traditional long-term monitoring programs have been the mainstay of assessing of physicochemical and biological patterns in aquatic ecosystems and will continue to be an important component of limnological analysis. This is particularly true of biological components such as fish, plankton, invertebrates, and macrophytes. The frequency of such monitoring is question dependent. Fish, macroinvertebrate, or plant populations may require only annual or seasonal monitoring to determine long-term population changes. Phytoplankton, bacterioplankton, and zooplankton (and some physiochemical patterns such as temperature or conductivity) may be understood through weekly or bi-weekly sampling during critical times. Biological sampling methods have been reasonably standardized for decades (Wetzel and Likens 2000). More recently, data capturing sensors and probes for temperature, pH, dissolved oxygen, specific conductance, chlorophyll *a*, phycocycanin, and turbidity have become reasonably inexpensive and easy to use. However, most nutrients (e.g., N, P, SiO_2) and organic compounds still require bringing water samples back to the laboratory for analysis.

During the past 25 years there has been a revolution in sensor technology and accompanying cyberinfrastructure that has empowered ecological science in ways not foreseen during much of the 20th century. None of these efforts would be possible without cyber-technology that continues to advance at a rapid pace. Environmental sensors used in long-term monitoring can be coupled with computers, hardware, software, and middleware that can detect, transmit, and store data from remote field sites. Beyond the more standard stream discharge or meteorological conditions (e.g., temperature, wind speed and direction, surface photosynthetically active radiation (PAR), humidity), transmitting sensors have become available for many of the physicochemical conditions in a water body (temperature, dissolved oxygen, oxidation-reduction potential, pH, turbidity, chlorophyll *a*, chromaphoric dissolved organic matter, nitrates, subsurface PAR). New sensors are being developed at a very rapid pace to detect CO_2, methane, bacteria, viruses, specific organic chemicals, plant pigments, and nutrients.

Miniaturization and ruggedization of sensors has opened new perspectives for aquatic ecologists, environmental scientists, engineers, and information technology experts who are working in the water sciences studying the effects of human disturbances, climate change and land-use change. High-frequency data collected by sensors placed in strategic locations on buoys in lakes or mounted on permanent structures in streams and rivers can be rapidly transmitted via radio waves, satellites, or cell phones to a central location for storage and retrieval by scientists, engineers, modelers, educators, and citizens who can use them to forecast water quality and quantity conditions in near real-time. Rapid remediation and management feedback to episodic changes in water quality is a clear benefit of instantaneous, automated monitoring strategy investment.

Monitoring on Kentucky Lake: Long-Term

The Center for Reservoir Research (CRR, now called the Watershed Studies Institute) at Murray State University began its long-term monitoring program on Kentucky Lake in 1988 with the goals of providing data for understanding the basic limnology, assessing long-term changes, and providing correlative data for experimental studies (White 1990, White et al. 2007). Monitoring cruises occur every 16 days (corresponding with LandSat flyovers) at 12 reservoir sites (Fig. 1). Standard limnological parameters are measured at each site including physical data, nutrients (N, P, SiO_2), biology (zooplankton, phytoplankton, chlorophyll *a*, ^{14}C primary productivity) along with profiles of dissolved oxygen, temperature, pH, specific conductance, oxidation-reduction potential, and turbidity. To date there have been 425 cruises. Photosynthetically active radiation (PAR) and meteorological conditions are recorded at the Hancock Biological Station's main laboratory building (White et al. 2007). Monitoring of stream sites on Ledbetter Creek (agricultural/rural) and Panther Creek (undisturbed) was added in 1995. Stream sites generally are sampled every 32 days, one day before or one day after a monitoring cruise on Kentucky Lake. Atmospheric deposition is measured weekly at the National Atmospheric Deposition Program (NADP) site KY 99 located in the Land Between The Lakes National Recreation Area.

Given 20 years of data (408 sampling dates), we are able to view a number of annual and long-term water chemical and biological patterns. Most chemical constituents are quite variable within any one year but on average are similar from one year to the next (Fig. 2) (Yurista et al. 2004). Unexpected was the gradual decrease in SO_4^{-2} over the first 10 years sampling. Does this pattern reflect a decrease in sulfate deposition resulting from tighter emission standards for coal fired power plants? We presently are examining the entire 20-year pattern taking into account other data from throughout the Tennessee River watershed. In another example, Secchi depth patterns have been correlated with drought years followed by distinct increases in submerged macrophyte growth. Does this condition also correlate to changes in grazing pressures? How will these trends be affected by climate change or land-use alterations?

The long-term monitoring program also has been able to detect invasive species and their potential interactions with more native species. *Daphnia lumholtzi* Sars first appeared in reservoirs throughout the mid-south in the early 1990s (Fig. 3). Although it may have appeared in other reservoirs earlier, it was discovered first in Kentucky Lake in 1991 by searching archived samples (Yurista et al. 2000). This subtropical species seemed to have thrived at peak summer water temperatures (20-25 °C) potentially outcompeting *Diaphanosoma birgei* Korinek and *Daphnia retrocurva* Forbes and limiting their distributions to cooler water periods. While *D. birgei* and *D. retrocurva* densities have remained relatively consistent from one year to the next, *D. lumholtzi* appears much more variable. Because neither *D. birgei* nor *D. retrocurva* nor many of the other 20+zooplankton species occurring in Kentucky Lake existed in this part of the Tennessee River prior to impoundment, all may be considered invasive but have adapted over the past 50+ years. The long-term monitoring program permits us to follow the progress of this and other invaders.

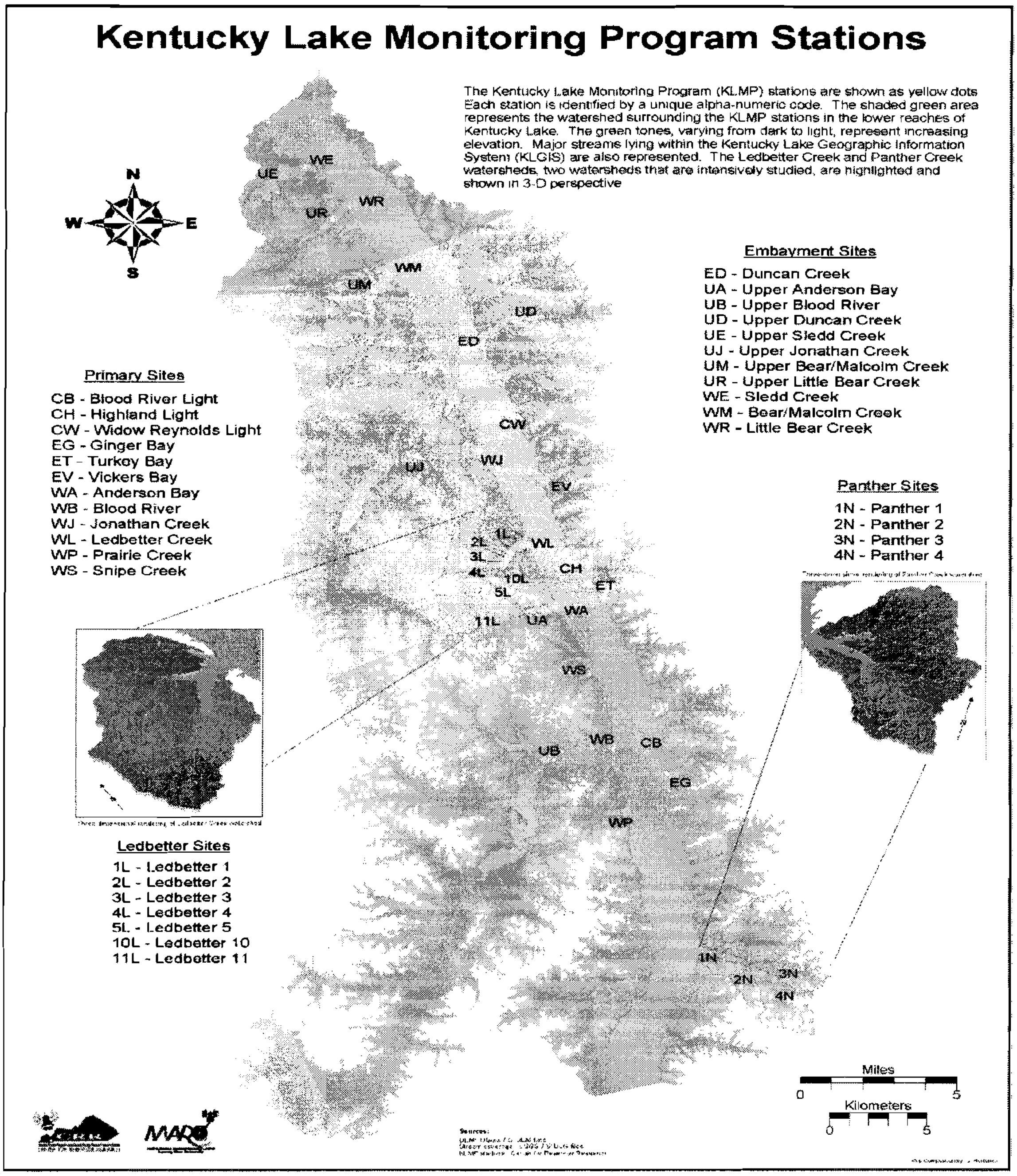

Figure 1. Map of Kentucky Lake, Kentucky and Tennessee, showing sites with monitoring data. Only the central 12 sites are sampled on the 16-day interval.

One advantage of long-term monitoring is the ability to archive samples, particularly biological samples, for future examination. Our archived zooplankton and phytoplankton samples provide a set of legacy data that will continue to be mined for years to come. Disadvantages in traditional long-term field monitoring include labor intensity – laboratory measurements must be completed and data entered before any further analyses can be accomplished; there is often no way to assess cause and effect responses; and critical, episodic events may be missed.

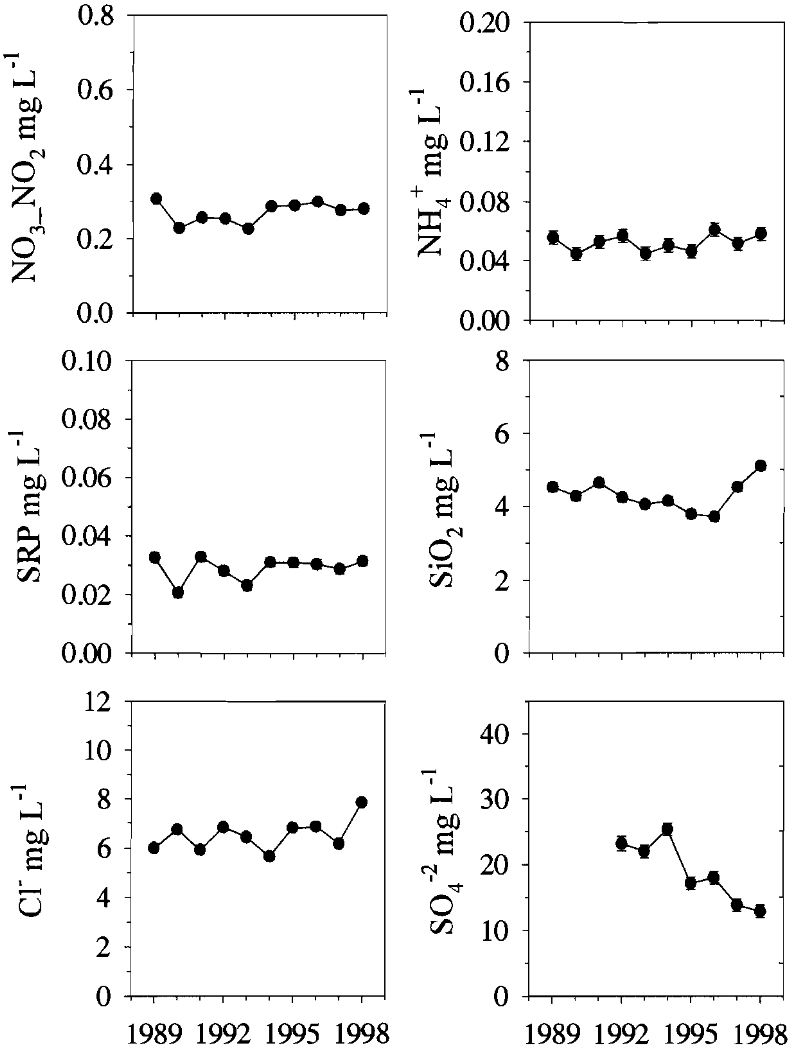

Figure 2. Annual means for selected water chemistry parameters over the first 10 years of the long-term monitoring program. Note that the annual mean concentration of SO_4^{-2} had decreased by about half. From Yurista et al. 2004.

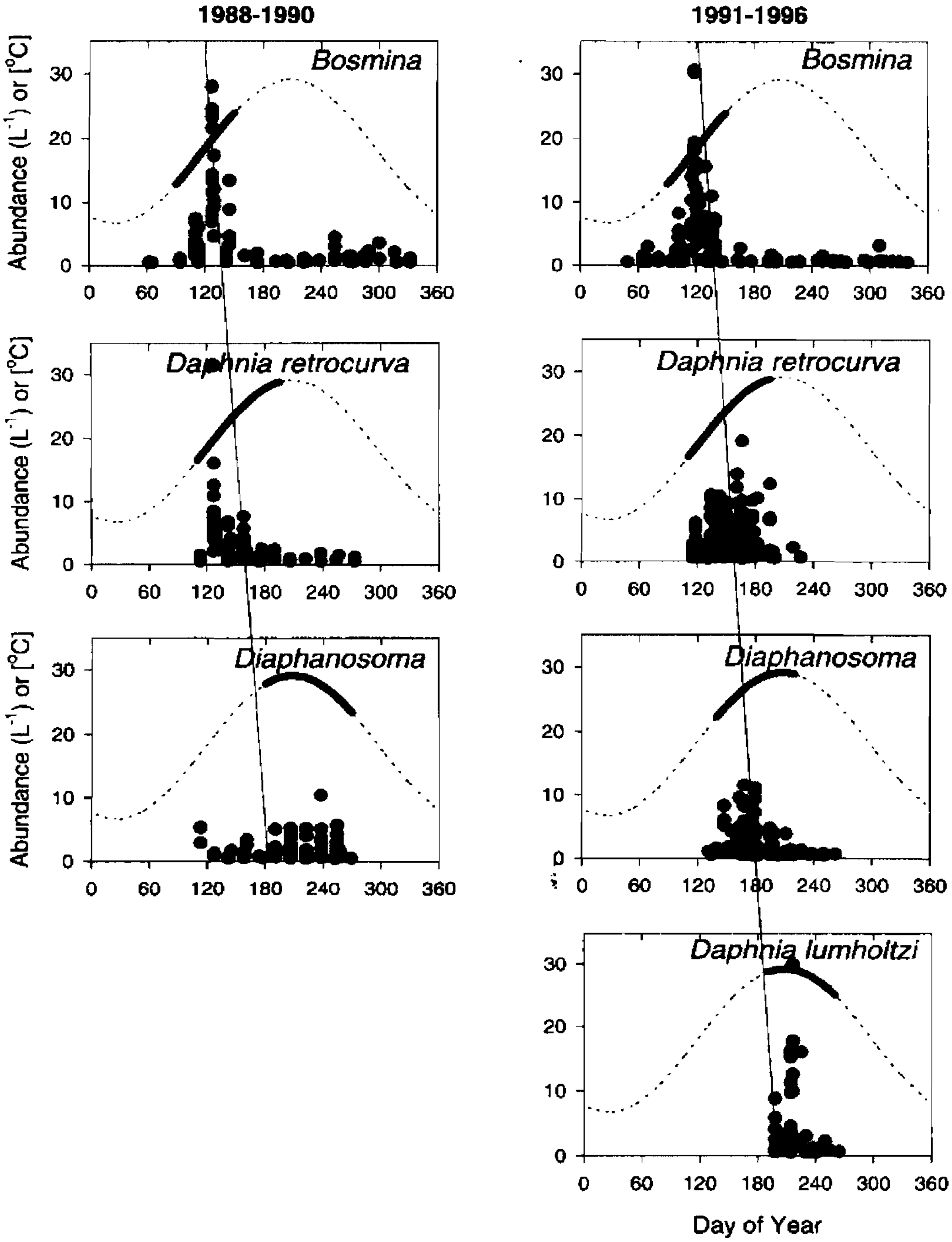

Figure 3. Temperature preferences of major zooplankton species before and after the introduction of *Daphnia lumholtzi* based on the long-term monitoring program. Note that much of the *Diaphanosoma* population now occurs at cooler temperatures slightly earlier in the year. From Yurista 2000.

Monitoring on Kentucky Lake: High-frequency

On February 16, 2005, we established an automated, high-frequency monitoring site in Kentucky Lake at the Highland Light channel marker pylon, site CH (Fig. 4), also one of our long-term monitoring sites. Data are taken at one meter deep and one meter of the lake bottom every 15 minutes and radioed to the Biological Station. Parameters include temperature, dissolved oxygen, pH, specific conductance, oxidation-reduction potential, turbidity, lake elevation, and chlorophyll *a* (surface only). [Each of these parameters is measured at all long-term monitoring sites as well]. Established at the same time was a weather station located at the Biological Station with data recorded at 15 minute intervals. All data from the real-time, high-frequency monitoring site and weather station are available to researchers, educators, and the general public at www.murraystate.edu/hbs. Collection and archiving of high-frequency data present a suite of challenges different from those encountered in standard long-term monitoring. Advantages are that data are collected rapidly, at short intervals, and can be examined instantaneously or at frequencies necessarily required by sophisticated modeling techniques. Disadvantages include requirements for cyberinfrastructure, computing power, and data storage capabilities that may be beyond the means of some organizations. Data collected at high temporal frequency (e.g. every 15 minutes or more) requires more storage power and hence increased investment in the supporting cyberinfrastructure. Accessibility of the data base is a 2 edged sword: In order to make data available to researchers interested in high-frequency data there needs to be a user friendly, yet hack-free access/retrieval system that can be shared among collaborators. Another advantage, however, is that these data can be shared with non-research entities for use among citizens, educators, managers, and agencies for various public purposes.

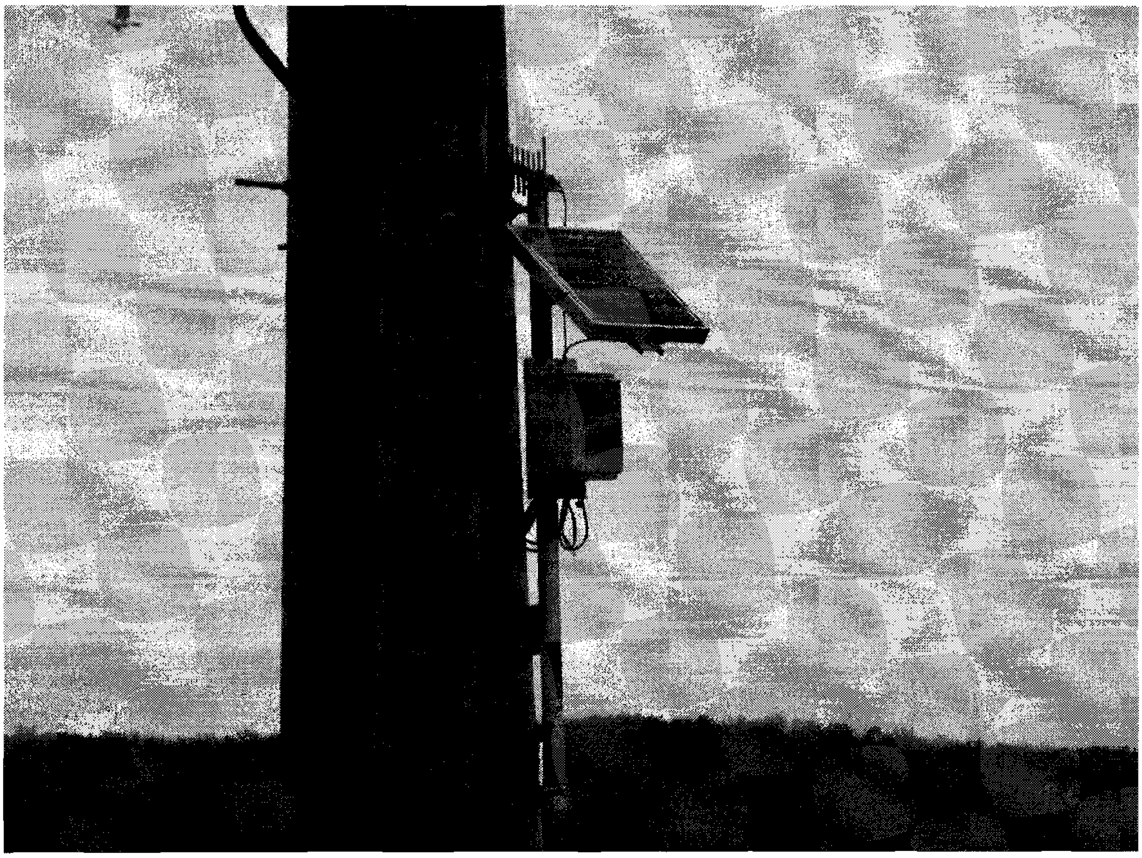

Figure 4. High-frequency monitoring equipment attached to Highland Light (Site CH) in Kentucky Lake. Shown are transmitting antenna, solar power source, and battery. Data sondes are located at 1 m from the surface and 1 m off the bottom.

As one example of the value of high-frequency data capture over long-term monitoring data, Hurricane Ike passed over Kentucky Lake in early September, 2008. Winds pushed the water from the west to the east shore creating an internal seiche that was captured instantaneously in the database (e.g., lake surface elevation changes, Fig. 5). Although no personal injuries were reported, the rocking motion of the seiche left boats far from the water on both shorelines. The data would be valuable to insurance companies assessing damage caused by rapid changes in water levels during storms that might go undetected by conventional methods. These types of data are available along marine coasts but are generally lacking for most inland lakes and reservoirs.

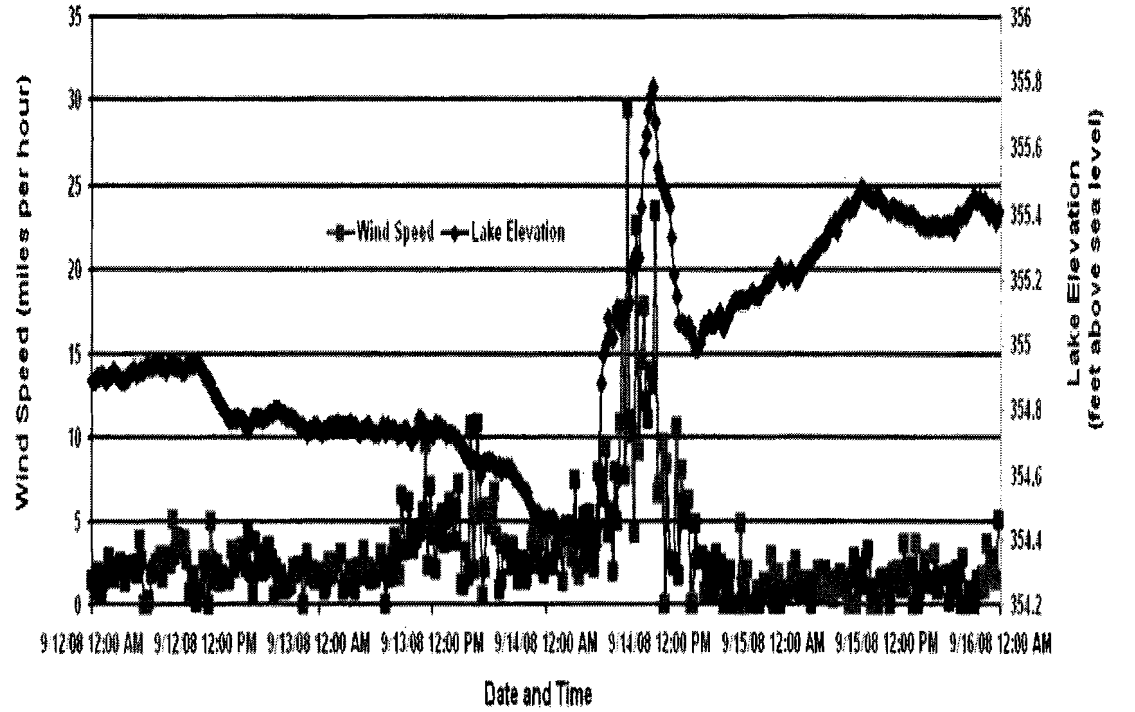

Figure 5. A plot of high-frequency data showing the results of wind speed and lake elevation changes during Hurricane Ike, 12 September to 16 September, 2008.

In the beginning we may have underestimated the regional and local importance of having our real-time data available on the web. The web site (www.murraystate.edu/hbs) is now receiving about 10,000 hits per month. Many of the hits come from federal, state and local agencies; however, the largest user of the data appears to be marinas and the recreational sport fishery. Many of the local marinas have links to the database on their web sites. For one reason or another, our sensors, the software, or the site itself has occasional glitches. When this occurs, we are quick to hear about it by phone calls or e-mails from average citizens. Buoys with sensor data systems that can be accessed for recreational or commercial purposes may be becoming more common. In March of this year, the USGS deployed a buoy equipped with temperature and DO chains for a fishing tournament at Lake Dardanelle, Arkansas (http://ar.water.usgs.gov/lake_dardanelle/).

A number of ecological research questions can be addressed using high-frequency data. Cross-system comparisons of basic ecological processes such as lake metabolism (i.e., shifts in photosynthesis vs. respiration) can be carried out using temperature and dissolved oxygen sensors collecting data hourly or at shorter intervals throughout 24 h time periods required of predictive modeling. Long-term shifts in metabolism are expected to be a measurable consequence of climate change, particularly when viewed within a comparative, world-wide perspective (Poff et al. 2008, Bates et al. 2008, Tilak et al. 2007, Williamson et al. 2008). Comparative lake metabolism studies are an ongoing research effort by GLEON collaborators.

Other examples of the value of high-frequency data include plant pigment sensors (phycoerythrin, phycocyanin, chlorophyll *a*) for detecting rapid changes in dominant algal communities that result from changing nutrient patterns or algal grazing pressures. An unexpected surge in blue-green algae might signal a decrease in water quality. Sensors for measuring CDOM (chromaphoric or 'colored' dissolved organic matter), can detect shifts in water transparency that may result from changes in either herbivory/predation pressures or the effects of UV light on dissolved organic carbon quality/quantity. CDOM levels may ultimately affect or indicate lake productivity and water quality. Rapid, episodic shifts in the above-mentioned parameters would go otherwise undetected by conventional long-term monitoring strategies carried out at longer time intervals.

Monitoring on Kentucky Lake: Long-Term Coupled with High-frequency

We will continue our long-term monitoring program as the basis for most biological observations, as a question generator, and as legacy data for comparative purposes. High-frequency data will be used to address specific limnological questions as well as capturing the results of short-term events. As mentioned earlier, processes in lakes and possibly small reservoirs can be assessed using one or two monitoring buoys. Larger reservoirs have both longitudinal and lateral features that need to be monitored in order to understand the effects of land-use change, climate change, and invasive species consequences. This was built into the original design of the Kentucky Lake long-term monitoring program (Fig. 1)

We are now proposing to add high-frequency monitoring at each of the main channel sites to better understand longitudinal processes. Buoys also would be placed in Ledbetter and Panther bays. Based on our long-term monitoring results, both bays act as mini-impoundments and as integrators of the local landscapes within Kentucky Lake. Similar types of instrumentation would be placed in both Ledbetter and Panther creeks along with real-time gauging stations. Initial instrumentation would include the suite of parameters present at our existing CH site. Automated high-frequency data would permit us to have a much better understanding of how lake metabolism varies spatially between the smaller embayments and the reservoir mainstem or temporally over the next decades. The addition of sensors for phycoerythrin, phycocyanin, chlorophyll *a*, and CDOM, particularly in bay sites, would allow a more full understanding of the effects of allochthonously-generated nutrient runoff differences seen in the long-term monitoring data. As new sensors are developed and added, the list of questions grows as should the number of researchers, educators, agencies, and citizens who can take advantage of the data.

ACKNOWLEDGMENTS

The 20+ years of long-term monitoring and the initiation of high-frequency monitoring at Hancock Biological Station has involved hundreds of students, scientists, and faculty. Particular acknowledgments go to G. Richard Marzolf, Gary Rice, Karla Johnston, Gerry Harris, Jane Benson, Matthew Williamson, Meredith Morris, and Russell Trites who maintain the continuity of both programs.

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CONTRIBUTED PAPERS

SESSION 1: BOTANY

Saturday, April 4, 2009

Moderated by:

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THE WOODY FLORA OF LAND BETWEEN THE LAKES, KENTUCKY AND TENNESSEE – A REVISED CHECKLIST

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ABSTRACT. Land Between The Lakes (LBL), a 69,000-ha National Recreation Area (NRA) in southwestern Kentucky and northwestern central Tennessee, was established in 1964 and administered by the Tennessee Valley Authority until 1999 when the USDA Forest Service assumed control. The NRA is managed for outdoor recreation, environmental education and historic interpretation, receiving more than two million visitors yearly. Prior to NRA development, LBL consisted of farms, communities and a National Wildlife Refuge. The area is surrounded by water on three sides and is about 80% forested. A 1976 checklist of the woody flora (trees, shrubs, woody vines) included 188 species and lower taxa in 99 genera and 49 families. The current list includes 247 species in 116 genera and 56 families. State-listed and excluded taxa are appended.

INTRODUCTION

Land Between The Lakes (LBL) National Recreation Area (NRA) in southwestern Kentucky and northwestern central Tennessee is a 69,000-ha inland peninsula between the impounded Cumberland River (Lake Barkley) and Tennessee River (Kentucky Lake); a man-made canal connects the reservoirs and forms the north boundary. The NRA was established in 1964 from lands previously in farms (row crops, livestock, hay, timber), communities (homes, stores, churches, cemeteries), and a National Wildlife Refuge. Administration was by the Tennessee Valley Authority until 1999 when the USDA Forest Service assumed control. The NRA is now more than 80% forested and is managed for outdoor recreation (camping, hunting, fishing, hiking, biking, horseback riding, among others), environmental education and historic interpretation, drawing more than two million visitors yearly (LBL Homepage 2008). A detailed account of the area, including floristic, faunistic, and descriptive and historical data was provided by Chester and Fralish (2002). A previous listing of the woody flora (trees, shrubs, woody vines) included 188 species and lower taxa in 99 genera and 49 families (Chester et al. 1976). Nomenclatural changes, taxonomic revisions, error corrections, family realignments, and field work resulting in numerous additions dictate an up-dating of the earlier list, thus providing current information for those interested in the LBL flora as well as a reliable list for other researchers who need to compare floristic data from separated areas.

METHODS

The woody flora was targeted during >60 collecting trips over the growing seasons of 2006-2009. Specimens vouchering the 1976 list and the current paper are maintained in the Austin Peay State University Herbarium (APSC), where numerous families or genera have been annotated by experts (e.g., *Vitis* by Dr. Michael Moore; *Cornus* by Dr. Zack Murrell). Significantly, the entire LBL woody collection from Kentucky counties was annotated recently by Dr. Ross Clark and included in the compilation of the woody flora of Kentucky (Clark and Weckman 2008). Using the 1976 list, taxonomy, nomenclature, and family alignments were corrected to follow that of Chester et al. (2009) and all new collection records incorporated.

RESULTS AND DISCUSSION

The LBL woody flora is now known to include 247 species within 116 genera and 56 families (Appendix 1). This includes 2 families, 5 genera, and 10 species of gymnosperms; 3 families, 3 genera, and 6 species of monocots, and 51 families, 108 genera, and 231 species of dicots. Seventy-two (29%) species are not native. The largest families are the Rosaceae (43), Fagaceae (23), Fabaceae (13), Juglandaceae and Salicaceae (12 each), and Vitaceae (11). *Quercus* (20 taxa) is the largest genus, followed by *Carya* (10), *Crataegus* (9), *Prunus* and *Vitis* (8 each), *Salix* (7), *Acer*, *Rosa*, and *Rubus* (6 each), and *Lonicera, Malus, Populus*, and *Ulmus* (5 each).

Several previously reported taxa are excluded; reporting authors and reason(s) for exclusion are given in Appendix 2. Seven taxa are currently state-listed by either or both the Kentucky State Nature Preserves Commission (2008) and the Tennessee Natural Heritage Program (2008). Taxa, listed status, and LBL distribution are given in Appendix 3.

SUMMARY

This report provides a 33-year update of the woody flora (trees, shrubs, woody vines) of the Land Between The Lakes National Recreation Area, Kentucky and Tennessee. Additional work is required, especially for genera that present taxonomic problems, such as *Amorpha, Crataegus, Malus* and *Prunus*. Further monitoring will be required to observe floristic changes that may result as forests mature. Anthropogenic and other influences also will affect floristic composition in the future. These include the long-term effects of the reservoirs and their annual fluctuation cycles, construction of roads, campgrounds, ORV areas, horse-riding areas, the withdrawal of agricultural practices from much of the area, the often over-abundant wildlife (especially beaver, turkey and deer), selective and clear-cutting of some forests, and prescribed burning of extensive areas as part of open-land management programs.

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APPENDIX 1: ANNOTATED CHECKLIST

The checklist is divided into three groups: Gymnosperms, Angiosperms-Monocots, and Angiosperms-Dicots. Families, genera, species and lower taxa are arranged alphabetically. Non-native taxa are preceded by an asterisk (*); an exclamation (!) indicates a taxon not reported in the 1976 list. The major habitat type(s) in which the taxon has been observed in LBL is given. Abundance is subjectively indicated by the following parameters: **abundant** =expected in the habitat type(s) indicated, usually in large numbers; **frequent** = usually, but not always, encountered in the type(s) indicated, often, but not always, in large numbers; **occasional** =occasionally found in the type(s) indicated, rarely in large numbers: **rare** =known from fewer than 10 localities. Vouchered county distributions are given as L for Lyon County, S for Stewart County, and T for Trigg County. Synonymy should be sought in Chester et al. (2009).

GYMNOSPERMS

CUPRESSACEAE, Cedar Family
*!*Juniperus chinensis* L., Chinese Juniper. Persisting, homesites and cemeteries; rare (L,S).
Juniperus virginiana L., Red Cedar. Fields, fencerows, bluffs, open forests; abundant (L,S,T).
Taxodium distichum (L.) Rich., Bald Cypress. Coves and swampy ravines along the Tennessee River; frequent (L,S,T). Planted in a few bottomlands of both river systems.
*!*Thuja orientalis* L., Oriental Arbor-Vitae. Persisting, homesites and cemeteries; rare (L,S,T).

PINACEAE, Pine Family
**Picea abies* (L.) Karst., Norway Spruce. Persisting, homesites and cemeteries; rare (S,T).
*!*Picea glauca* (Moench) Voss, White Spruce. Persisting, homesites and cemeteries; rare (L,S).
Pinus echinata Mill., Shortleaf or Yellow Pine. Native on a few ridges and slopes where abundant (S), persisting elsewhere (L,S,T).
**Pinus strobus* L., White Pine. Persisting, rarely spreading (L,S,T).
**Pinus taeda* L., Loblolly Pine. Persisting, sometimes invasive in fields and cut-over woods (L,S,T).
Pinus virginiana Mill., Virginia Pine. Native on some xeric bluffs and slopes above the Tennessee River where abundant (L,S,T), planted elsewhere.

ANGIOSPERMS-MONOCOTS

AGAVACEAE, Century-Plant Family
*!*Yucca flaccida* Haw., Beargrass, Spanish Bayonet. Homesites, cemeteries, fields; occasional (L,S,T).

POACEAE, Grass Family
Arundinaria gigantea (Walt.) Muhl., Cane. Slopes, streambanks, bottomlands; frequent (L,S,T).

SMILACACEAE, Catbrier Family
Smilax bona-nox L., China-Brier. Mesic thickets, fencerows, fields; frequent (L,S,T).
Smilax glauca Walt., Sawbrier. Fields, fencerows, other disturbed sites; frequent (L,S,T).
Smilax hispida Muhl., Bristly Greenbrier. Low woods, thickets, fencerows; frequent (S,T).
Smilax rotundifolia L., Common Greenbrier. Mesic thickets and woods; frequent (L,S,T).

ANGIOSPERMS-DICOTS

ADOXACEAE, Moschatel Family
Sambucus canadensis L., Elderberry. Mesic thickets, fields, fencerows; frequent (L,S,T).
!*Viburnum dentatum* L., Arrowwood. Know only from a 1964 collection; probably extirpated (T).
!*Viburnum prunifolium* L., Plumleaf Viburnum. Dry woods, thickets; rare (S).
Viburnum rufidulum Raf., Rusty Blackhaw. Rocky woods, bluffs, thickets; frequent (L,S,T).

ALTINGIACEAE, Sweetgum Family
Liquidambar styraciflua L., Sweetgum. Wet woods, fields, streambanks, bottomland forests; abundant (L,S,T).

ANACARDIACEAE, Cashew Family
Rhus copallina L., Shining or Winged Sumac. Fields, thickets, fencerows; abundant (L,S,T).
Rhus glabra L., Smooth Sumac. Same habitats as the previous species; abundant (L,S,T).
Toxicodendron radicans (L.) Kuntze, Poison Ivy. Fields, forests, disturbed sites; abundant (L,S,T).

ANNONACEAE, Custard-Apple Family
Asimina triloba (L.) Dunal, Pawpaw. Mesic woods, ravines, streambanks; abundant (L,S,T).

APOCYNACEAE, Dogbane Family
*!*Vinca major* L., Large Periwinkle. Persisting, homesites, sparingly spreading; rare (S).
**Vinca minor* L., Common Periwinkle. Persisting, homesites, cemeteries, spreading into adjacent woods and thickets; frequent (L,S,T).

AQUIFOLIACEAE, Holly Family
Ilex decidua Walt., Deciduous Holly. Around embayments and the lakeshores, in ravines and moist forests; frequent (L,S,T).
Ilex opaca Ait., American Holly. Native, slope forests; rare (S); persisting, homesites and cemeteries (S,T).

ARALIACEAE, Ginseng Family
*!*Acanthopanax sieboldianus* Makino, Spiny Panax. Persisting at a homesite; rare (L).
Aralia spinosa L., Devil's Walking Stick. Dry woods, forest borders, disturbed sites; frequent (L,S,T).
**Hedera helix* L., English Ivy. Persisting, homesites and cemeteries, sparingly adventive; rare (L,S,T).

ARISTOLOCHIACEAE, Birthwort Family
Isotrema tomentosa (Sims) Reed, Dutchman's Pipe. Thickets and woods on lakeshores; rare (S,T).

BERBERIDACEAE, Barberry Family
*!*Berberis thunbergii* DC., Japanese Barberry. Persisting at a homesite; rare (T).

BETULACEAE, Birch Family
Alnus serrulata (Ait.) Willd., Common Alder. Lakeshores, swampy areas, creekbanks; abundant (L,S,T).
Betula nigra L., River or Black Birch. Streambanks, swamps, reservoir shorelines; abundant (L,S,T).
Carpinus caroliniana Walt., Blue Beech. Slope, ravine and streambank forests; frequent (L,S,T).
Corylus americana Walt., Hazelnut. Roadside thickets, mesic open woods; frequent (L,S,T).
Ostrya virginiana (Mill.) K.Koch, Hop Hornbeam. Slope and bottomland forests (L,S,T).

BIGNONIACEAE, Bignonia Family
Bignonia capreolata L., Cross-Vine. Mesic woods, thickets, fencerows; occasional (L,S,T).
Campsis radicans (L.) Seem., Trumpet Creeper. Fields, fencerows, thickets; frequent (L,S,T).
**Catalpa speciosa* (Ward.) Engelm., Catalpa. Persisting, homesites and cemeteries, spreading into fields and woods; occasional (L,S,T).

CANNABACEAE, Hemp Family
Celtis laevigata Willd., Sugarberry. Low woods, fencerows, fields, reservoir shorelines, especially around outcrops; frequent (L,S,T).
Celtis occidentalis L., Hackberry. Streambanks, low forests, mesic slopes; occasional (L,S,T).

CAPRIFOLIACEAE, Honeysuckle Family
*!*Lonicera* x *bella* Zabel, Bush Honeysuckle. Persisting, homesites; rare (S).
**Lonicera japonica* Thunb., Japanese Honeysuckle. Thickets, fencerows, fields, other disturbed sites; abundant (L,S,T).

*!*Lonicera morrowii* A.Gray, Morrow's Honeysuckle. Persisting and spreading around homesites; rare (T).
*!*Lonicera xylosteum* L., Dwarf Honeysuckle. One roadside collection (identification by Dr. Ross Clark); rare (L).
Lonicera sempervirens L., Trumpet or Coral Honeysuckle. Thickets, fencerows; occasional (S,T).
Symphoricarpos orbiculatus Moench, Coralberry. Fields, thickets, disturbed sites; frequent (L,S,T).

CELASTRACEAE, Staff-Tree Family
!*Celastrus scandens* L., American Bittersweet. No voucher seen but reported from Stewart County by Scott Gunn (personal communication).
Euonymus americanus L., Strawberry Bush. Mesic woods, especially in ravines and on streambanks; occasional southward, rare to the north (L,S,T).
Euonymus atropurpureus Jacq., Wahoo. Mesic woods; occasional to rare (L,S,T).
*!*Euonymus hederaceus* Champ. & Benth., Winter Creeper. Persisting, homesites, sparingly adventive; occasional (L,S,T).
*!*Euonymus japonicus* Thunb., Japanese Spindle-Tree. Persisting at a homesite; rare (S).

CORNACEAE, Dogwood Family
Cornus amomum Mill., Swamp Dogwood, Red Willow. Lakeshores, swampy thickets and fields, shrub swamps; frequent (L,S,T).
!*Cornus drummondii* Meyer, Rough-Leaved Dogwood. Low woods and thickets; rare (T).
Cornus florida L., Flowering Dogwood. Slope and ridge forests, fields, thickets, fencerows; abundant (L,S,T).

EBENACEAE, Ebony Family
Diospyros virginiana L., Common Persimmon. Fields, woods, fencerows, shorelines; frequent (L,S,T).

ELAEAGNACEAE, Oleaster Family
*!*Elaeagnus umbellata* Thunb., Autumn Olive. Planted by TVA in the 1960s around waterholes and at various other sites for wildlife food; abundant, invasive (L,S,T).

ERICACEAE, Heath Family
!*Chimaphila maculata* (L.) Pursh, Spotted Wintergreen. Slope and ridge forests; rare (S).
Gaylussacia baccata (Wang.) K.Koch, Black Huckleberry. Xeric ridge forests; abundant (S,T).
Kalmia latifolia L., Mountain Laurel. Some slopes and bluffs near Kentucky Reservoir; abundant (S,T).
Oxydendrum arboreum (L.) DC., Sourwood. Dry ridge and slope forests; occasional (L,S,T).
Vaccinium arboreum Marsh., Farkleberry, Sparkleberry. Dry woods; abundant (L,S,T).
Vaccinium pallidum Ait., Sugar Huckleberry. Dry ridge and slope forests; abundant southward (S,T).
Vaccinium stamineum L., Deerberry, Squaw Huckleberry. Dry ridge and slope forests; frequent, (L,S,T).

FABACEAE, Legume or Pulse Family
**Albizia julibrissin* Durazz., Mimosa. Persisting, homesites and cemeteries, adventive on roadsides, fields, reservoir shorelines; frequent (L,S,T).
Amorpha fruticosa L., False Indigo. Lakeshores, swampy woods; frequent (L,S,T).
Amorpha nitens Desf. F.E. Boynt., Shining False Indigo. Lakeshores, swampy woods; rare (S).
Cercis canadensis L., Redbud. Mesic forests, fields; frequent (L,S,T).
!*Dioclea multiflora* (Torr. & A.Gray) C.Mohr, Boykin's Cluster Pea. Rocky slopes adjacent to the Tennessee River; occasional (L,S,T).
Gleditsia triacanthos L., Honey-Locust. Disturbed sites; frequent (L,S,T).
*!*Gymnocladus dioica* (L.) K.Koch, Kentucky Coffee Tree. Perhaps native in LBL but all vouchers are from trees planted around homesites; rare (S,T).
**Lespedeza bicolor* Turcz., Bicolor Lespedeza. Planted by TVA for wildlife in the 1960s, now invasive in fields and thickets (L,S,T).
**Pueraria montana* (Lour.) Meritt var. *lobata* (Willd.) Maesen & S.Almeida., Kudzu Vine. Planted for erosion control on roadbanks, invasive (L,S,T).

Robinia hispida L., Rose or Bristly Locust. Persisting, homesites and cemeteries, spreading by root sprouts; occasional (L,S,T).
Robinia pseudoacacia L., Black Locust. Fields, fencerows, disturbed woods; occasional L,S,T).
*!*Wisteria floribunda* (Willd.) DC., Japanese Wisteria. Homesites and cemeteries; rare (S,T).
Wisteria frutescens (L.) Poir., American Wisteria. Lakeshore thickets; frequent (L,S,T).

FAGACEAE, Beech Family
Castanea dentata (Marsh.) Borkh., American Chestnut. Ridge and slope forests as stump sprouts and small trees; occasional to rare (S,T).
*!*Castanea mollissima* Blume, Chinese Chestnut hybrids. Persisting, planted by the USFWS within the former Kentucky Woodlands National Wildlife Refuge; rare (T).
Fagus grandifolia Ehrh., American Beech. Mesic forests; abundant , especially southward (L,S,T).
*!*Quercus acutissima* Carr., Sawtooth Oak. Planted by TVA in Barnes Hollow and along the Trace, especially in Trigg County, not know to spread although fruiting (T).
Quercus alba L., White Oak. Slope and ridge forests; abundant (L,S,T).
!*Quercus bicolor* Willd., Swamp White Oak. Low woods; rare (L,T).
Quercus coccinea Muenchh., Scarlet Oak. Dry upland woods; abundant (L,S,T).
Quercus falcata Michx., Southern Red Oak, Spanish Oak. Dry woods, fencerows, fields; abundant (L,S,T).
Quercus imbricaria Michx., Shingle Oak. Along streams, lakeshores, mesic woods; frequent (L,S,T).
Quercus lyrata Walt., Overcup Oak. Reservoir shorelines, especially Kentucky Lake; occasional (L,S,T).
!*Quercus macrocarpa* Michx., Mossycup/Bur Oak. Low woods by Barkley Reservoir; rare (S).
Quercus marilandica Muenchh., Blackjack Oak. Ridge and slope woods; abundant (L,S,T).
Quercus michauxii Nutt., Swamp Chestnut Oak. Bottomland forests, streambanks; occasional (L,S,T).
Quercus muehlenbergii Engelm., Chinkapin Oak. Slopes and upper terraces; occasional (L,S,T).
Quercus nigra L., Water Oak. Tennessee River shoreline; rare and perhaps extirpated (S). The report from Trigg County on the Cumberland River (Thomas 1963) is unsubstantiated.
Quercus pagoda Raf., Cherrybark Oak. Lower slopes, terrace and reservoir-margin forests; frequent (L,S,T).
Quercus palustris Muenchh., Pin Oak. Lakeshores and low woods; infrequent (L,S,T).
Quercus phellos L., Willow Oak. Mesic woods, sometimes in wet upland sites; rare (L,S,T).
Quercus prinus L., Chestnut Oak. Dry ridge and slope forests; abundant (L,S,T).
Quercus rubra L., Northern Red Oak. Mesic slope forests; frequent (L,S,T).
Quercus shumardii Buckl., Shumard Red Oak. Bottomland forests; occasional (L,S,T).
Quercus stellata Wang., Post Oak. Dry ridge and slope forests; abundant (L,S,T).
Quercus velutina L., Black Oak. Dry ridge and slope woods; abundant (L,S,T).

GROSSULARIACEAE, Gooseberry Family
!*Ribes missouriense* Nutt., Missouri Gooseberry. Mesic thickets along upper Elbow Creek; extirpated as a result of expansion of Highway 68 in 2009 (T).

HYDRANGEACEAE, Hydrangea Family
Hydrangea arborescens L., Common Hydrangea. Wooded bluffs and outcrops; rare (L).
!*Hydrangea cinerea* Small, Ashy Hydrangea. Wooded slopes and outcrops; frequent, includes most specimens previously identified as *H. arborescens* L.
*!*Philadelphus coronarius* L., Mock-Orange. Persisting, homesites and cemeteries; rare (L,T).
*!*Philadelphus inodorus* L., Appalachian Mock-Orange. Persisting, homesites; rare (S).
Philadelphus pubescens Loisel., Ozark Mock-Orange. Native on some Cumberland River bluffs; rare (S,T); persisting, homesites and cemeteries; occasional (L,S,T).

HYPERICACEAE, St. John's-Wort Family
Hypericum hypericoides (L.) Crantz, St. Andrew's Cross. Ravine and shoreline forests; occasional (L,S,T).
Hypericum prolificum L., Shrubby St. John's-Wort. Woods, mostly near the lakeshores; frequent (L,S,T).
!*Hypericum stragulum* Adams & Rob., Decumbent St. Andrew's Cross. Dry woods, fields, roadsides; frequent (L,S,T).

ITEACEAE, Sweet-Spire Family
!*Itea virginica* L., Virginia Willow. Swampy woods and thickets near reservoirs; rare (T).

JUGLANDACEAE, Walnut Family
!*Carya aquatica* (Michx.f.) Nutt., Water Hickory. Shorelines of Kentucky Reservoir; rare (S,T).
Carya carolinae-septentrionalis (Ashe) Engl. & Graebn., Carolina Hickory. Mesic to dry slope forests; rare (S,T).
Carya cordiformis (Wang.) K.Koch, Bitternut Hickory. Footslope, ravine and streambank forests; frequent, especially southward (L,S,T).
Carya glabra (Mill.) Sweet, Pignut. Slope and ridge forests, fields, fencerows; frequent (L,S,T).
Carya illinoinensis (Wang.) K.Koch, Pecan. Native in low woods along both reservoirs; rare (L,S,T). Also rarely seen persisting from former yard plantings.
Carya laciniosa (Michx.f.) Loud., Big Shellbark Hickory, Kingnut. Bottomland, ravine and streambank forests; occasional in the south, rare northward (L,S,T).
Carya ovalis (Wangenh.) Sarg., Red Hickory. Mesic woods, scattered throughout (L,S,T).
Carya ovata (Mill.) K.Koch, Shagbark/Scalybark Hickory. Mesic forests, fields, fencerows; frequent (L,S,T).
Carya pallida (Ashe) Engelm. & Graebn., Sand Hickory. Dry ridge and slope forests; occasional (L,S,T).
Carya tomentosa Nutt., Mockernut or White-Heart Hickory. Woods, fencerows, fields; frequent (L,S,T).
Juglans cinerea L., Butternut, White Walnut. Ravine and streambank forests; rare (S,T).
Juglans nigra L., Black Walnut. Mesic slope, bottomland and ravine forests; frequent (L,S,T).

LAMIACEAE, Mint Family
*!*Callicarpa americana* L., Beauty-Berry. Persisting at a homesite; rare (T).

LAURACEAE, Laurel Family
Lindera benzoin (L.) Blume, Spicebush. Ravine, lower slope and streambank forests; abundant (L,S,T).
Sassafras albidum (Nutt.) Nees, Sassafras. Fields, roadsides, fencerows, disturbed forests; abundant (L,S,T).

LYTHRACEAE, Loosestrife Family
*!*Lagerstroemia indica* L., Crepe Myrtle. Persisting, homesites and cemeteries; rare (L,S).

MAGNOLIACEAE, Magnolia Family
Liriodendron tulipifera L., Tulip Tree or Yellow Poplar. Mesic slopes and ravines, successional fields; abundant (L,S,T).
*!*Magnolia grandiflora* L., Evergreen Magnolia. Persisting, homesites and cemeteries; rare (L,S).

MALVACEAE, Mallow Family
**Hibiscus syriacus* L., Rose-of-Sharon. Persisting, homesites and cemeteries, sparingly spreading to fields and roadsides; rare (L,S,T).
Tilia heterophylla Vent., White Basswood. Mesic woods, especially on reservoir slopes and bluffs; occasional (L,S,T).

MENISPERMACEAE, Moonseed Family
Calycocarpum lyoni (Pursh) Gray, Cupseed. Rich woods and thickets; occasional to rare (L,S,T).
Cocculus carolinus (L.) DC., Red-Berried Moonseed, Snailseed. Low fencerows and thickets, mesic woods, especially along reservoir shorelines; occasional (L,S,T).
Menispermum canadense L., Moonseed, Yellow Parilla. Rich woods and thickets; rare (L,S,T).

MORACEAE, Mulberry Family
**Broussonetia papyrifera* (L.) Vent., Paper Mulberry. Persisting, homesites and cemeteries, sparingly spreading by root sprouts; rare (T).
**Maclura pomifera* (Raf.) Schneid., Osage Orange, Bois D'Arc. Lowland fencerows, thickets, reservoir shorelines; occasional (L,S,T).

Morus alba L., White Mulberry. Persisting, homesites and orchards, in thickets and on reservoir shorelines; rare (S,T).
Morus rubra L., Red Mulberry. Mesic woods; frequent (L,S,T).

NYSSACEAE, Sour-Gum Family
Nyssa aquatica L., Cotton-Gum, Water Tupelo. Low woods along Kentucky Reservoir; rare (S,T).
Nyssa sylvatica Marsh., Black-Gum. Woods, fields, fencerows, thickets; abundant (L,S,T).

OLEACEAE, Olive Family
!*Forestiera acuminata* (Michx.) Poiret, Swamp Privet. Shoreline of Lake Barkley in shallow water; rare (T).
**Forsythia viridissima* Lindl., Yellowbells, Forsythia. Persisting, homesites and cemeteries; occasional (S,T).
Fraxinus americana L., American/White Ash. Mesic woods, fields, fencerows; frequent (L,S,T).
Fraxinus pennsylvanica Marsh., Green Ash. Streambank and bottomland forests; abundant (L,S,T).
Fraxinus quadrangulata Michx., Blue Ash. Wooded bluffs along Lake Barkley; rare (S).
*!*Ligustrum obtusifolium* Sieb. & Zucc., Privet. Persisting, homesites; rare (L,S).
**Ligustrum vulgare* L., Privet. Persisting, homesites and cemeteries, invasive throughout; abundant (L,S,T).
**Syringa vulgaris* L., Lilac. Persisting, homesites and cemeteries; rare (L,S,T).

PAULOWNIACEAE, Empress-Tree Family
**Paulownia tomentosa* (Thunb.) Steud., Princess/Empress Tree. Persisting, homesites and cemeteries, sparingly spreading to fields and roadsides; occasional (L,S,T).

PLATANACEAE, Plane-Tree Family
Platanus occidentalis L., Sycamore. Along streams, pond margins, moist to wet woods and fields; abundant (L,S,T).

POLYGONACEAE, Buckwheat Family
Brunnichia cirrhosa Gaertn., Ladies' Eardrops. Thickets along the reservoirs and embayments; frequent on Kentucky Lake, occasional to rare on Barkley (L,S,T).

RANUNCULACEAE, Crowfoot Family
Clematis virginiana L., Virgin's Bower. Thickets, weedy fields; occasional (L,S,T).
*!*Clematis terniflora* DC., Sweet Autumn Clematis. Thickets along Cumberland River; rare (S).

RHAMNACEAE, Buckthorn Family
Ceanothus americanus L., New Jersey Tea. Dry woods, roadsides, woodland borders; occasional (L,S,T).
Rhamnus caroliniana Walt., Carolina Buckthorn. Mesic woods, fencerows, thickets, usually on limestone outcrops; occasional (L,S,T).

ROSACEAE, Rose Family
Amelanchier arborea (Michx.f) Fern., Serviceberry. Slope and ridge woods and forest borders; frequent (L,S,T).
**Chaenomeles lagenaria* (Loisel.) Koidz., Flowering Quince. Persisting, homesites and cemeteries; occasional (L,S,T).
Crataegus calpodendron (Ehrh.) Medicus, Pear Hawthorn. Mesic woods and thickets; occasional (L,S,T).
!*Crataegus coccinea* L., Fireberry Hawthorn. Low woods; rare (T).
!*Crataegus collina* Chapmn., Hill Hawthorn. Dry woods and thickets; occasional (L,S,T)
Crataegus crus-galli L., Cockspur Hawthorn. Dry woods and fields; occasional (L,S,T).
!*Crataegus mollis* (Torr. & A.Gray) Scheele, Downy Hawthorn. Low woods and thickets; occasional (L,S,T).
Crataegus phaenopyrum (L. f.) Medic., Washington Hawthorn. Mesic woods, fields, thickets, reservoir margins; occasional (L,S,T).
!*Crataegus pruniosa* (Wendl.) K. Koch, Frosted Hawthorn. Mesic to wet woods; rare (T).
!*Crataegus spathulata* Michx., Little-Hip Hawthorn. Low woods, thickets, old pastures; rare (T).
!*Crataegus viridis* L., Green Haw. Low woods, swamp margins; occasional (L,S,T).

Malus angustifolia (Ait.) Michx., Narrow-Leaved Crabapple. Dry woods, fields, roadsides; frequent (L,S,T).

!*Malus coronaria* (L.) P.Mill., Wild Sweet Crab Apple. Dry woods, fields, thickets; occasional (L,S,T); in need of study, some material possibly *M. ioensis* (Wood) Britt.

**Malus pumila* P.Mill., Common Apple. Persisting, homesites and orchards, sometimes appearing on roadsides and around campgrounds; occasional (L,S,T).

*!*Malus prunifolia* (Willd.) Borkh., Cultivated Crab. Know only from one heavily-bearing tree at a Golden Pond homesite; now extirpated due to widening of Highway 68 (T).

*!*Malus sieboldii* (Reg.) Rehder, Toringo Crab. Persisting from wildlife food plantings; rare (L,S,T).

Prunus americana Marsh., American Plum. Dry woods and thickets; occasional (L,S,T).

Prunus angustifolia Marsh., Chickasaw Plum. Fields, fencerows, disturbed sites; occasional (L,S,T).

*!*Prunus cerasus* L., Sour Cherry. Persisting, homesites and orchards; rare (T).

*!*Prunus domestica* L., Cultivated Plum. Persisting, homesites and orchards; rare (L,S,T).

!*Prunus mexicana* S.Wats., Mexican Plum. Low woods; rare (T).

**Prunus persica* (L.) Batsch, Common Peach. Persisting, homesites and orchards, spreading onto roadsides; frequent (L,S,T).

Prunus serotina Ehrh., Wild Black Cherry. Mesic to dry slopes, fencerows, fields; frequent (L,S,T).

*!*Prunus triloba* Lindl., Flowering Almond. Persisting, homesites and cemeteries; rare (L,S,T).

*!*Pyrus calleryana* Dcne., Bradford Pear. Planted, sparingly spreading; rare (S,T).

**Pyrus communis* L., Common Pear. Persisting, homesites and orchards; occasional (L,S,T).

*!*Rhodotypos scandens* (Thunb.) Makino, Jetbead. Persisting and spreading around the site of a former "summer cabin," Ginger Bay area; rare (S).

Rosa carolina L., Carolina Rose. Barrens, weedy fields and thickets; occasional (L,S,T).

**Rosa multiflora* Thunb., Multiflora Rose. Fields, thickets, fencerows; abundant, invasive (L,S,T).

*!*Rosa odorata* (Andr.) Sweet, Cultivated Rose. Persisting, homesites and cemeteries; it is probable that several taxonomic entities are involved; rare (T).

!*Rosa palustris* Marsh., Swamp Rose. Thickets in open swamps and marshes; rare (T).

Rosa setigera Michx., Prairie Rose. Fields, thickets, roadsides; frequent (L,S,T).

*!*Rosa wichuraiana* Crepin., Rambling Rose. Persisting, homesites and cemeteries (other cultivar elements probably included); occasional (L,S,T).

!*Rubus allegheniensis* Porter ex Bailey, Allegheny Blackberry. Low thickets; rare (S).

Rubus argutus L., Common Blackberry. Fields, roadsides; abundant (L,S,T).

*!*Rubus discolor* Weiche & Nees, European Blackberry. Forming thickets near a homesite; rare (S).

Rubus flagellaris Willd., Dewberry. Fields, roadbanks, open disturbed woods; frequent (L,S,T).

**Rubus occidentalis* L., Black Raspberry. Persisting, homesites and orchards, sometimes appearing on roadsides and in fields and woods; occasional (L,S,T).

**Rubus phoenicolasius* Maxim., Wineberry. Persisting, homesites, slowly spreading; rare (S).

*!*Spiraea prunifolia* Sieb. & Zucc., Bridal-Wreath. Persisting, homesites and cemeteries, sparingly adventive; occasional (L,S,T).

*!*Spiraea salicifolia* L., Willow-Leaved Spiraea. Persisting at a homesite, possibly extirpated; rare (S).

*!*Spiraea thunbergii* Sieb. & Zucc., Thunberg's Bridal-Wreath. Persisting, homesites and cemeteries, sparingly adventive; occasional (L,T).

**Spiraea vanhouttei* Zabel, Vanhoutt's Bridal-Wreath. Persisting, homesites and cemeteries, sparingly adventive; frequent (L,S,T).

RUBIACEAE, Madder Family

Cephalanthus occidentalis L., Buttonbush. Swampy thickets, especially around the lakeshores and embayments, often in dense stands; abundant (L,S,T).

RUTACEAE, Rue Family

Ptelea trifoliata (L.) Raf., Wafer Ash. Rich woods, bluffs, fencerows; rare (S,T).

!*Xanthoxylum americanum* Mill., American Prickly Ash. Thickets and open woods with limestone outcrops; rare (T, based on *Athey 4002*, MUR and VDB at BRIT).

SALICACEAE, Willow Family

**Populus alba* L., White or Silver Poplar. Persisting, homesites and cemeteries, extensively spreading from root sprouts; occasional to rare (L,S,T).

*!*Populus canescens* (Ait.) Sm., White Poplar. Persisting, homesites and cemeteries, spreading from root sprouts; rare (S).

Populus deltoides Bartr., Cottonweed. Reservoir shorelines, around embayments and ponds and in bottomland and streambank forests; frequent (L,S,T).

!*Populus grandidentata* Michx., Big-Toothed Aspen. Mesic slope forests; rare (S,T).

*!*Populus nigra* L., Black Poplar. Persisting, homesites, sparingly spreading from root sprouts (S). Including var *italica* Muenchh., Lombardy Popular, collected once from a homesite which has since been cleared for road construction (T).

**Salix babylonica* L., Weeping Willow. Persisting, homesites and cemeteries; rare (S,T).

Salix caroliniana Michx., Carolina or Ward's Willow. Wet fields, streambanks, ditches; occasional (L,S,T).

Salix exigua Nutt., Sandbar Willow. Embayment margins along Kentucky Reservoir; rare (L,S,T).

Salix humilis Marsh. var. *humilis,* Upland Willow. Wet fields, roadsides, ditches, barrens; occasional (L,S,T).

!*Salix humilis* Marsh. var. *microphylla* (Anderss.) Fern., Dwarf Upland Willow, Sage Willow. Dry upland woods and forest borders; rare (T).

Salix nigra Marsh., Black Willow. Reservoir and embayment shorelines, stream and pond margins, swamps; abundant (L,S,T).

!*Salix sericea* Marsh., Silky Willow. Wet fields, thickets and ditches; rare (S,T).

SANTALACEAE, Sandalwood Family

Phoradendron serotinum (Raf.) Johnson, Mistletoe. Epiphytic on various hardwood species, most often in lowlands; occasional (L,S,T).

SAPINDACEAE, Soapberry Family

!*Acer floridanum* (Chapm.) Pax, Southern Sugar Maple. Mesic woods; abundant (L,S,T).

Acer negundo L., Box Elder. Moist woods, fields, thickets; abundant (L,S,T).

!*Acer nigrum* Michx., Black Maple. Riparian woods; rare (T).

Acer rubrum L., Red Maple. Low woods, bottomlands, other mesic sites; abundant (L,S,T).

Acer saccharinum L., Silver or Water Maple. Bottomland and streambank forests; abundant (L,S,T).

Acer saccharum Marsh., Sugar Maple. Mesic woods; also, old plantings are a frequent indicator of former homesteads; abundant (L,S,T).

Aesculus glabra Willd., Ohio Buckeye. In a few streambank, ravine and bluff forests southward, becoming rare northward (S,T).

Aesculus pavia L., Red Buckeye. Alluvial woods, Bear Creek; rare (S).

SAPOTACEAE, Sapodilla Family

Sideroxylon lycioides L., Southern Buckthorn. Mesic woods, fencerows, thickets, usually around bluffs and outcrops; occasional to rare (L,S,T).

SIMAROUBACEAE, Quassia Family

**Ailanthus altissima* (Mill.) Swingle, Tree-of-Heaven. Persisting, homesites and cemeteries, invasive in fields and thickets and on roadsides; occasional (L,S,T).

STAPHYLEACEAE, Bladdernut Family

Staphylea trifolia L., Bladdernut. Streambanks, ravines, rocky slopes and bluffs; occasional (L,S,T).

STYRACACEAE, Storax Family

Halesia carolina L., Carolina Silverbell. Ravines and slopes near Kentucky Reservoir; frequent (L,S,T).

Styrax americana Lam., American Snowbell. Swamp thickets along Kentucky Reservoir; occasional (L,S,T).

!*Styrax grandifolia* Ait., Big-Leaf Snowbell. Dry woods; rare (L,S).

ULMACEAE, Elm Family

!*Planera aquatica* (Walt.) Gmel., Water-Elm. Shoreline of Kentucky Reservoir; rare (S,T).

Ulmus alata Michx., Winged Elm. Woods, fields, fencerows, roadsides; abundant (L,S,T).

Ulmus americana L., American Elm. Bottomland, streambank, mesic slope and bluff forests; frequent (L,S,T).

**Ulmus pumila* L., Siberian Elm. Persisting, homesites and cemetery; rare (L,S,T).

Ulmus rubra Muhl., Red or Slippery Elm. Mesic woods, especially in bottomlands and along streams; also in fencerows and fields; abundant (L,S,T).

!*Ulmus serotina* Sarg., September Elm. Woods and mesic bluffs along the Cumberland River; rare (L,S).

VITACEAE, Grape Family

Ampelopsis arborea (L.) Koehne, Pepper-Vine. Persisting, homesites, thickets along the Tennessee River where it may be native; occasional (L,S,T).

Ampelopsis cordata Michx., Heart-Leaf Ampelopsis. Mesic fencerows and thickets, especially in bottomlands; occasional (L,S,T).

Parthenocissus quinquefolia (L.) Planch., Virginia Creeper. Woods, fencerows, thickets and disturbed sites throughout; abundant (L,S,T).

Vitis aestivalis Michx., Summer Grape. Woods and fencerows throughout, thicket-forming or a high climber; frequent (L,S,T).

!*Vitis cinerea* (Engelm.) Engelm. ex Millard var. *baileyana* (Munson) Comeaux, Bailey's Downy Grape. Bottomland fencerows and thickets; occasional (L,S,T).

!*Vitis cinerea* (Engelm.) Engelm. ex Mill. var. *cinerea,* Downy Grape. Low woods; rare (L).

!**Vitis labrusca* L., Fox Grape. Persisting at a homesite, probably extirpated; rare (T).

!**Vitis labruscana* Bailey, Cultivated Grape. Persisting, homesites and orchards, probably extirpated (L,T).

Vitis palmata Vahl, Red Grape. Sandy thickets near the outer edges of the Kentucky Reservoir fluctuation zone; frequent, occasional (L,S,T).

Vitis rotundifolia Michx., Muscadine Grape. Both dry and wet woods throughout, thicket-forming or trailing on the forest floor; frequent, (L,S,T).

Vitis vulpina L., Frost Grape. Mesic woods, fencerows and thickets, thicket-forming or high-climbing; frequent, (L,S,T).

APPENDIX 2: EXCLUDED WOODY TAXA

Reporting reference(s) given in parentheses, followed by reason(s) for exclusion; NCR =taxon not currently recognized, based on Chester et al. (2009).

Acer rubrum L. var. *trilobum* Koch (Ellis et al. 1971, Chester et al. 1976). NCR.
Acer saccharum Marsh. var. *schneckii* Rehder (Ellis et al. 1971, Chester et al. 1976). NCR.
Amorpha glabra Desf. ex Poir. (Ellis et al. 1971, Chester 2003). Identification error.
Carya ovalis (Wang.) Sarg. var. *obcordata* (Muhl.) Sarg. (Chester et al. 1976, Chester 2003). NCR.
Carya texana Buckl. (Fralish and Crooks 1989). Specimen is *C. pallida* (Ashe) Engl. & Graebn.
Celtis tenuifolia Nutt. (Ellis et al. 1971). Taxon not verified from LBL.
Cornus foemina Mill. (Chester et al. 1976, Chester 1993) = *C. amomum* (annotation by Zack Murrell, Appalachian State University).
Cornus obliqua Raf. (Chester et al. 1976, Chester 1993) =*C. amomum* (annotation by Zack Murrell).
Diospyros virginiana L. var. *pubescens* (Pursh) Dippel (Chester et al. 1976). NCR.
Forsythia suspensa (Thunb.) Vahl (Chester et al. 1976). LBL specimens are not distinct.
Fraxinus americana L.var. *biltmoreana* Beadle (Ellis et al. 1971, Chester et al. 1976). NCR.
Fraxinus nigra Marsh. (Thomas 1963). No vouchers were found at the University of Louisville to substantiate this report and the species is unknown from Kentucky (Jones 2005).
Fraxinus pennsylvanica Marsh. var. *subintegerrima* (Vahl.) Fern. (Ellis et al. 1971, Chester et al. 1976). NCR.
Hypericum densiflorum Pursh (Ellis et al. 1971). Not vouchered.
Ostrya virginiana (Mill.) K.Koch var. *lasia* Fernald (Chester et al. 1976). NCR.
Prunus avium L. (Chester 2003) =*P. cerasus* L. (annotation by Ross Clark, Eastern Kentucky University).
Quercus falcata Michx. var. *triloba* (Michx.) Nutt. (Chester et al. 1976). NCR.
Quercus shumardii Buckl. var. *schneckii* Sarg. (Chester et al. 1976). NCR.
Sassafras albidum (Nutt.) Nees var. *molle* (Raf.) Fernald (Chester et al. 1976). NCR.
Smilax walteri Pursh (Ellis et al. 1971, Chester et al. 1976). Identification error.
Viburnum molle Michx. (Ellis et al. 1971, Chester et al. 1976) =*V. dentatum* L. (annotation by Tim Weckman, Eastern Kentucky University).
Vitis riparia Michx. (Carpenter and Chester 1987) =V. *vulpina* L. (annotation by Michael Moore, University of Georgia).

APPENDIX 3: LISTED WOODY TAXA

Taxa	Status in KY[1]	Status in TN[1]	LBL Distribution[2]
Carya aquatica (Michx.) Nutt., Water Hickory	T	-	S,T
Carya carolinae-septentrionalis (Ashe) Engl. & Graebn., Carolina Shagbark Hickory	T	-	S,T
Castanea dentata (Marsh.) Borkh., American Chestnut	E	S	S,T
Halesia carolina L., Silverbell	E	-	L,S,T
Juglans cinerea L., White Walnut	S	T	S,T
Philadelphus pubescens Loisel., Mock-Orange	E	-	S,T
Ulmus serotina Sarg., September Elm	S	-	L,S

[1]Status designations: T =Threatened; E =Endangered; S =Special Concern
[2]LBL distribution: S =Stewart County, TN; L =Lyon County, KY; T =Trigg County, KY

In addition, *Aesculus pavia* and *Quercus nigra*, each listed Threatened in Kentucky, are known from the Tennessee portion (Stewart County) of LBL. *Ribes missouriense* and *Zanthoxylum americanum*, each listed Special Concern in Tennessee, are known from the Kentucky side (Trigg County) of LBL.

CHARACTERISTICS OF SEVERAL EAST TENNESSEE PINE-DOMINATED FOREST STANDS

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ABSTRACT. A study of certain characteristics of eight *Pinus* forest stands has been made in the Valley and Ridge of East Tennessee (one stand was located on north Chilhowee Mountain, thus technically at the western edge of the Blue Ridge). All stands occurred over sandstone bedrocks (Clinch, Grainger, Rome, Bays) or conglomerate (Cochran). Stands had a south or west aspect. They occurred on side slopes, ridge crests, and one was on a river bluff and cliff edge. Most stands had overstory dominance of pine (*Pinus virginiana*) or mixed pine with oak or mixed hardwood. One stand was *Quercus-Pinus virginiana* dominated. The flora totaled 293 taxa of which 6.6% were introduced. Stand size and amount of open edge and probably deer activity influenced stand floristic richness. Proportions among floristic elements were similar to those seen in other studies. Stands were arrayed, using site factors, from xeric to subxeric. Relative density of *Pinus* and ericad taxa numbers were highest in the xeric half of the array. A group of 14 mesic and submesic tree taxa, occurring mainly in the understory, had somewhat more importance in subxeric stands. A study of tree diameters by stand revealed the reverse J-shaped, bell-shaped, and reverse S-shaped diameter distribution types. Pines in four stands exhibited the bell-shape. Other hardwoods in seven stands exhibited the reverse J-shape. Disturbances were thought to have influenced floristic richness of trees, numbers of introduced taxa, and the numbers of other types of taxa.

INTRODUCTION

The study of the flora of the Southern Appalachians was examined early in the twentieth century (Small 1903), and intensively in the last generation or so (Strausbaugh and Core 1952-1964, Harvill et al. 1992, White 1982, Wofford 1989, Wofford and Kral 1993, Radford et al. 1968, Duncan and Kartesz 1981). Some local lists in the Tennessee Valley include Mann et al. (1985), Bullington (1997) and Van Horn (1981). Some Valley vegetation studies that included *Pinus* types are those of Crownover (1983), Hardaway (1962), Hedge (1979) and Martin (1971); some such studies with partial to complete *Pinus* stand floras were De Selm (1984), Hedge (1979), Thomas (1966), and Wolfe (1956).

In metes and bounds survey records of presettlement and early Euroamerican settlement of the Valley, in over one dozen counties, *Pinus* percentages varied from 3.1 to 13.5% of trees (De Selm 1995, 1997, 1999, 2001, 2003, 2006; De Selm and Rose 1995). Clearly *Pinus* species were an important part of the forests, whether due to disturbances or to site factors. *Pinus* and pine-hardwood vegetation was seen by Tennessee Valley Authority foresters and mapped as extensive (TVA Department of Forestry Relations 1941). Braun (1950) in personal and cited studies described *Pinus* vegetation; these descriptions were repeated by Küchler (1964) and Stephenson et al. (1993).

Stephenson et al. (1993) assigned pines (particularly *P. virginiana*) to disturbed sites where such vegetation "may remain for an indefinite period particularly if there are recurring episodes of drought and/or fires." Foresters with extensive forest observation and management experience have considered the shortleaf pine type (75) and Virginia pine type (79) chiefly successional and short-lived because of repeated logging and succession to hardwoods—particularly oaks. The shortleaf pine-oak type (76) and Virginia pine-oak type (78) have been also considered disturbance-caused or maintained. However, the former from the margins of the Cumberland Plateau, "may be stable communities and a physiographic climax." Regards the Virginia pine type on Appalachian uplands, "the type occurs on dry . . . shallow, rocky soils where drought-resistant pines can compete successfully with oaks" (Eyre 1980). It has been called a transitional species because of its low reproduction in stands which include hardwoods, and a pioneer or disaster species coming in after fire or in old field succession or eroded areas. The species is replaced "unless fire or other factors retard the hardwoods" (Fowells 1965, Burns and Honkala 1990, Hicks 1998, Smith 1968, Lafon et al. 2000).

This study was stimulated by the writer's experience in Valley *Pinus* stands (De Selm in progress) and realization that a one-hour stand examination reveals only a part of the flora. Several trips were made to each stand in this study. Data were examined to try to determine whether stands were entirely of disturbance origin or whether sites could be found where *Pinus* taxa persist (though disturbed periodically) in the face of hardwood competition.

Pinus species have some characteristics of interest. They have rapid growth at least on good sites, and a high light intensity tolerance/requirement that balances respirational losses that enables species to enter early in successional series. The leaves have desiccation-reducing sunken stomates, thick-walled hypodermal layers and endodermal cell walls and an epidermis with a thick cuticle. *Pinus rigida* sprouts after fire and has cone serotiny in some populations. Some *Pinus* species produce allelopathic substances that reduce seed germination in other species and may inhibit the growth of mycorrhizal fungi—both actions may reduce necessary functions of competitors. The leaf characteristics above, as well as others, enable *Pinus* species to grow on sandy or rocky, shallow soils (Kozlowski and Pallardy 1997, Gurevitch et al. 2002, Rice 1984, Hicks 1998).

Initiation of fire control in forests has permitted fire-sensitive species to increase in importance with subsequent decline in reproduction of *Quercus* and *Pinus* species (Lorimer 1993, Martin 1989). Non-significant increases in richness were found with one prescribed fire in *Quercus-Pinus* ridge stands in eastern Kentucky (Kuddes-Fischer and Arthur 2002). Periodic fire in the presettlement landscape and frequent understory burns and logging until the 1940s allowed *Quercus* and *Pinus* reproduction. Subsequent *Pinus* decline is thought caused by drought, southern pine beetle attacks, deer browsing and competition from hardwood trees and understory shrubs and woody vines (Vose et al. 1997).

THE STUDY AREA

The Valley and Ridge Physiographic Province extends from central Alabama northward into the Hudson River valley (Fenneman 1938). The Tennessee part of the Valley is underlain by bedrocks of Paleozoic age: sandstones, dolomites, limestones and shales which have been extensively folded and faulted in the past. The erosion which followed resulted in a topographic system of parallel ridges and valleys which extend to the northeast and southwest.

Elevations in the valley floor and many ridges ranged from 243-457 meters and above. Clinch Mountain *Pinus* stands (used here) ranged from 350-533 meters, other Valley sites ranged from 248 to 403 meters. The north Chilhowee Mountain site was at about 454 meters. Sample sites from this study were on the Clinch sandstone, Grainger Formation (especially sandstone), Rome Formation (sandstone), Bays Formation (sandstone) and Cochran conglomerate (Rodgers 1953, Hardeman 1966, Cattermole 1958).

Soils were characterized as Typic Hapludults, Typic Dystrochrepts, and Typic Rhodudults in the Tellico and/or Steekee series; also occurring were the Wallen, Muskingum and Jefferson series. One of the Wallen series sites and two Muskingum sites were also associated with Rough Land and the Sharp Ridge site was mapped as Muskingum-Lehew. Most were described as steep (to 50%), strongly to very strongly acid, sandy, and with up to 60% stone in the profile. The Monroe County site was over the Bays Formation; the soils there, of the Tellico/Steekee series, were noted as derived from red calcareous sandstone. Soils were residual except the Jefferson series on Goose Creek in Sevier County, and the Benton Springs Road site in Polk County which were of colluvial origin (USDA Soil Conservation Service Soil Survey Staff 1975 and various county soil surveys).

The study area climate is temperate with well distributed precipitation, mostly rainfall, of 112-122 cm (Dickson 1960, 1931-1960 data) or 114-130 cm (De Selm and Schmidt 2002, 1961-1990 data). Tornados and severe downdrafts are occasional in the Valley (Vaiksnoris 1971). Summer and autumn droughts are common (Vaiksnoris and Palmer 1973). The mean January minimum temperatures are near -1.0°C and the mean July maximums are near 31°C (Dickson 1960). Southwest aspect was most common (four stands), but sites with southeast, south or northwest-facing aspects were also encountered. Six stands were on upper or middle slopes.

Six stands had slope angles greater than 20%, exceptions were the Sharp Ridge crest site (5%), and the south Chilhowee Mountain footslope in Polk County (10%). Six stands were on slopes without topographic protection from nearby opposite ridges—only the Goose Creek and Joppa sites have such near ridges. Thus most stands were xeric with south or west aspect, steep slopes with mostly mid to upper slope position (and usually no protection) which increased radiation and potentially increased evapotranspiration.

Leaf litter warming on south-facing slopes leads to its redistribution downslope, increased soil temperatures, increased soil evaporation, erosion, and loss of organic matter; clay percentage is lowered as is cation exchange capacity (Wolfe et al. 1949, Finney et al. 1962, Hutchins et al. 1976, Orndorff and Lang 1981).

The generally westerly winds in the Valley, with their possible drying effects, would directly influence exposed slopes of four stands. On the other hand, were such winds moist, more precipitation would be expected on the windward than lee slopes (Trewartha 1968). Five stands were at an elevation of 174 m or more over the adjacent valley floor. Increased wind speed toward the crest (four upper slope stands and two middle slope stands) and the funnel effect of wind through gaps (two stands) may distribute precipitation unevenly on lee slopes and also reduce precipitation on uppermost windward slopes (Smallshaw 1953). The rocky, sandy and sometimes shallow soil profiles amplify the moisture stress (Brady and Weil 1999). Slightly lower temperatures (0.2℃/200 m) may be expected upslope with wind movement up ridges (Shanks 1954, Stephens 1969). Whether these slight temperature changes with elevation influence vegetation on these low mountains is, as yet, unknown.

The vegetation and flora have been evolving from at least the Cretaceous through the Recent times (Graham 1999). Land connections fostering plant migrations have occurred between North America and Asia and Europe thus enriching our flora. Cool periods of Pleistocene climate, effective at least as far south as the 34^{th} parallel, resulted in invasion of spruce and northern pine which doubtless restricted the growth of resident vegetation (Graham 1999, Delcourt and Delcourt 1987). Warm Interglacials, and the warm, dry Holocene Hypsithermal period 8400-5200 years B.P. (Dunbar 2000), the Little Climatic Optimum and Little Ice Age (Burroughs 2005) may have been instrumental in stimulating migrations of floras from near and far.

The entry of Native Americans in Holocene time resulted in consumptive use of land and plants and animals for food, villages, and burial grounds (Lewis and Kneberg 1958, Swanton 1946, Delcourt and Delcourt 1998).

During the late eighteenth century European-Americans entered the area occupying the land completely. Their practices included logging the forest, draining of some valley wetlands, cultivating row crops in valleys and building roads and communities. Woods burning and stock grazing were common (Folmsbee et al. 1969, Killebrew et al. 1874). Continued pressure on the landscape and its vegetation have included community growth, more intensive logging, grazing by stock (which may have much more effect when stock are confined by fencing), growing deer herds (McShea et al. 1997), herb collecting by local landowners and poaching by others, the invasion of wild areas by weeds and foreign insects and diseases (cf. Nolt et al. 1997, Nash 1999), fire control, and climate change (Weart 2003, Lovejoy and Hannah 2005).

METHODS AND SAMPLE AREAS

Pinus stands are commonly seen in the Valley—but most have developed from severely logged oak forests, from old field succession (Smith 1968) and from planting. Stands have been seen on some high ridges, as White Oak Mountain, but were inaccessible; no stands are known to me on Newman Ridge or Powell Mountain. Fourteen stands were found in the examination of Valley forests from 1998-2000. Additional sites were sought in spring 2007. Some ridge sites were lost to development or to logging or to southern pine beetle attack. Seven stands were selected for the current study and an additional one was located by reconnaissance in 2007. In five stands, maximum tree diameter was 51-76 cm but in three the maximum diameter was 28-36 cm suggesting the xeric nature of the site and/or periodic disturbance such as beetle infestation. All eight stands were examined March through November 2007 about every three weeks for inventory of the vascular flora (Fig. 1).

At each site a 100-200 meter transect was walked during each observation period. Specimens were collected and determined and species ranges determined using standard manuals with the aid of facilities at TENN. Sources included Gleason and Cronquist (1991), appropriate volumes of the *Flora of North America* (Flora of North America Editorial Committee 1993 et seq.). Chester et al. (1993, 1997), Jones (2005), Kartesz (1994), Wofford (1989), Wofford and Chester (2002), Cope (2001), Lance (2004), Isley (1990). Floras were compiled by sample site. Sites are described briefly in Appendix 1.

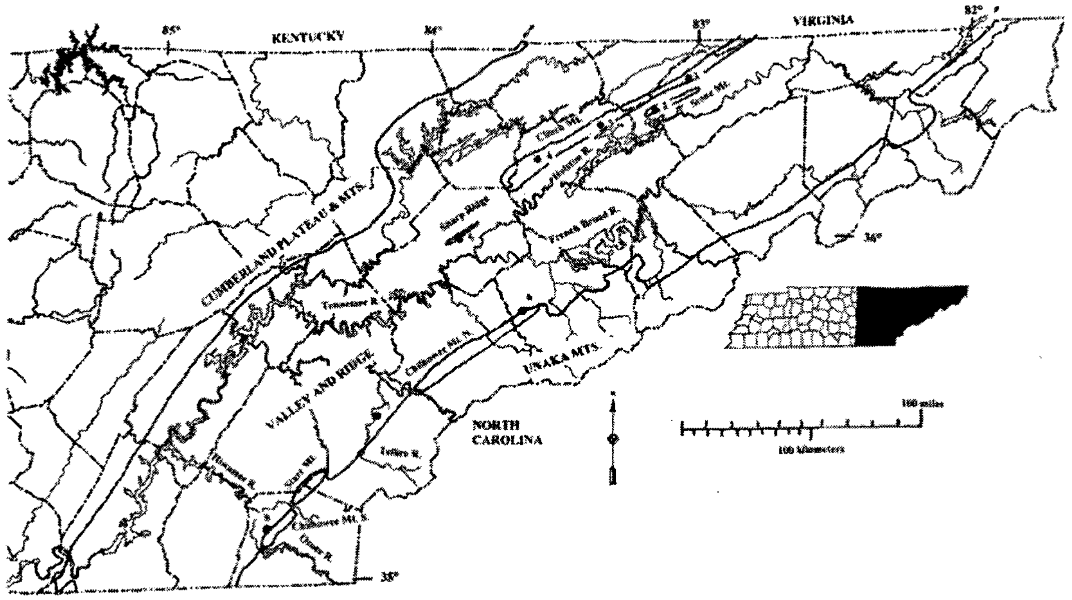

Figure 1. Map of East Tennessee locating the eight study pine stands (small solid circles) and significant topographic features.

RESULTS AND DISCUSSION

General – Flora

The taxa found on the eight sample areas totaled 293; these included unknown blackberries/dewberries (*Rubus* spp.), violets (*Viola* spp.), grapes (*Vitis* spp.) and an unknown narrow-leaved cherry (*Prunus* sp.) (Appendix 2). Introduced taxa were 6.6% of the total; weeds (Underwood 1965) accounted for 11.9% (of which nearly one-fifth was introduced). Woody taxa totaled one-third (33.6%); grasses totaled 13.6%; sedges and a wood rush at 2.4% and ferns only 1.7%. Grass, sedge and fern numbers compared with 7.8%, 5.9% and 6.2% in 15 Valley mesic stands sampled using the same procedures in 2003 and 2004 (De Selm 2006). The xeric nature of these pine sites was probably responsible for the higher grass and lower proportions of sedge and fern taxa.

Floristic elements were intraneous at 63.6%, extraneous southern 21.8%, extraneous northern 10.8%, Appalachian 2.9% and extraneous western at 1.0%. Although these proportions vary somewhat from those of the Valley barrens and glades (De Selm 1993), the element percentages are in the same order.

The small Appalachian element consisted of seven taxa (Appendix 2) with ranges from Kentucky, Virginia or West Virginia, south to Alabama or Georgia (Gleason and Cronquist 1991). *Vaccinium hirsutum* occurs only in the mountains of North Carolina and Georgia and the Unaka Mountains and Valley and Ridge of Tennessee (Chester et al. 1997, Radford et al. 1968, Jones and Coile 1988). This taxon was once on the Tennessee Rare Plant List but has since been removed (Bailey 2004).

Stand Classification

Several floristic or vegetation studies have been made in the Valley or on Chilhowee Mountain that are comparable. Pine types studied by Martin (1971), Crownover (1983) and Thomas (1966) yielded 77-85% the same tree taxa as seen here. Thomas's (1966) shrub list was 80% similar, and Oxendine's (1971) most xeric type shrub list was 91% similar. In addition, 51-80% of the herbaceous species documented by Wolfe (1956), Hedge (1979) and Thomas (1966) in studies of similar sites occurred on the present study sites. Whittaker's (1956) Great Smoky Mountain Virginia pine forest tree, shrub and herb list contained 84% of the same species as in the present study. Similarly, the Cumberland Plateau pine stand overstory taxa (Schmalzer 1989; Smith 1977) have 88-95% the same species as in the present study.

Percent species presence among the eight stands follows the distributions shown by Oosting (1956, from Sierran fir data). In distributing species presence from eight samples, six presence categories were used instead of five as shown by Oosting. Here the species percent declines from classes one through four: rare, seldom present, often present, mostly present, and then rises somewhat in the constantly present class—reminiscent of Oosting's frequency distribution data. Thus the distribution approximates normal.

The stands here were classed into four pine vegetation types: Virginia pine-oak-eastern redcedar (one stand), Virginia pine-hardwood (two stands), mixed pine-oak (two stands), and mixed pine-hardwood (two stands). One stand was classed as a mixed oak-Virginia pine type. These types would have been mapped as yellow pine-hardwood, which was extensive and variable in the 1930s (Tennessee Valley Authority Division of Forestry Relations 1941). Some would be included in the Society of American Foresters Type 79 Virginia Pine, or Virginia Pine-Oak Type 78 (Eyres 1980). The mixed oak-Virginia pine stand found here was similar to the oak-pine cover type of Thomas (1966) and was also similar to the chestnut oak-pine type of Hedge (1979). The pine type may be represented in the *Pinus virginiana-Pinus (rigida-echinata)-Quercus prinus/Vaccinium pallidum* forest of Weakley et al. (1998). The pine types found here were not represented in the descriptions of pine vegetation in Thomas (1966), Martin (1971), Hedge (1977), nor Crownover (1982). Although this pine nomenclature was not determined using a statistical classification process, the new types do suggest that continued search and sampling activities are justified.

Numbers of native tree taxa were compared across stands. Tree taxa (numbers range 8-13) did not vary by community among types. The types may be of small areal extent, low geographic frequency, or short tenure as to not facilitate species accumulation over time. Similarly site, bedrock or location on a river did not seem to sort sites into low versus higher taxa numbers. Understory taxa numbers were compared across stands. Most stands clustered, however, the Tellico River bluff site and Chilhowee Mountain sites ranged higher than all others. The Tellico flows many miles across East Tennessee and its headwaters lie in the Blue Ridge of North Carolina. Chilhowee Mountain forms the west edge of the Blue Ridge in two areas of East Tennessee. These factors, a long, continuous habitat intersecting other rich habitats, and a habitat which is part of a physiographically and biologically unique area both increase diversity.

This small group of samples may inadequately sample the Valley pine vegetation flora; sample site numbers are low and sample areas are small. Examination of herb taxa per sample site indicated that the size of site floras was influenced by site area, deer activity, and amount of exposed (lighted) stand edge. Herb taxa/total taxa per site ranged from 38/83 to 76/118. The August and September drought in 2007 may have reduced herb growth and thus their visibility.

Other factors influencing species presence are their reaction to allelopathic substances as those produced by shrubs as *Kalmia* and *Rhus copallina*, *Rubus*, *Gaultheria* and *Lonicera*, and herbs such as *Aster* *macrophyllus*, *Solidago*, *Euphorbia corollata*, and trees as *Prunus serotina*, *Quercus alba*, *Q. marilandica*, *Q. rubra* and *Q. stellata* (Rice 1984). The possible actions and effects here are, as yet, unknown.

Understory herb distribution and abundance, as well as that of trees, shrubs and woody vines are thought to be controlled within a stand by topography: elevation, aspect, and microtopography (especially tip-up pits and mounds), soil quality (especially fertility), wet and dry year sequence, herbivory, and with overstory composition, basal area and cover with gap sizes and gap timing (Beatty 2003, McCarthy 2003). Reports of floristic sampling results may be based on small or few area samples, or sampling only in one or two seasons of one year which decrease the probability of adequacy (McCarthy 2003, De Selm personal observation). Multi-year sampling "of the same plant populations" may have differing results among years because of weather, deer browse, branch fall, and shoot death due to light availability changes or desiccation (McCleahen and Long 1995).

The Stand Array

Stands were arrayed from presumed most xeric to subxeric using aspect and slope angle (Beers et al. 1966), slope position, slope protection and soil profile rock and sand percentages based on soil type or series descriptions (as Moore et al. 1979). The results were from most xeric above to subxeric below in the following list:

1. Goose Ck. Rd., north Chilhowee Mt., Sevier Co.
2. Ballplay Rd., Monroe Co.
3. Old Rt. 25E, Clinch Mt., Grainger Co.
4. Rt. 70, Clinch Mt., Hawkins Co.
5. Rt. 66, Stone Mt., Hawkins Co.
6. Benton Springs Rd., base of south Chilhowee Mt., Polk Co.
7. Joppa Rd., Clinch Mt., Grainger Co.
8. Sharp Ridge, Knox Co.

In the upper (xeric) half versus subxeric lower half, *Pinus* relative density averaged about 3:2. Numbers of ericad taxa were twice as abundant in the upper (xeric) versus lower half. The relationship predicted about seven ericad taxa at 100% of pine overstory. Grass species numbers were about equally distributed across the array, with fewest taxa at each end. Sedges, the rush and ferns, with few taxa, were unevenly distributed. Tree taxa were non-uniformly distributed and the taxa varied by almost 2X between sites. The shrub-vine taxa were distributed between stands similarly to tree taxa. Vine taxa:shrub taxa varied from 1:1 to about 1:3 but six stands were centered between the extremes. Forb taxa were variable across the array and varied by 2X between sites. Some mesic or submesic tree taxa (sensu Whittaker 1956) had slightly more average importance in the subxeric half of the array.

Bole Diameter Distributions

In these pine-oak and pine-hardwood stands, overstory composition and structure may be used to understand probable stand reproduction, stability and tenure. Of particular interest was the stand character of *P. virginiana* which constituted 88% of the pine density across all stands. *Pinus virginiana* shade intolerance, fire and windthrow sensitivity and relatively short life span (up to about 100 years, Burns and Honkala 1990; Hicks 1998) do not suggest *P. virginiana* as a long-term forest dominant. Previous widespread observations of its abundance locally may have been of old field, burned or logged forests, as suggested by its propensity to invade such sites (Burns and Honkala 1990). Most *P. virginiana* stands seen today seem to be young, disturbance-origin stands (De Selm in progress). The species has characteristics which enable it to invade and thrive on disturbed sites. It has an edaphic and microclimatic tolerance for a wide variety of growing conditions; it may produce multiple flushes of growth in one season; it produces cones and seed when as young as five years; seeds are produced most years with a heavy crop about each three years; seeds are light (winged) and may blow over 30 meters from the parent tree. On poor sites it can outgrow *Pinus echinata* and some *Quercus* and *Carya* species at least initially, and out-produce *P. echinata* on a 50-year rotation (Burns and Honkala 1990, Hicks 1998).

Quercus species comprised a substantial number of tree stems in stands of this study. Their importance as regional dominants was well known (see Stephenson et al. 1997). Many *Quercus* species grow to large size and great age on many kinds of sites and their thick bark enables them to survive surface fires. Many are drought tolerant and have a large taproot and extensive lateral root system. Leaf morphology reduces transpiration rates, and even when leaves are at less than full turgor, they can carry out gas exchange. The acorn crop is prolific but mainly periodic. Upland *Quercus* species are intermediate to intolerant to very intolerant of shade with resulting problems of seedling survival. Acorns are subject to animal predation and disease. The trees are subject to a wide range of diseases and insect pests. Three recent epidemics include oak wilt, oak decline which killed nearly 10% of the oaks in east Tennessee and neighboring states in the 1980s, and the elm spanworm infestations which were severe in east Tennessee 1955-1963 (Oak 2002, Dey 2002b, Burns and Honkala 1990).

Quercus importance in forests has continued from the presettlement period, through the exploitative period to recent decades (McWilliams et al. 2002, Abrams 2002, Dey 2002b). Chestnut (*Castanea dentata*) loss in the 1920s has increased oak importance (Woods and Shanks 1959). Modern forest conditions, with little fire, a large deer herd, diseases and insect pests, fragmented land ownership, present logging procedures and probable current climate change, have resulted in severe *Quercus* forest reproduction and survival problems (Dey 2002a, Frelich and Reich 2002).

Stand bole diameter distributions were arrayed (2.5 cm classes, 12.7 cm DBH and above) and examined. Trees were classed as *Pinus*, *Quercus* species, and other hardwoods (the few *Juniperus virginiana* stems were omitted from the analysis). Stems ranged to 76 cm; six stands had stems 46 cm DBH and larger. Maximum DBH of *P. virginiana*, important in each stand, ranged from 28 to 46 cm. *Pinus rigida*, in three stands, ranged in maximum diameters per stand from 30 to 41 cm. *Pinus echinata*, in three stands, ranged in maximum diameter in those stands from 25 to 46 cm. There was a 63 cm *Pinus strobus*.

Quercus species were distributed as trees, in seven of the eight stands (as saplings only in the Rt. 70 stand). Among the seven stands, numbers of *Quercus* taxa ranged from two to five, and numbers of stems from three to 37. In all but two stands, *Quercus* contributed over one-third to nearly two-thirds of the hardwood density. Maximum *Quercus* diameters in the seven stands ranged from 15 to 61 cm.

Three kinds of stem number patterns were seen in the diameter array. The most common was the reverse J-shape with many small stems, and the numbers of stems decreasing with increasing diameter class. The large numbers of stems derived from reproductive potential, side lighting and shade intolerance versus tolerance among the age groups of the taxa. The second kind of diameter array observed was the normal or bell-shaped with maximum stem numbers in the middle part of the array but stem number then declined toward both the smaller and larger diameter ends of the array. This type was reported for two *Pinus* species of the Great Smoky Mountains (Whittaker 1956). It was thought to represent arrival and survival of a cohort following some change in the proceeding community structure (in shade intolerant *Pinus* and *Quercus*, a canopy opening). The third type was one in which one or more groups of larger diameter stems (each thought to be a chronological cohort) occurred, scattered along the array. This was the reverse S-shaped or rotated S-shaped type. Each stem cluster represented a cohort of a particular species or different growth rates among one or more species which probably resulted from a local structural change such as periodic overstory tree species death or removal (Oliver and Larson 1990, Smith et al. 1997, Hicks 1998).

The reverse J-shaped distribution occurred in *Pinus* at Ballplay Road and Old 25E, in other hardwoods in seven stands, and in oak at Ballplay Road and Old 25E. These were stands where maximum tree DBHs were 30-46 cm and other stem size distribution may have been related to a fairly recent stand origin, side lighting and shade tolerance among the other hardwoods.

The bell-shaped curve was seen in *Pinus* species on Goose Creek, Stone Mountain, Benton Springs Road and Joppa Road. The diameter ranges of the clusters were 20-31, 18-25 and 23-31 cm, respectively. It seems possible that these cohorts originated from past stand pine beetle attacks or some widespread oak infestation which opened the canopies.

The reverse S-shaped curves occurred in five stands. One was in the Rt. 70 *Pinus* population. Another was the Stone Mountain *Quercus* species with stems to 51 cm DBH (the nearest *Quercus* stems of any size there were at 30 cm). This may represent an older infestation, lightning strike opening, or a logging residual. The Benton Springs Road stand had one *Quercus* stem cluster at 23-30 cm. The diameters were near enough to the *Pinus* bell-shaped curve cohort in that stand to suggest the same physical cause. The Joppa Road stand contained few other hardwoods but there were small peaks at 25 and 46 cm and a 76 cm *Acer rubrum*. There were only four stems below 25 cm of any species there. This was the stand with charcoal on a snag. The stems at 25 cm were in the 25-31 cm *Pinus* and *Quercus* cohorts and may have had the same cause (fire?). The 46 and 76 cm hardwood stems may have been from other natural disturbances or logging residuals. The Sharp Ridge *Pinus* had a few stem clusters at 25 and at 41 cm. The 25 cm cluster was the same diameter of *Pinus* clusters (cohorts) at Joppa Road, Benton Springs Road and Stone Mountain and may have represented a widespread beetle infestation. The 36-41 cm cluster represented some other earlier structural change (a small power line was cut through the forest adjacent to the Sharp Ridge stand). *Quercus* stems exhibited multiple low peaks and other hardwood stems had reverse-J distribution.

In these stands, no land use history was known from records. Most stands were privately owned, one was in a city park, one was on TVA lake edge land, and one was between two state roads and may be state owned. None exhibited recent disturbances as logging or grazing (deer browse evidence was common). No records existed for disease outbreaks or insect infestations (though most stands had fairly recently killed *Pinus* boles on the ground).

According to Price et al. (1998), between 1967 and 1996, there was southern pine beetle damage to *Pinus* in all six counties where stands occurred. Losses occurred in Hawkins and Grainger counties during 1-4 years with up to 2.8 cubic meters of wood lost per year. In Knox and Sevier counties it was 9-12 years and 2.8-8.5 cubic meters lost per year. In Monroe and Polk counties, it was about 13-18 years with 14.2-19.8 cubic meters lost per year. Precise outbreak locations were not stated. Other diseases/infestations (as in *Quercus*) are known to have occurred in east Tennessee in past decades but not known specifically in these stands.

Trees in the study stands were not cored, so diameter/age relationships were not known. Thus, relating diameters to an actual chronology can only be approximate. However, this diameter distribution study showed a probable varied disturbance history, involving weather, disease (Myers et al. 2004), insects (De Selm and Boner 1984), logging episodes, or multiple causes (McGee 1986).

Tree coring remains possible in these stands. A core yields multiple kinds of information from tree growth and site index (Hebb 1962) and successional structural and composition change (Hart et al. 2008) to precipitation variation and dry year frequency (studies in Virginia and North Carolina, Copenheaver et al. 2002, Puckett 1981, Stahle et al. 1988; studies in the Valley in Tennessee, Hawley 1937, Lassetter 1938). Tree ring reconstructions that measured spring rainfall over the "southeast" (actually the Coastal Plain of Georgia, and South and North Carolina) showed enormous annual variation from 1890-1980 (Stahle and Cleaveland 1994). Reconstructed statewide Palmer Drought Severity Index in Arkansas showed many peaks between 1880 and 1980 and earlier (Stahle et al. 1985). *Juniperus virginiana* tree rings in Missouri projected drought years in the past: 1945-1955, 1930, 1934, 1936, 1898-1902, 1879, 1881 and earlier (Couyette et al. 1980).

Episodic drought, high winds, tree disease, insect infestations and logging all contributed to stem size diversity/irregularity and past canopy openings have created opportunity for shade intolerant species entry into the stands. Conversely, long periods without openings created continuously closed canopy conditions ideal for shade tolerant taxa persistence. These stands contained a mixture of shade tolerant and intolerant taxa such as has been seen in other kinds of stands in this study series (e.g., De Selm 2006, 2008a, 2008b). Modest positive relationships between disturbance number and numbers of tree taxa and numbers of introduced taxa occurred.

Stand size and consequent species richness, however, influenced these relationships. When the small area Sharp Ridge stand was excluded from the series, a positive relationship apparently occurred between numbers of disturbances and total numbers of taxa, of herb taxa numbers, and of graminoid taxa numbers.

SUMMARY AND CONCLUSIONS

Seven of the eight pine stands examined in this study were from the Valley in Tennessee and their vegetation and flora are thought to be representative of the forms of the types found. Most overstories were dominated by *P. virginiana* sometimes with *P. echinata* and *P. rigida* and commonly a large hardwood element in which *Quercus*, especially *Q. montana* and *Q. velutina*, were prominent. In one stand *Juniperus virginiana* was third codominant. The understory was usually dominated by tree reproduction (hardwoods); shrubs, vines, and herbs were interspersed with tree seedlings and saplings. In one stand *Vaccinium arboreum* was prominent but other ericad shrubs were mostly of low presence (among 0-9 taxa, average 2.6 per stand). The north Chilhowee Mountain stand had a >50% cover of *Kalmia latifolia* and *Rhododendron maximum*. Among all stands, tree taxa numbered 22-29, shrub and vine taxa 14-26, and herb taxa 39-70 per stand.

Stands were classed into four pine types (Virginia pine and mixed pines were leading dominants in various stands). There was one mixed oak-Virginia pine type. Some types have not been described in other local literature suggesting that further study is justified. Woody diversity was greatest in the understory in two stands, one on the Tellico River bluffs and on Chilhowee Mountain. This suggests that the river's long, continuous, connected habitat, and proximity to the Unaka Mountains, act to increase diversity.

Stands were arrayed from xeric to subxeric using site and soil factors. *Pinus* species were more important in the xeric half of the array; ericad taxa were twice as numerous there. Tree, shrub, vine, forb and grass taxa numbers varied widely by stand across the array. A group of mesic and submesic tree taxa had slightly more importance in the subxeric half of the array. The absolute numbers of taxa per stand, especially of herbs, was thought to be much influenced by stand area, deer browse intensity and perhaps amount of stand edge in the sample. Most stands were floristically similar to other *Pinus* stands reported in the Valley, the Cumberland Plateau and Great Smoky Mountains.

Arraying numbers of stems of *Pinus*, *Quercus* and other hardwoods by stem DBH revealed three kinds of stem distribution, the reverse J-shaped, the bell-shaped and reverse S-shaped curves. The *Pinus* and *Quercus* in two stands and other hardwood stems in seven stands exhibited the reverse J-shaped curve. Four *Pinus* stands exhibited the bell-shaped curve. The S-shaped, multiple cohort type, occurred in four stand *Quercus* populations, two stand *Pinus* populations and one other hardwood stand population. Several kinds of environmental and historical factors have probably produced these species and species group number/size responses. Floristic richness (numbers of tree taxa and numbers of introduced taxa) were weakly positively related to stand size and disturbance number. Differences in stand sizes and other factors operating with disturbance number masked clear relationships.

ACKNOWLEDGMENTS

The writer acknowledges the kindness of landowners who allowed use of land. Determination of species names was in part possible by use of facilities of the Herbarium of the University of Tennessee directed by Dr. B. E. Wofford. B. E. Wofford, John Beck, Dr. Randy Small and Aaron Flodin were helpful with problem collections. The Pendergrass Library, University of Tennessee, provided bibliographic factual and material assistance; the Department of Ecology and Evolutionary Biology supported the project. Thanks are due to Ms. Eunice Turner who formatted and typed the manuscript. My wife, Bee, accompanied me on several autumn trips and did most of the driving. The cost of the field work was personal; for my family's help and forbearance, I am grateful.

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APPENDIX 1: SAMPLE AREA SITES USED IN THE 2007 STUDY

1. State Rt. 70 on Clinch Mountain, 00-291, Hawkins, side slope, Clinch ss, SE, 57%, mixed pine-hardwood. Area was a small, chiefly low ridge and adjacent roadcut. Also present was a southeast-facing rock outcrop which was explored only at its base because of very steep slope angle. Three ericads were present with low cover.
2. State Rt. 66 on Stone Mt. near crest, 00-287, Hawkins, upper slope, Grainger Form., ss, SW, 40%, Virginia pine-hardwood. The small stand was dissected by Rt. 66 creating edge. There were four ericad taxa with low cover.
3. Old Rt. 25E on Clinch Mt., 99-268, Grainger, side slope, Clinch ss, S, 30%, Virginia pine-hardwood. Site was elongate, cut by the old roadway. A sandstone rock outcrop also occurred. Three ericad taxa were present with low cover.
4. Joppa Rd. on Clinch Mt., 99-248, Grainger, side slope, Clinch ss, S, 22%, mixed oak-Virginia pine. The stand extended for about 100 meters along the side of the slope. There are two ericad taxa with low cover. Fire evidence was present.
5. Sharp Ridge Park, 98-196, Knox, upper slope, Rome Form., ss, NW, 5%, mixed pine-oak. This area on top of Sharp Ridge was surrounded by chestnut oak (*Quercus montana*)forest. There were no ericads.
6. Goose Ck. Rd. on north Chilhowee Mt., 07-01, Sevier, side slope, Cochran Form. (congl.), SW, 85%, mixed pine-hardwood. This small side-slope ridge site was 0.1 mile west of the Smoky Mountain fault. There were four shrub ericad taxa and the understory was mountain laurel (*Kalmia latifolia*) dominated. There were 13 unique native woody taxa here.
7. Ball Play Rd. on Tellico River bluff, 00-35, Monroe, bluff and cliff edge, Bays Form., ss, SW, 20, 150%, Virginia pine-oak-eastern redcedar. This was a narrow mostly cliff-edge site with lateral lighting. There were six low-cover ericad taxa.
8. Benton Springs Rd. base of south Chilhowee Mt., 00-121, Polk, lower slope, Rome Form., ss, SW, 10%, mixed pine-oak. This site was 0.6 miles west of the Smoky Mountain fault. The surface was extremely rocky, colluvial. There were two ericads, each with low cover.

Sequence: Stands arranged north to south; Abbreviations: Number, stand name, stand sample number, county, slope position, geologic formation, aspect, mean slope angle (s), vegetation dominants. Rock ss =sandstone, Form. = formation, congl. =conglomerate.

APPENDIX 2: FLORA OF THE STANDS[1,2,3]

Acer pensylvanicum L. – 6.
A. rubrum L. – 1, 2, 4, 5, 6, 7, 8.
A. saccharum Marshall – 1, 3. 5, 6, 7.
Ageratina aromatica (L.) Spach – 1, 3, 5, 8. (*Eupatorium*)
Agrimonia pubescens Wallr. – 6.
**Albizia julibrissin* Durazz – 1, 3, 5.
Amelanchier arborea (F. Michx.) Fern. – 1, 2, 4, 6, 7, 8.
Amphicarpaea bracteata (L.) Fern. – 4, 6, 8.
Andropogon ternarius Michx. – 1, 2, 3.
A. virginicus L. – 1, 2, 3, 7, 8.
Antennaria plantaginifolia (L.) Richardson – 3, 4, 5, 6, 7.
A. solitaria Rydb. – 6.
**Anthoxanthum odoratum* L. – 2.
Arabis laevigata (Muhl.) Poir. – 8.
Aralia spinosa L. – 5.
Asclepias amplexicaulis Sm. – 4.
A. variegata L. – 8.
Asplenium platyneuron (L.) BSP. – 3, 4, 7, 8.
Aureolaria laevigata (Raf.) Raf. – 2, 4, 7.
Bidens frondosa L. – 2, 5.
Bignonia capreolata L. – 6, 7.
Brickellia eupatorioides (L.) Shinners. – 1, 4. (*Kuhnia*)
Bromus pubescens Muhl. – 3, 4, 7.
Calycanthus floridus L. – 8.
Campsis radicans (L.) Seem. ex Bureau – 4, 7, 8.
Carex digitalis Willd. – 4, 6.
C. hirsutella Mack. – 5, 7.
C. laxiflora Lam. – 7.
C. sparganioides Muhl. ex Willd. – 5.
Carya glabra (Mill.) Sweet – 2, 4, 5, 6, 7, 8.
C. ovalis (Wang.) Sarg. – 5.
C. ovata (Mill.) K. Koch. – 2, 7.
C. pallida (Ashe) Engl. & Graebn. – 1, 3, 4, 7, 8.
C. tomentosa (Poir.) Nutt. – 5.
Castanea dentata (Marshall) Borkh. – 6.
Ceanothus americana L. – 4.
Celastrus scandens L. – 5.
Celtis occidentalis L. – 1, 4, 5, 7, 8.
C. tenuifolia Nutt. – 3, 7.
**Centaurea maculosa* Lam. – 3.
Cercis canadensis L. – 1, 3, 4, 6, 7, 8.
Chaerophyllum tainturieri Hook. – 2.
Chasmanthium latifolium (Michx.) H. O. Yates – 7.
C. laxum (L.) H. O. Yates subsp. *laxum* – 7.
C. laxum (L.) H. O. Yates subsp. *sessiliflorum* (Poir) L. Clark – 7.
Cheilanthes alabamensis (Buckley) Kunze – 7.
Chimaphila maculata (L.) Pursh – 1, 2, 3, 4, 5, 7, 8.
Chrysopsis mariana (L.) Elliott – 2.
Clematis virginiana L. – 1.
Clitoria mariana L. – 2, 4, 8.
**Commelina communis* L. – 3.
Coreopsis major Walter – 1, 2, 3, 4, 8.
Cornus florida L. – 2, 4, 5, 6, 7, 8.
Crataegus intricata Lange – 3.

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1 Asterisk (*) taxa are introduced.
2 App. =Appalachian floristic element.
3 Stand numbers are in north to south stand arrangement of Table 1.

C. uniflora Munchh. – 3.
Croton monanthogynus Michx. – 3.
Cunila origanoides (L.) Britton – 2, 8.
Cyperus lupulinus (Spreng.) Marcks. – 3.
Danthonia sericea Nutt. – 2, 3.
D. spicata (L.) P. Beauv. – 1, 3, 8.
**Daucus carota* L. – 1, 3, 8.
Desmodium ciliare (Muhl. ex Willd.) DC. – 1.
D. dillenii Darl. – 3, 4, 8.
D. laevigatum (Nutt.) DC. – 1, 3, 4, 6.
D. nudiflorum (L.) DC. – 4, 6.
D. paniculatum (L.) DC. – 5, 6, 7.
D. rotundifolium DC. – 4, 6, 8.
D. viridiflorum (L.) DC. – 4.
Dichanthelium acuminatum (Sw.) Gould & C.A. Clark – 2. (*Panicum*)
D. boscii (Poir.) Gould & C. A. Clark – 1, 2, 3, 4, 5, 6, 8. (*Panicum*)
D. commutatum (Schult.) Gould – 1, 2, 3, 4, 7, 8. (*Panicum*)
D. depauperatum (Muhl.) Gould – 2, 3. (*Panicum*)
D. dichotomum (L.) Gould subsp. *dichotomum* – 6. (*Panicum*)
D. dichotomum (L.) Gould subsp. *microcarpon* (Muhl. ex Elliott) Freckman & Lelong – 2, 3, 4, 5, 7, 8. (*Panicum*)
D. linearifolium (Scribn.) Gould – 2. (*Panicum*)
D. polyanthes (Schult.) Mohlenbr. – 2, 3, 4, 5. (*Panicum*)
D. ravenelii (Scribn. & Merr.) Gould. – 1. (*Panicum*)
D. villosissimum (Nash) Freckmann subsp. *villosissimum* Nash – 2. (*Panicum*)
**Dioscorea polystachya* Turcz. – 1, 8.
D. villosa L. – 3, 6, 8.
Diospyros virginiana L. – 1, 3, 8.
Elephantopus carolinianus Raeusch. – 4.
Elymus glabriflorus (Vasey) Scribn. & C. R. Ball – 7, 8.
E. virginicus L. – 5.
Epigaea repens L. – 6.
Eragrostis hirsuta (Michx.) Nees – 3, 8.
E. intermedia Hitchc. – 1.
Erechtites hieracifolia (L.) Raf. – 3.
Erigeron annuus (L.) Pers. – 7.
E. philadelphicus L. – 1, 2, 4, 8.
E. strigosus Muhl. ex Willd. – 1, 2, 3, 7, 8.
Euonymus americanus L. – 3, 4, 5, 7.
**E. fortunei* (Turcz.) Hand.-Mazz. – 6.
Eupatorium fistulosum Barratt – 2, 7.
E. hyssopifolium L. – 3, 7.
E. purpureum L. – 2, 5.
E. rotundifolium L. – 1, 2.
E. serotinum Michx. – 3.
E. sessilifolium L. – 2.
Euphorbia corallata L. – 1, 2, 3, 4, 5, 6, 7, 8.
Eurybia macrophylla (L.) Cass. – 4. (*Aster*)
E. surculosa (Michx.) G. L. Nesom – 2. (*Aster*)
Fagus grandifolia Ehrh. – 4, 6, 7.
Festuca subverticillata (Pers.) E. B. Alexeev. – 7.
Fragaria virginiana Duchesne – 1, 2.
Fraxinus americana L. – 1, 2, 3, 6, 7, 8.
Galactia volubilis (L.) Britton – 4, 8.
Galax urceolata (Poir.) Brummitt. – 6.
Galium aparine L. – 4, 5, 7.
G. circaezans Michx. – 4, 5, 6, 8.
G. pilosum Aiton – 1, 4, 5, 7, 8.
Gamochaeta purpurea (L.) Cabrera – 6. (*Gnaphalium*)
Gaultheria procumbens L. – 6.
Gaylussacia baccata (Wangenh.) K. Koch. – 1, 2, 3.

Hamamelis virginiana L. – 6.
Helianthus divaricatus L. – 1, 2, 3, 4, 5.
H. microcephalus Torr. & Gray – 1, 2, 3, 4, 5, 6, 7, 8.
Heuchera americana L. – 4.
Hexastylis arifolia (Michx.) Small var. *ruthii* (Ashe) H. L. Blomq. – 4. 7.
Houstonia purpurea L. – 4, 5, 6, 8.
Hydrangea arborescens L. – 4.
Hypericum prolificum L. – 7.
H. punctatum Lam. – 7.
H. stragulum W. P. Adams & N. Robson – 2, 5, 7.
Ilex montana Torr. & Gray ex Gray – 6. (App.)
I. opaca Ait. – 1.
Ipomoea pandurata (L.) G. Mey. – 3, 5, 6, 7, 8.
**Iris germanica* L. – 3.
I. verna L. var. *smalliana* Fern. ex M. E. Edwards – 4, 6.
Juglans nigra L. – 3, 5, 8.
Juniperus virginiana L. – 1, 2, 3, 4, 5, 7, 8.
Kalmia latifolia L. – 2, 6, 7.
Krigia biflora (Walter) S. F. Blake – 2.
Lactuca canadensis L. – 1, 3.
L. floridana (L.) Gaertn. – 6.
Lechea minor L. – 3.
Leersia virginica Willd. – 6.
**Lespedeza cuneata* (Dum. Cours.) G. Don. – 1, 8.
L. hirta (L.) Hornem. – 1, 4, 8.
L. intermedia (S. Watson) Britton – 1, 3, 4, 6, 7, 8.
L. procumbens Michx. – 1, 4, 5, 7, 8.
L. repens (L.) Barton – 4, 8.
L. violacea (L.) Pers. – 4.
L. virginica (L.) Britton – 3, 8.
Leucanthemum vulgare Lam. – 1, 2, 3, 8. (*Chrysanthemum*)
Liatris spicata (L.) Willd. – 2.
**Ligustrum sinense* Lour. – 3, 5, 7, 8.
Liquidambar styraciflua L. – 1, 2, 4, 6.
Liriodendron tulipifera L. – 1, 2, 3, 4, 5, 6, 7.
Lobelia siphilitica L. – 6.
**Lonicera fragrantissima* Lindl. & Pax. – 2, 3.
**L. japonica* Thunb. – 1, 2, 3, 4, 5, 7, 8.
**L. maackii* (Rupr.) Maxim. – 5, 8.
Luzula bulbosa (A. Wood) Smyth – 8.
Lysimachia quadrifolia L. – 6, 7.
L. tonsa (A. Wood) K. Kunth. – 4.
Maclura pomifera (Raf.) C. K. Schneid. – 3.
Magnolia fraseri Walter – 6. App.
Maianthemum racemosum (L.) Link – 3, 4, 5, 7, 8. (*Smilacina*)
Melica mutica Walter – 7, 8.
**Melilotus alba* Medik. – 3.
Mitchella repens L. – 6.
Monarda clinopodia L. – 8.
Morus rubra L. – 1, 3, 5, 7, 8.
Nyssa sylvatica Marshall – 1, 2, 3, 4, 5, 6, 7, 8.
Opuntia humifusa (Raf.) Raf. – 3.
Ostrya virginiana (Mill.) K. Koch. – 1, 3, 5, 6, 7.
Oxalis dillenii Jacq. – 7.
Oxydendrum arboreum (L.) DC. – 1, 2, 4, 6, 7, 8.
Packera anonyma (A. Wood) W. A. Weber & A. Love – 1, 2, 3, 5, 7, 8. (*Senecio*)
Panicum anceps Michx. – 5, 7.
Parthenocissus quinquefolia (L.) Planch. – 2, 3, 4, 5, 6, 7, 8.
Paspalum pubiflorum Rupr. – 3.
Passiflora lutea L. – 8.

Paulownia tomentosa (Thunb.) Steud. – 2, 3.
Pellaea atropurpurea (L.) Link – 7.
Penstemon calycosus Small – 2, 3, 4.
P. canescens (Britton) Britton – 5, 7.
Phacelia dubia (L.) Trel. – 3.
Phaseolus polystachios (L.) BSP. – 4.
Philadelphus hirsutus Nutt. – 7. App.
P. pubescens Loisel – 5.
Pinus echinata Mill. – 2, 4, 5, 6, 8.
P. rigida Mill. – 1, 2, 6. App.
P. strobus L. – 6.
**P. taeda* L. – 5.
P. virginiana Mill. – 1, 2, 3, 4, 5, 6, 7, 8.
Piptochaetium avenaceum (L.) Parodi – 1, 3, 4, 7, 8. (*Stipa*)
Pityopsis graminifolia (Michx.) Nutt. – 1, 2, 3, 4, 7. (*Heterotheca*)
Pleopeltis polypodioides (L.) var. *michauxianum* (Weath.) E. G. Andrews & Windham – 4, 7. (*Polypodium*)
Poa cuspidata Nutt. – 7.
P. languida Hitchc. – 3.
**P. pratensis* L. – 7.
Polygonatum biflorum (Walter) Elliott – 4, 5, 7.
Polymnia canadensis L. – 1, 3.
Polystichum acrostichoides (Michx.) Schott. – 4, 5, 6, 7.
Porteranthus stipulatus (Muhl. ex Willd.) Britton – 8. (*Gillenia*)
Potentilla simplex Michx. – 2, 4, 5, 6, 8.
Prenanthes altissima L. – 6.
P. serpentaria Pursh – 2, 4.
Prunella vulgaris L. – 4.
**Prunus persica* (L.) Batsch – 3.
P. serotina Ehrh. – 1, 4, 5, 6, 7, 8.
P. sp. – 3.
Pseudognaphalium obtusifolium (L.) Hilliard & B. L. Burtt – 2, 3, 4, 5. (*Gnaphalium*)
Pycnanthemum loomisii Nutt. – 3.
P. montanum (L.) Michx. – 8.
P. muticum (Michx.) Pers. – 4.
P. pycnanthemoides (Leavenw.) Fern. – 3, 4, 5, 6, 8.
Pyrularia pubera Michx. – 6. App.
Quercus alba L. – 2, 4, 5, 6, 7, 8.
Q. coccinea Munchh. – 1, 2, 4, 5, 6, 8.
Q. falcata Michx. – 2, 7, 8.
Q. marilandica Munchh. – 1, 3, 8.
Q. montana Willd. – 1, 2, 3, 4, 5, 6, 8.
Q. muehlenbergii Engelm. – 7.
Q. stellata Wangenh. – 1, 5, 7, 8.
Q. velutina Lam. – 1, 2, 3, 4, 5, 6, 7, 8.
**Ranunculus bulbosus* L. – 2.
Rhamnus caroliniana Walter – 1, 2, 3, 4, 5, 7, 8.
Rhododendron calendulaceum (Michx.) Torr. – 7. App.
R. maximum L. – 6.
Rhus copallina L. – 1, 3, 4.
R. glabra L. – 1, 3, 4, 5.
Robinia pseudoacacia L. – 1, 2, 4, 5.
Rosa carolina L. – 3.
**R. multiflora* Thunb. – 2, 3, 5, 8.
Rubus sp. – 1, 2, 3, 5, 7, 8.
Ruellia caroliniensis (J. F. Gmel.) Steud. – 1, 4, 8.
Saccharum alopecuroideum (L.) Nutt. – 1. (*Erianthus*)
Salvia lyrata L. – 1, 2, 4, 5, 7.
Sambucus canadensis L. – 7.
Sanicula canadensis L. – 4.
S. smallii E. P. Bicknell – 4, 8.

Sassafras albidum (Nutt.) Nees. – 1, 2, 4, 5, 6, 8.
Schizachyrium scoparium (Michx.) Nash – 1, 2, 3, 4, 8.
Scleria oligantha Michx. – 4, 7.
Scutellaria elliptica Muhl. – 4, 8.
Sedum ternatum Michx. – 7.
Setaria parviflora (Poir.) Kerguelen – 3. (*S. geniculata* (Lam.) Beauv.)
Silene stellata (L.) Aiton – 4.
Smilax bona-nox L. – 1, 4, 7, 8.
S. glauca Walter – 1, 2, 4, 5, 6, 7, 8.
S. rotundifolia L. – 1, 2, 6, 7, 8.
Solidago altissima L. – 1, 3.
S. arguta Aiton var. *caroliniana* A. Gray – 7, 8.
S. caesia L. – 4, 6, 8.
S. canadensis L. var. *hargeri* Fern. – 8.
S. curtissii Torr. & Gray – 8.
S. erecta Banks ex Pursh – 2, 3, 4, 6.
S. flaccidifolia Small – 1.
S. juncea Aiton – 1, 2, 3, 4, 6, 7, 8.
S. nemoralis Aiton – 1, 2, 3, 4, 5, 7, 8.
S. puberula Nutt. – 7.
S. rugosa Mill. subsp. *aspera* (Aiton) Fern. – 7.
Sorghastrum nutans (L.) Nash – 3.
Sphenopholis nitida (Biehler) Scribn. – 3.
S. obtusata (Michx.) Scribn. var. *major* (Torr.) Erdman – 4, 7.
Spigelia marilandica L. – 6, 8.
Sporobolus clandestinus (Biehler) Hitchc. – 3.
Stylosanthes biflora (L.) BSP. – 7.
Symphyotrichum cordifolium (L.) G. L. Nesom – 1, 3, 7, 8. (*Aster*)
S. divaricatum (Nutt.) G. L. Nesom – 1, 2, 3. (*Aster*)
S. dumosum (L.) G. L. Nesom – 3. (*Aster*)
S. lateriflorum (L.) A. Love & D. Love – 1, 2, 3, 4, 6, 7, 8. (*Aster*)
S. patens (Aiton) G. L. Nesom – 1, 2, 3, 4, 5, 6, 8. (*Aster*)
S. pilosum (Willd.) G. L. Nesom – 1, 3. (*Aster*)
S. undulatum (L.) G. L. Nesom – 1, 2, 3, 4, 5, 7, 8. (*Aster*)
Thaspium barbinode (Michx.) Nutt. – 4, 7.
T. trifoliatum (L.) A. Gray – 4.
Tilia americana L. – 6.
Toxicodendron radicans (L.) Kuntze – 1, 2, 3, 4, 5, 6, 7, 8. (*Rhus*).
Tridens flavus (L.) Hitchc. – 1, 2, 3, 5, 7, 8.
Tsuga canadensis (L.) Carriere – 6.
Ulmus alata Michx. – 3, 4, 5, 6, 7, 8.
U. rubra Muhl. – 1, 2, 3, 5, 7.
Uvularia perfoliata L. – 4, 5.
Vaccinium arboreum Marshall – 3, 4, 7, 8.
V. hirsutum Buckley – 7. App.
V. pallidum Aiton – 1, 2, 3, 4, 6, 7, 8.
V. stamineum L. – 1, 2, 4, 7.
Valerianella radiata (L.) Dufr. – 2.
**Verbascum blattaria* L. – 3.
Verbena simplex Lehm. – 1, 8.
V. urticifolia L. – 5.
Verbesina alternifolia (L.) Britton – 1, 5.
V. occidentalis (L.) Walter – 2, 3, 4, 5.
Viburnum acerifolium L. – 6.
V. rufidulum Raf. – 4, 7.
Viola hastata Michx. – 4.
V. sp. – 1, 2, 6, 7.
Vitis rotundifolia Michx. – 4, 5, 6, 7, 8.
Vitis sp. – 1, 2, 3, 4, 5, 6, 7, 8.
Yucca filamentosa L. – 5.

TWENTY-YEAR CHANGE IN COMPOSITIONALLY-STABLE FOREST COMMUNITIES AT LAND BETWEEN THE LAKES, KENTUCKY AND TENNESSEE

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ABSTRACT. **From 1987 to 1989, permanent plots were established in 64 compositionally-stable stands representing a variety of forest community types at Land Between The Lakes, Kentucky and Tennessee. The results of this early study on forest community-species-site environment relationships were reported by Franklin (1990), Fralish et al. (1993), and Franklin et al. (1993). The sampling unit in each stand consisted of two 0.06 ha plots for obtaining tree species and diameter data, and four nested 0.006 and 0.003 ha plots for obtaining species and number of sapling and seedling stems, respectively. Franklin (1990) used COMPAH, an agglomerative hierarchical clustering program, to objectively group the stands into community types. Detrended Correspondence Analysis (CANOCO) was used to ordinate and further cluster the stands. Eight community types were identified base on leading dominant species or groups of species: *Quercus prinus*, *Quercus marilandica*, *Quercus stellata*, Mixed Oak, *Quercus alba*, Mixed Mesophytes, *Fagus grandifolia*, and *Acer saccharum*. Multiple regression analysis was used to relate stand composition index to soil physical and topographic factors. The most parsimonious model using slope position, soil available water capacity (or effective soil depth), elevation, and aspect accounted for 72-73% of the variation in composition index. Slope position accounted for the most variance (55%). In 2007, 57 stands were relocated and measured to determine the development and changes that occurred during the past 18-20 years. The plots for seven stands were either not relocated or the stands had been partially cut. Subroutines of the program PC-ORD were used to cluster and ordinate the stands; this program incorporates the same algorithm as in the clustering and ordination programs. Generally, stand composition did not change appreciably, and basal areas varied depending on tree growth, ingrowth, and mortality. However, there was an overall loss of trees and basal area in the "red oak" group (*Quercus marilandica*, *Quercus falcata*, *Quercus coccinea*, *Quercus velutina*, and *Quercus rubra*). This loss follows a pattern first identified by a comparison of data from the 1966, 1976, and 1986 Continuous Forest Inventory plots in LBL (Wellbaum 1989). The Mixed Oak community had the greatest loss at 18% in the 20-year period. The most parsimonious multiple regression model using slope position, soil calcium, soil available water capacity, elevation, and aspect accounted for 82% of the variation in composition index. The most variance was accounted for by slope position (55%) and calcium (14%).**

PREDICTING THE SPATIAL DISTRIBUTION OF AN INVASIVE PLANT, *LONICERA JAPONICA* (CAPRIFOLIACEAE), BASED ON SPECIES OCCURRENCE DATA FROM TWO WATERSHEDS IN WESTERN KENTUCKY AND TENNESSEE

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ABSTRACT. **The invasion of alien plants has serious ecological and economic consequences. Geographic factors including human disturbances and habitat characteristics such as land cover, terrain, water, and soils play an important role in plant invasion. However, the spatial distribution of most invasive plants is poorly documented, the path of dissemination is sketchy and the mechanism of spatial dispersal is mostly unclear. This project examines and compares the spatial distribution of a successful invasive plant, Japanese honeysuckle (*Lonicera japonica*), in two watersheds of similar size but ecologically distinct in Western Kentucky (Ledbetter Creek) and Western Tennessee (Panther Creek). The occurrence data of Japanese honeysuckle and nine environmental variables were collected and measured from a total of 283 random plots at the two watersheds. A spatial logistic regression model was developed to identify the factors that contribute most to the spread of this invasive plant. Our results show that the spatial distribution of this invasive plant appears to be different in the two watersheds. The Ledbetter Creek watershed, with heavier anthropogenic disturbances, has a greater distribution of Japanese honeysuckle than the forested Panther Creek Watershed. The spatial regression model indicates that distance from the main road, soil moisture, light intensity, and plant species richness of each plot were significantly correlated with the spatial distribution of invasive species at the Ledbetter Creek Watershed. However, elevation was the only significant factors in relation to the spatial distribution of Japanese honeysuckle at the Panther Creek Watershed. Furthermore, our results suggest that the invasion risk is strongly linked to anthropogenic disturbances.**

EVALUATING SELECTED SOIL PROPERTIES FOLLOWING BACKYARD GARDENING IN WESTERN KENTUCKY

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ABSTRACT. **Land restoration can improve soil quality and ecosystem productivity. However, limited data exists with regard to the impact of home-based yard gardening and management on soil properties. A study was conducted in Sedalia, Kentucky to evaluate the changes in soil organic matter, soil water content and soil acidity following two years of gardening. Surface soil samples were collected from 13 different garden designs and two control treatments, consisting of grassland and soil before cultivation. Among the restored sites, the soil under Oak-Hickory leaf litter provided the greatest soil organic matter and water content. When compared to the grassland control, the Oak-Hickory leaf litter treatment improves soil organic matter and water content up to 70% and 100%, respectively. The average soil acidity was lower in all gardens (pH=6.9) as compared to grassland (control 1) which had a soil pH of 5.47 and before gardening (control 2) with a pH of 5.88. The data suggest that trees and soil amendments in the garden systems have the potential to enhance soil fertility and sustainability of backyard land by improving soil organic matter, soil acidity, and soil water content.**

WATER-USE EFFICIENCY IN *LONICERA MAACKII* AND *SYMPHORICARPOS ORBICULATUS* (CAPRIFOLIACEAE) IN RESPONSE TO INCREASING LIGHT AND CO_2 LEVELS

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ABSTRACT. **A variety of strategies have been proposed to explain how exotic species out-compete natives. Among these, greater resource use in exotics has been shown in various ecosystems; exotics tend to have higher levels of productivity and water-use efficiency (WUE). Plant physiological parameters, including rates of photosynthesis and transpiration, are affected by environmental factors such as CO_2 and light levels. Therefore WUE is also affected by these environmental factors since WUE is a measure of the relationship between carbon gain and water loss. For example, an increase in WUE is a response that plants have demonstrated in response to rising atmospheric CO_2 concentrations. Changes in atmospheric CO_2 concentrations and light levels are environmental outcomes that often result from disturbance, fragmentation, and urbanization. Compared to rural areas, disturbance and fragmentation in urban natural areas create habitats that promote invasion of exotic species as evidenced by the higher populations of exotics, both in number of species and density of individuals. To study the relationship between urbanization and the success of exotics, water-use efficiency was compared in an invasive exotic species, *Lonicera maackii*, and a native species, *Symphoricarpos orbiculatus*. Each species was exposed to varying levels of CO_2 and PAR to compare the species' WUE responses using a LI-6400. Compared to the native species, *Lonicera* had an overall greater WUE as both CO_2 concentrations and light levels increased. The data suggest that exotic species respond favorably to the increasing CO_2 and light levels that accompany urbanization. Implications for higher WUE will be discussed in relation to drought and other environmental changes due to urbanization.**

USING MOLECULAR MARKERS TO STUDY THE PATTERNS OF GENOTYPIC DIVERSITY OF AN INVASIVE PLANT, ALLIGATOR WEED (*ALTERNANTHERA PHILOXEROIDES*, AMARANTHACEAE) IN SOUTHEASTERN UNITED STATES

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ABSTRACT. **Alligator weed (*Alternanthera philoxeroides*) is a successful invader native to South America. It has invaded all continents except Africa, Antarctica, and Europe. In spite of its serious invasiveness in various regions around the globe, alligator weed has been rarely studied in terms of its invasion mechanisms. It is even more surprising that knowledge on the relationships between its genetic variation and invasiveness is still very limited. This project attempts to uncover the mechanisms of alligator weed invasion using molecular markers to examine the patterns of genotypic variation of this successful invader. The analysis of genetic variation was carried out using Inter-Simple Sequence Repeat markers (ISSRs) on plant samples collected from three states in the southeastern United States. The molecular evidence indicates that there is genetic variation in alligator weed populations. The results of this study suggest that genetic variation is closely related to the history of species introduction. Moreover, high genetic variation found in alligator weed populations contributes to its invasion success.**

GRASSLAND SOIL PROPERTIES IN CALLOWAY COUNTY, KENTUCKY

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ABSTRACT. Soil properties are important to grassland productivity and function. A study was conducted to investigate the effect of five grass species on soil properties in Calloway County, Kentcuky. Grass species were annual ryegrass (*Lolium multiforum*), tall fescue (*Festuca arundinacea*), johnsongrass (*Sorghum halepense*), bermudagrass (*Cynodon dactylon*), and a mixed grass/herb association consisting of crabgrass (*Digitaria sanguinalis*) and clovers (*Trifolium* spp.). Surface soil samples were collected from five sites from each grass species and analyzed for bulk density, soil organic carbon, particulate organic matter, and aggregate distribution. Results show that soil under johnsongrass has the highest bulk density (1.3 mg m^{-3}) and the lowest was in mixed grass/herb and bermudagrass (1.10 mg m^{-3}). Bermuda grass provides the greatest amount of soil organic carbon (32 g kg^{-1}) and ryegrass has the lowest soil organic carbon (14.50 g kg^{-1}). The greatest particulate organic matter was found in bermudagrass soil (5.5 g kg^{-1}) and the lowest was in johnsongrass (0.8 g kg^{-1}). Soil in mixed grass/herb has the best soil aggregation as indicated by the ratio of macroaggregates to microaggregates (1.78), while soil under tall fescue has the weakest soil aggregation (0.7). Our observation shows that diversity of grass species in one field improved soil aggregate formation and this may help to curb soil loss by maintaining surface conditions that are resistant to soil erosion. In addition, the results can provide more information to assist grass researchers in evaluating or interpreting efficiency of forage species regarding to conservation, carbon sequestration, and soil stabilization.

EVALUATING RIPARIAN SOIL PROPERTIES IN PANTHER CREEK, TENNESSEE AND LEDBETTER CREEK, KENTUCKY

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ABSTRACT. The total organic carbon (TOC) in riparian soils and sediments is a key component in these ecosystems. Total organic carbon significantly influences water chemistry and nutrient availability. The particulate organic carbon (POC) is a positive indicator of soil quality since it is the biologically active portion of total organic carbon. Little information is known about carbon pools in riparian soils and sediments in contrasting watershed land-use ecosystems. The objective was to determine TOC and POC trends in riparian soils and sediments collected from contrasting watershed land-use. Sites for this study were selected due to their similar soils present, weather conditions, and their close proximity to one another. Also, Ledbetter Creek is in an agriculture ecosystem and Panther Creek is located in a forested ecosystem. The TOC and POC levels were evaluated. We found that riparian soil TOC and POC are significantly affected by watershed land-use. TOC in soil was significantly varied between seasons. In August, Panther Creek had high quantities of TOC (77 g/kg). At the depth of 0-10cm this carbon is in a stable form. During November the TOC remained high at Panther Creek and Ledbetter Creek had low TOC. This could be because there is not as much vegetation in agricultural areas or because carbon is degraded faster. Ledbetter Creek had greater amounts of POC in the summer at 35 g/kg but in winter the amount at Panther Creek was greater (30 g/kg). This could have been influenced by the water level in Kentucky Lake. During the summer the water is high and in winter the lake is lower, but not for the TOC found in the sediments it was consistent. The POC had variability in the soil and the sediments for both sites.

A NEW SPECIES OF *POLYMNIA* (ASTERACEAE) FROM TENNESSEE

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ABSTRACT. *Polymnia* (Asteraceae) is a North American genus of robust herbs containing three species: *P. canadensis*, *P. laevigata*, and *P. cossatotensis*. *Polymnia canadensis* is widespread in eastern North America and is found from Vermont, Ontario, and Minnesota south to Georgia, Alabama, and Oklahoma. *Polymnia laevigata* is a rare species found in southeastern Tennessee, northern Alabama, and northwestern Georgia as well as the panhandle of Florida and the central Mississippi River Valley of southeastern Missouri, western Kentucky, and northwestern Tennessee. The third member of the genus, *P. cossatotensis*, is a relatively recently described species endemic to just a few sites in the Ouachita Mountains of Arkansas. In September 2008, what appears to be a fourth and undescribed species of *Polymnia* was discovered on the calcareous forested karst slopes of Little Cedar Mountain in the southern Cumberland Plateau region of Marion County, Tennessee. This putative new species is intermediate between *P. canadensis* and *P. laevigata* in the number of ray and disk flowers per capitulum. It is similar to typical *P. canadensis* in its strongly pubescent stems, general appearance and size of the capitula, and 3-angled achenes. It is somewhat reminiscent of *P. laevigata* in its large number of leaf lobes relative to *P. canadensis* and *P. cossatotensis*; however, the pattern of dissection and number of lobes in *Polymnia* sp. nov. is unique within the genus. Subsequent research at the University of Tennessee Herbarium resulted in the discovery of two additional populations of *Polymnia* sp. nov. from nearby sites in the same general area. Observations of plants at one of the three known populations clearly indicate that this new species is fertile and fully capable of sexual reproduction. Furthermore, the one observed population is extensive and consists of thousands of individuals over approximately 2 hectares. Plants in this population are morphologically consistent and clearly distinguishable from individuals of *P. canadensis* and *P. laevigata* found nearby. The new species is currently in the process of being described and will be named in honor of one of the Southeast's best field botanists, my close friend and colleague John T. Beck, who collected this species from Little Cedar Mountain in 2003.

A NEW SPECIES OF *CAREX* SECTION *PHACOCYSTIS* (CYPERACEAE) FROM GREAT SMOKY MOUNTAINS NATIONAL PARK, NORTH CAROLINA AND TENNESSEE

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ABSTRACT. *Carex* sect. *Phacocystis* includes 70-90 species of worldwide distribution with 31 species occurring in North America north of Mexico. One of the most distinctive groups within the section is the *Carex crinita* complex which includes three closely-related species and one nonautonymic variety: *C. crinita* var. *brevicrinis*, *C. crinita* var. *crinita*, *C. gynandra*, and *C. mitchelliana*. The members of this complex are characterized by three-veined, scabrous-awned pistillate scales, relatively wide (> 2 mm) non-involute leaf blades, veinless perigynia (weakly veined in *C. mitchelliana*), relatively thick (3-8.5 mm) pendent spikes, ladder-fibrillose proximal sheaths, and frequently constricted achenes. Recent field and herbarium studies have revealed the presence of a fourth species that is heretofore undescribed. This "Smoky Mountain sedge" differs from the closely related and sympatric *C. gynandra* in its dark reddish-brown pistillate scales that are strongly retuse apically, shorter spikes, narrower leaves, and red-scabrous proximal sheath faces. It is presently known only from high-elevation (>1500 m) clearings in spruce-fir forest in Great Smoky Mountains National Park, North Carolina and Tennessee, and is often one of the dominant graminoid taxa where it occurs. Additional information concerning its taxonomy, collection history, ecology, and distribution will be presented.

SITE AFFINITIES OF *CASTANEA DENTATA* (FAGACEAE) AT MAMMOTH CAVE NATIONAL PARK

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ABSTRACT. From 2003 to 2006, 2156 *Castanea dentata* (chestnut) specimens of all sizes were inventoried at Mammoth Cave National Park. Sixty-nine percent of the recorded stems had a diameter at breast height less than 2.54 cm, and 60% were less than 1.5 m tall. The highest chestnut density, approximately 9 trees per hectare, was found in the "Big Woods," an old growth forest in Hart County in the northeastern section of the Park. Chestnut was found rarely in the areas of the park that had been in cultivation or pasture at the time the land was purchased in the 1920s. Most (69%) of the chestnut trees were found at an elevation of 213 m to 244 m, and 56% of the trees were on relatively dry ridges and south to west-facing slopes. In the Hart County portion of the Park, 50% of the chestnut trees were on the Bledsoe-Wallen-Rock outcrop complex with a slope steepness of 20-30%, and 23% of the chestnuts were on Riney loam, ridge sites, with a 6-20% slope. Throughout the park, chestnut was more often on soils derived from sandstone, especially Big Clifty sandstone, than those on limestone-based soils. Chestnut was often associated with *Carya* spp., *Quercus* spp., *Acer rubrum*, *Liriodendron tulipifera*, *Cornus florida*, *Nyssa sylvatica*, *Fagus grandifolia*, *Oxydendrum arboreum*, and *Amelanchier arborea*. Shrub/liana associates were often *Smilax* spp., *Kalmia latifolia*, and *Vaccinium* spp. A habitat suitability map based on ecological niche factor analysis indicated that 19% of the Park was suitable habitat for finding surviving chestnut trees.

TAXONOMY, ECOLOGY, AND DISTRIBUTION OF UNUSUAL POPULATIONS OF *LYSIMACHIA HYBRIDA* (MYRSINACEAE) FROM TENNESSEE AND ALABAMA

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ABSTRACT. The genus *Lysimachia* (Myrsinaceae) is a large genus of cosmopolitan distribution, with 13 species in eastern North America. There are seven species within the subgenus *Seleucia* recognized including *L. ciliata, L. graminea, L. hybrida, L. lanceolata, L. quadriflora, L. radicans,* and *L. tonsa.* Within this group of related species the *L. lanceolata* - *L. hybrida* complex is perhaps the least understood taxonomically. Botanists working in south-central Tennessee and northern Alabama have discovered several populations of an anomalous *Lysimachia* which have been difficult to identify. These unusual *Lysimachia* exhibit some characteristics suggestive of *L. hybrida* and other features indicative of *L. lanceolata* or *L. tonsa,* but also possess unique features not found in any other species of subgenus *Seleucia.* The primary goal of this study was to determine the taxonomic identity of these unusual populations by carefully comparing their morphological features, geographic distribution, and ecological requirements to other species of *Lysimachia* subgenus *Seleucia.* Preliminary field observations, herbarium work, and morphological analyses suggest that these populations may represent an undescribed species of subgenus *Seleucia.*

BACCHARIS HALIMIFOLIA (ASTERACEAE), A POTENTIALLY INVASIVE SHRUB NEW TO KENTUCKY WITH AN UPDATE ON THE EXPANSION OF THE SPECIES INTO NORTHERN TENNESSEE

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ABSTRACT. *Baccharis halimifolia* L. (ASTERACEAE) is reported as new for the state of Kentucky. The groundseltree is most common on the southeastern Coastal Plain, growing as far inland as Arkansas and the central Piedmont Plateau. It is typically found in old fields, forest margins, and roadsides. The species is thought to have once been restricted to the outer coastal areas and only recently extended its habitat inland north and west. Utilizing herbarium records along with recorded GIS data sets, we review the inland range expansion of *B. halimifolia* in context with its discoveries in northern Tennessee and southwestern Kentucky.

VITIS RUPESTRIS (VITACEAE) REDISCOVERED IN TENNESSEE

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ABSTRACT. ***Vitis rupestris*, rock grape, is a globally uncommon species discontinuously distributed from Texas and Oklahoma east to Virginia and Pennsylvania. It is most common in the Interior Highlands of Missouri where it is ranked as vulnerable. In the other eleven states from which it has been reported, the species is considered to be imperiled or vulnerable and is generally known from only a few sites. *Vitis rupestris* inhabits flood-scoured limestone or cherty streambeds and riverbanks, cobble bars, outcrops and bluffs. Rock grape was first collected in Tennessee by Augustine Gattinger in 1880 from an island in the Cumberland River near Nashville, Davidson County. During the 1960s-1980s, the species was reported from Hickman, Houston, Maury, and Wilson counties in Tennessee; however, these specimens were later determined to represent misidentified collections of other species. In September 2008, we discovered a single population of *V. rupestris* in Montgomery County, Tennessee approximately 50 river miles downstream from the original Gattinger location. The newly discovered population was found on a limestone ledge below a barren-like slope above the Cumberland River. Numerous other rare or uncommon species also occur or were known historically to occur at this site including *Amsonia tabernaemontana* var. *gattingeri*, *Cornus obliqua*, *Diarrhena obovata*, *Lobelia appendiculata* var. *gattingeri*, *Packera plattensis*, *Physaria globosa*, *Solidago rupestris*, and *Symphyotrichum priceae*. *Vitis rupestris* is currently tracked by the Tennessee Department of Environment and Conservation as state-endangered. Our find represents the first confirmed report for rock grape in Tennessee in 128 years.**

CONTRIBUTED PAPERS

SESSION II: AQUATIC BIOLOGY AND ZOOLOGY

Saturday, March 31, 2007

Moderated by:

Andrew N. Barrass
The Center of Excellence for Field Biology
Austin Peay State University

PHYCOLOGICAL ANALYSIS OF THE WEST FORK OF THE RED RIVER IN NORTH-CENTRAL TENNESSEE

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ABSTRACT. A phycological analysis of the West Fork of the Red River was conducted in a reach located in Billy Dunlop Park in Clarksville, Tennessee. Evaluations included production of photoautotrophic and heterotrophic periphyton, composition of diatom genera, and growth assays of the pollution-intolerant alga, *Selenastrum capricornutum*. Results of periphyton production and growth of *S. capricornutum* were compared to those of a separate study of Whipporwill Creek, also sampled during the fall of 2008 and also located in the Red River watershed. Heterotrophic periphyton production of the West Fork of the Red River was significantly lower relative to Whippoorwill Creek. The maximum specific growth rate of *S. capricornutum* in water collected from the West Fork of the Red River was significantly greater relative to water collected from Whippoorwill Creek. The diatom genera composition of the West Fork of the Red River supports conclusions from the periphyton and *S. capricornutum* growth assays which indicate the West Fork of the Red River had good water quality during the sampling period.

INTRODUCTION

The Red River drains 383,838 ha of north-central Tennessee and south-central Kentucky. The river's name is derived from the red color of the water due to the iron oxides associated with the heavy load of clay and silt the river carries. The Red River watershed is severely impacted by anthropogenic activity. Most of the watershed is used to produce agriculture products such as tobacco, corn, soybean, and livestock. Nonpoint-source pollution (i.e., different pollutants entering water bodies from surface runoff) is the most significant pollution problem in the watershed (Flynt et al. 2001). The watershed is targeted for implementation of best-management practices to improve the quality of water in the Red River and its tributaries by the Kentucky Department of Natural Resources and The Center of Excellence for Field Biology at Austin Peay State University.

The West Fork of the Red River drains eastern Christian and western Todd counties, Kentucky and joins the Red River two km upstream of where the mouth of the Red River joins the Cumberland River in Clarksville, Tennessee. The West Fork of the Red River watershed is in the Western Pennyroyal Plain subsection of the Pennyroyal Karst ecoregion (Baskin et al. 1997). This subsection is characterized by limestone, chert, shale, siltstone, sandstone, and dolomite. Soils are of the Pembroke, Crider, and Baxter series and form a highly erodible, loess mantle over limestone (Miller 1974). Forests are Western Mesophytic and consist largely of *Quercus* and *Carya* species (Braun 1950).

Eutrophication of streams changes the trophic relations and other biotic interactions (Scott et al. 2008). Because nonpoint-source pollutants affect photoautotrophic genera in different ways (Delong and Brusen 1992), several different analyses were conducted to evaluate the phycological components of the West Fork of Red River. These included determinations of the standing crop of photoautotrophic periphyton, production of photoautotrophic periphyton, the biomass ratio of heterotrophic- to photoautotrophic-periphyton, diatom genera composition, diatom generic index of pollution, and growth of the pollution-intolerant alga, *Selenastrum capricornutum* Printz. Results of periphyton production and growth of S. *capricornutum* from the West Fork of the Red River were compared to those of a separate study of Whippoorwill Creek, also sampled during the fall of 2008 and also located in the Red River watershed. This research is a supplement to other bio-monitoring studies being conducted in the watershed by the Kentucky Department of Natural Resources and The Center for Field Biology at Austin Peay State University.

MATERIALS AND METHODS

Sampling Site Locations and Times

Periphyton was sampled in the West Fork of the Red River in Billy Dunlop Park located in Clarksville, Tennessee between Sept. 16 and Oct. 8, 2008. Periphyton was sampled in Whippoorwill Creek 50 m downstream of Cedar Grove Road Bridge in Logan County, Kentucky between Sept. 1 and Sept. 18, 2008. Water samples for *S. capricornutum* growth assays were collected from Whippoorwill Creek on Sept. 18, 2008 and from the West Fork of the Red River on Oct. 8, 2008 from the same locations that periphyton was sampled.

Periphyton Sampling From Artificial Substrate

Methods followed the procedures described by Eaton et al. (2005) using periphytometers holding 25- by 75-mm glass microscope slides. Periphytometers are widely used to sample periphyton because they provide standardization which allows comparisons among different production studies (Lowe et. al. 1996). Periphytometers holding 20 glass slides parallel to flow and 5 cm below the stream surface were secured by chains to the stream bottom in a section of the reach with low velocity ($\leq 0.1\ m \cdot s^{-1}$). Periphyton was removed using razor blades from both sides of slides to yield four replicates for all assays.

Chlorophyll *a* Concentration

Periphyton was ground with a mortar and pestle for 3 minutes in 90% acetone. The homogenate was filtered through Whatman no. 1 filter-paper circles. Optical density was determined at 664 nm, then at 665 nm following acidification with 0.1 N HCl to correct for pheophytin *a* content, a degradation product of chlorophyll *a*. Chlorophyll *a* concentration and photoautotrophic periphyton biomass were calculated as described by Eaton et al. (2005).

Ash-Free Periphyton Dry Weight and Autotrophic Index

Periphyton was scraped into preweighed crucibles and dried at 105°C for 24 h. Dried periphyton was weighed to the nearest 0.1 mg, ashed at 550°C for 2 h leaving only inorganic sediment and ash. Ash-free periphyton dry weight was determined by subtraction of the inorganic sediment and ash weight. The autotrophic index (AI) was calculated using the equation of Crossy and LaPoint (1988): AI = [Ash-free periphyton dry weight (mg/m^2)]/[chlorophyll *a* (mg/m^2)].

Diatom Composition and Generic Index of Pollution

Frustule preparation for permanent mounts followed the methods of Carr et al. (1986). Periphyton was preserved in 1.5 % glutaraldehyde and concentrated by settling. Preserved periphyton (5 mL) was pelleted by centrifugation (1000 g for 5 min) and the supernatant discarded. The pelleted frustules were cleaned by adding 0.5 mL of 2.6 % sodium hyperchlorite for 1 h. Frustules were washed in 10 mL of water, pelleted by centrifugation (1000 g for 5 min), and suspended in 0.5 mL of water. Aliquots of cleaned frustules (0.05 mL) were pipetted onto glass cover slips, dried at 50^{O} C, and mounted on glass microscope slides with Permount mounting medium. Genera were identified according to Whitford and Schumaker (1984). A total of 722 frustules were counted and the richness (R; number of taxa) and the percent of each genus (P_i) relative to the total determined. The Shannon diversity index (H') and evenness (J) were calculated by the equations of Shannon and Weaver (1949): $H' = -\Sigma(P_i \cdot \ln P_i)$; $J = H'/\ln R$. The generic index of pollution (GI) described by Wu (1999) was calculated as the ratio of the sum of the number (N) of the pollution-intolerant genera *Achnanthes, Cocconeis,* and *Cymbella* to the sum of the number of the pollution-tolerant genera *Cyclotella, Melosira,* and *Nitzschia*: $GI = [N_{Achnanthes} + N_{Cocconeis} + N_{Cymbella}]/[N_{Cyclotella} + N_{Melosira} + N_{Nitzschia}]$.

Benthic Photoautotroph Standing Crop

Sampling followed the recommendations of Naiman (1983) on Sept. 16, 2008. Eight midstream plots 2 m apart were established with 0.25 m^2 wire frames. The fraction of cobble and gravel in each plot was recorded. Cobble from four plots was removed by hand. One gravel sample from each of the other four plots was removed with a 10 cm^2 core sampler. Samples were transported to the laboratory at 4^O C in darkness.

Measurements of chlorophyll *a* concentration and estimation of benthic photoautotrophic biomass followed the procedures described by Eaton et al. (2005). Cobble samples were placed in 50 mL of 90 % acetone and periphyton removed with test tube brushes. Gravel samples were placed in bottles containing 50 mL of 90 % acetone and periphyton removed by shaking by hand for 3 min. The chlorophyll extracts were filtered through Whatman no. 1 filter-paper circles. Optical density of the supernatant was determined at 664 nm, then at 665 nm following acidification with 0.1 N HCl to correct for pheophytin *a* content.

***Selenastrum capricornutum* Growth Assays**

Laboratory growth assays utilizing the green alga *Selenastrum capricornutum* were conducted following the methods described by Eaton et al. (2005). *Selenastrum capricornutum* cells (University of Texas Culture Collection, Austin, Texas) were transferred to a 125 mL flask containing 50 mL of dilute nutrient media ($1/30^{th}$ strength Bolds 1 NV media; 25 mg salts/L). The flask was capped with aluminum foil and secured to a rotating platform (60 oscillations/min) under fluorescent white light (50 μmol photons$\cdot m^{-2} \cdot s^{-1}$) at 24 $\pm 2^O$C for 5 days to initiate exponential growth of stock cells. The stock cells were centrifuged (10 min at 1000 g), washed in 10 mL of 0.2 mM $NaHC0_3$, centrifuged again (10 min at 1000 g), and resuspended in 0.1 mL of 0.2 mM $NaHCO_3$ for use as water sample inoculum. A water sample (0.5 L) was collected in a borosilicate glass container 5 cm below the surface at midstream. The sample was transported to the lab at 4^OC in darkness and filtered through a 0.45 μm filter. Four replicate water-sample cultures were established by inoculating 5 mL aliquots of water sample contained in 25 X 100 mL test tubes with an initial cell density of 10^5 cells/mL. The tubes were covered with aluminum foil caps and placed on slanted test tube racks at a 45^O angle secured to a rotating platform (60 oscillations/min) under fluorescent white light (50 μmol photons$\cdot m^{-2} \cdot s^{-1}$) at 24 $\pm 2^O$C. Cell densities were determined using a hemocytometer following 3, 5, 7, and 12 d of growth. The carrying capacity (maximum cell density) was determined and the specific growth rate (μ) during each incubation period (0 - 3 d, 3 - 5 d, 5 - 7 d, and 7 -12 d) was calculated (Eaton et al. 2005): $\mu = [\ln (X_2/X_1)]/[t_2 - t_1]$ where: X_1 =cell no. at t_1 ; X_2 =cell no. at t_2; $t_2 - t_1$ =time interval in days.

Stream Morphological Characteristics

Stream depths at midstream and 1 m from each bank were determined at two transects using a meter stick. Stream velocity was measured by determination of the time a density-neutral object traveled 5 meters downstream in two sections of the reach (Robins and Crawford 1954). Stream flow was calculated using the equation of Robins and Crawford (1954): Flow = Width · Depth · Velocity · 0.9. Photosynthetic photon flux densities (PPFD) at the stream surface (1-cm depth) and stream bottom were measured with a spherical underwater quantum sensor coupled to a Li-Cor quantum meter at 5 midstream locations. The PPFD data were used to calculate the vertical extinction coefficient (n") according to Lind (1979): $n'' = (\ln PPFD_{surface} - \ln PPFD_{bottom})/\text{bottom depth (m)}$.

Statistical Methods

Means from periphytometer data and *S. capricornutum* growth assays were compared to means from a separate study of Whippoorwill Creek by unplanned tests (Tukey-Kramer Honestly Significantly Different Test; Sokal and Rolf 1985). Means were determined significantly different if they were dissimilar at the experimentwise error rate of alpha =0.05.

RESULTS AND DISCUSSION

The morphological characteristics of the reach of the West Fork of the Red River studied (Table 1) are typical of the middle sections of the river (personal observation). Photoautotrophic periphyton associated with cobble is three-fold greater relative to periphyton associated with gravel (Table 2). That larger, more stable substrate supports a greater periphyton biomass is well documented (Lowe et al. 1996, Myers et al. 2007).

Table 1. Abiotic characteristics of the reach sampled in the West Fork of the Red River.

Characteristic	Mean ±SE
Width (m)	15.9 ±2.8
Depth (m)	0.24 ±0.04
Velocity (m/s)	0.37 ±0.02
Flow (m^3/s)	1.24 ±0.01
Vertical extinction coefficient	0.40 ±0.02
Temperature (°C)	18.5 ±0.0
pH	7.4 ±0.0
Fraction of benthic substrate	
Cobble	0.60 ±0.07
Gravel	0.40 ±0.07

Table 2. Standing crop of benthic photoautotrophs of the reach sampled in the West Fork of the Red River.

Assay	Mean ±SE
Cobble chlorophyll *a* (mg/m^2)	14.1 ±4.5
Gravel chlorophyll *a* (mg/m^2)	4.0 ±2.7
Total chlorophyll *a* (gravel +cobble) (mg/m^2)	18.2 ±5.7
Cobble photoautotrophic biomass (mg/m^2)	919 ±291
Gravel photoautotrophic biomass (mg/m^2)	261 ±176
Total photoautotrophic biomass (gravel +cobble) (mg/m^2)	1180 ±369

Benthic photoautotrophic periphyton are the most important primary producers in most wadeable streams (Lambert and Steinman 1997). Benthic photoautotroph standing crop is largely dependent on water quality and is most often increased by decreased water quality resulting from nutrient loading (Baxter 1977). The benthic photoautotroph standing crop of the West Fork of the Red River (Table 2) is similar to that of most other wadeable streams in middle and east Tennessee (i.e., Keithan and Lowe 1985). The benthic photoautotroph standing crop of the West Fork of the Red River is substantially lower compared to streams heavily impacted by nonpoint source pollution. For example, Pleasant Grove Creek, which is heavily impacted by nonpoint source pollution and also located in the Red River watershed, has a benthic photoautotroph standing crop 5-fold greater (111 ±38 mg/m^2; Lebkuecher, unpublished data) relative to the West Fork of the Red River.

Primary production is the rate at which inorganic carbon is assimilated into organic form and is often measured as the rate of photoautotrophic biomass accumulation (Lamberti and Steinman 1997). Approximately 1.5% of the dry weight of algae is chlorophyll *a*, and the concentration of chlorophyll *a* is widely used to determine the concentration of benthic primary producers (Eaton et al. 2005). Photoautotrophic production in the West Fork of the Red River is not significantly different than in Whippoorwill Creek (Table 3) and is similar to other streams in Tennessee that are not substantially impacted by nonpoint-source pollution (i.e., Steinman 1992, Rosemond, 1993).

Table 3. Periphyton production, sediment accumulation rates, and autotrophic indexes determined from artificial substrates placed in the West Fork of the Red River (WFRR) and Whippoorwill Creek. Assay values represent means ±SE and are significantly different if followed by a different letter at the experiment-wise error rate of alpha =0.05.

Assay	WFRR	Whippoorwill
Chlorophyll *a* ($mg{\cdot}m^{-2}{\cdot}d^{-1}$)	0.34 ±0.06^{A}	0.27 ±0.05^{A}
Photoautotrophic biomass ($mg{\cdot}m^{-2}{\cdot}d^{-1}$)	22.1 ±4.0^{A}	17.4 ±2.6^{A}
Ash-free periphyton ($mg{\cdot}m^{-2}{\cdot}d^{-1}$)	12.9 ±0.9^{A}	65.0 ±2.3^{B}
Sediment ($mg{\cdot}m^{-2}{\cdot}d^{-1}$)	55.8 ±3.40^{A}	534 ±15^{B}
Autotrophic index	45 ±13^{A}	262 ±37^{B}

Periphyton production, rate of inorganic sediment accumulation, and the autotrophic index (AI) value determined from artificial substrate are significantly lower in the West Fork of the Red River relative to Whippoorwill Creek (Table 3). The autotrophic index (AI) is a ratio of periphyton biomass to photoautotrophic periphyton biomass and reveals the trophic nature of the periphyton community (Vannote et al. 1980). AI values typically range from 30 to 300; larger values indicate heterotrophic associations and poor quality water (Delong and Brusen 1992). AI values increase in the fall due to increased detritus input which, in turn, support a larger biomass of heterotrophs (Torres-Ruiz et al. 2007). The low fall AI value of the West Fork of the Red River indicates good quality water and is much lower relative to the AI value of Whippoorwill Creek (Table 3) as well as fall AI values determined from other streams of the Red River watershed (Lebkuecher et al. 2000).

Diatoms are preferred biological indicators of aquatic health because of their nutrient requirements, sensitivities to environmental changes, and essential status as a component of the trophic base (Stevenson et al. 2008). The diatom community on artificial substrate placed in the West Fork of the Red River included 17 genera (Table 4). Genera observed on artificial substrate but not encountered during the counts to evaluate community composition included *Cyclotella, Epithemia, and Melosira.* The Shannon diversity index (H') ranges from 0 to approximately 4.6, with higher values indicating greater diversity. Evenness (J) values range from 0 to 1, a sample of equal numbers of the same taxa having a J value of 1. The low values of H' and J of the diatom assemblage on artificial substrate in the West Fork of the Red River (Table 4) are partially due to the high frequencies of *Achnanthes* and *Cocconesis*, two genera used as indicators of oligotrophic to mesotrophic conditions by the generic index of pollution described by Wu (1999). The diatom community structure of the West Fork of the Red River is similar to the tributaries of the Kentucky River (South Fork of the Kentucky River H' = 1.5; Red River H' = 1.4) studied by Molly (1992). Molly (1992) also sampled using periphytometers and noted that *Achnanthes* and *Cocconeis* were dominant taxa in both of these streams.

Despite the large number of species in some diatom genera, most genus-level diversity evaluations mirror species-level diversity evaluations (Hill et al. 2001). Like other organisms, diatom diversity typically decreases with diminished environmental health. However, generic and species diatom diversity indices are not well correlated with nutrient changes and thus have limited value as indicators of water quality (Hill et al. 2001, Stevenson et al. 2008, Carlisle et al. 2008). The generic index of pollution described by Wu (1999) is based on the ratio of abundance of the pollution-intolerant genera *Achnanthes*, *Cocconeis*, and *Cymbella* to abundance of the pollution-tolerant genera *Cyclotella*, *Melosira*, and *Nitzschia*. This index can be used by researchers that do not have the many months to years of training needed to identify species correctly and correlates well with much more complicated indices that require species identification and/or the measurement of other water quality parameters (Hill et al. 2001). A generic index (GI) of 5 or above is correlated with oligotrophic to mesotrophic conditions, whereas values near 1 or below are correlated with eutrophic conditions (Wu 1999). The GI value of the diatom community on artificial substrate placed in the West Fork of the Red River (Table 4) indicates good quality water during the sampling period.

Table 4. Diatom genera composition and community metrics determined from artificial substrate placed in the West Fork of the Red River.

Genus	Percent of total
Achnanthes	45
Cocconeis	24
Cymatopleura	1
Cymbella	6
Fragillaria	4
Gomphonema	28
Gyrosigma	4
Meridion	2
Navicula	32
Nitzschia	6
Pinnularia	6
Rhopalodia	8
Stauroneis	1
Stephanodiscus	1
Surirella	2
Synedra	2
Tabellaria	1
Unidentified	4
Community metrics	**Value**
Shannon diversity index	1.6
Evenness	0.6
Generic index of pollution	1.3

The most reliable indicator of the effects of culture medium or water sample on the growth rate of algae in the laboratory is the effect on exponential growth (Eaton et al. 2005). Publication of specific growth rates during culture incubation periods permits researchers to readily compare exponential growth rates among different assays. A specific growth rate (μ) value of 0.7 corresponds to one population doubling per day; a μ value of 1.5 corresponds to two population doublings per day. The maximum specific growth rate of the pollution-intolerant alga *S. capricornutum* in water samples collected from the West Fork of the Red River and from Whippoorwill Creek occurred during the first 3 days of growth (Table 5). The specific growth rate of *S. capricornutum* in water collected from the West Fork of the Red River is significantly greater during the 0 - 3 d and 3 - 5 d growth periods relative to growth rates in water from Whippoorwill Creek. Water collected from the West Fork of the Red River also had a significantly greater carrying capacity of *S. capricornutum* relative to water collected Whippoorwill Creek (Table 5). These results indicate that the water sample collected October 8, 2008 from the West Fork of the Red River has better quality relative to the sample collected from Whippoorwill Creek on Sept. 18, 2008.

Table 5. Specific growth rates and carrying capacity of *Selenastrum capricornutum* in water collected from the West Fork of the Red River (WFRR) and Whippoorwill Creek. Means ±1 SE represent four replicates. Specific growth rates during the same growth period and carrying capacity are significantly different if followed by a different letter at the experiment-wise error rate of alpha =0.05.

	WFRR	Whippoorwill
Growth period (days)	Specific growth rate	
0 – 3	0.85 ± 0.01^{A}	0.79 ±0.01^{B}
3 – 5	0.38 ± 0.03^{A}	0.10 ±0.03^{B}
5 – 7	0.09 ± 0.05^{A}	0.09 ±0.05^{A}
7 – 12	0.04 ± 0.02^{A}	0.03 ±0.01^{A}
Carrying capacity (cells·10^5/mL)	38.8 ±3.6^{A}	14.3 ±0.3^{B}

CONCLUSION

This study characterizes periphyton production and trophic relations, diatom genera composition, and growth of a pollution-intolerant alga to assess water quality of the West Fork of the Red River. Periphyton production, autotrophic index value, and *S. capricornutum* growth were compared to those of a separate study of Whipporwill Creek and indicate that the West Fork of the Red River had good quality water relative to Whippoorwill Creek.

ACKNOWLEDGMENTS

Research of the West Fork of the Red River was funded by the Department of Biology and The Center of Excellence for Field Biology, both of Austin Peay State University. Research of Whippoorwill Creek was funded by the Kentucky Department of Natural Resources and The Center of Excellence for Field Biology of Austin Peay State University.

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GLOBAL ENVIRONMENTAL CONTAMINATION BY PERSISTENT CHEMICALS: TEMPORAL TRENDS AND EFFECTS ON WILDLIFE AND HUMANS

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ABSTRACT. During the past century a vast number of organic chemicals have been manufactured and used all over the world in industries, agriculture, public health and several other applications. Due to widespread use of organohalogen compounds including, polychlorinated biphenyls (PCBs), chlorinated pesticides (DDTs, hexachlorobenzene, chlordane compounds etc.), these chemicals are ubiquitous in the environment, bioaccumulate, biomagnify in the food chain and cause long-term health effects on aquatic and terrestrial animals including humans. In addition, emerging new pollutants such as flame retardant chemicals (polybrominated diphenyl ethers, PBDEs) and anindustrial chemical, perfluorinated compounds (PFCs) are also found in environmental samples and biological samples. Since these chemicals possess recalcitrant properties and chronic toxic effects, temporal trend investigations are essential for understanding their environmental behavior, fate and to prevent health hazards. Measurable levels of these organohalogen compounds were found in environmental and biological samples from western Kentucky lower Tennessee River and Cumberland Rivers. The levels found in the western Kentucky watershed were compared with levels reported for similar samples around the world. Based on temporal trends studies conducted over fifteen years on these historical chemicals and newly emerged persistent pollutants reveal that environmental contamination and human exposure to PBDEs and PFCs will continue to increase in the future for several decades.

BIOASSESSMENT OF STREAMS IN THE NEW RIVER WATERSHED OF EASTERN TENNESSEE IMPACTED BY COAL MINING

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ABSTRACT. Coal mining has been practiced since the 1940's in the New River watershed of East Tennessee. The effects of mining and reclamation on water quality and macroinvertebrate communities of headwater streams was studied previously from 1976-1984. In 2008 we collected water quality and macroinvertebrate data to assess stream recovery 50 plus years after cessation of mining. Eleven streams were sampled using the state of Tennessee Macroinvertebrate Bioassessment protocol. Abiotic factors including water temperature, dissolved oxygen, pH, total dissolved solids, and alkalinity were also measured. Habitat assessment scores of the streams ranged from not impaired to moderately impaired. There is wide variation in our physical and chemical results. The pH of a few streams was above 7.9 and specific conductivity is much higher in some streams compared to the reference streams. The Bioassessment shows that the streams sampled were slightly impaired including our reference streams. Sampling was done in the midst of a severe, two-year drought, and this may have suppressed metric scores of the reference steams.

LEVELS OF ENDOCRINE DISRUPTING POLLUTANTS IN WASTEWATER AND RIVER WATER SAMPLES FROM WESTERN KENTUCKY

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ABSTRACT. **Some pesticides and industrial chemicals can affect animal physiology by mimicking the effect of endogenous hormones. Bisphenol-A (2, 2-bis (hydroxyphenyl) propane (BPA) is a well known endocrine disruptor. Every year, over six billion pounds of BPA are used in the manufacturing of epoxy resins and polycarbonate plastics used in a wide variety of domestic products. Because of BPA's high volume production and extensive use in plastics, there is a widespread environmental contamination and well documented human exposure to BPA. To our knowledge, there exist no studies conducted on BPA contamination levels in western Kentucky regional waters. In this study, we measured BPA levels in Murray Wastewater Treatment Plant (WWTP) samples, Bee Creek (upstream and downstream), Clarks River and Kentucky Lake water. Five sampling events were conducted from December 2008 through March 2009. The samples were analyzed using BPA specific Enzyme Linked Immunosorbent Assay (ELISA). They revealed that measurable levels of BPA were found in all water samples analyzed. Among the samples analyzed, WWTP influent had highest concentration of BPA (Range 134 to 153 ng/L; Mean: 140 ng/L), followed by effluent (Range 105 to 142 ng/L; Mean: 126 ng/L). Upstream Bee Creek contained lower concentration (Mean: 103 ng/L) and downstream (Mean: 134 ng/L), indicating input of BPA from WWTP to the Bee Creek. Clark River (Mean: 116 ng/L) and Kentucky Lake (HBS) (Mean: 133 ng/L) had comparative concentrations to that of Bee Creek or WWTP samples. For loading estimate purposes, 24-hr composite samples were also collected from WWTP. In influent and effluent composite samples, BPA concentrations ranged from 118ng/L to 150ng/L and 119ng/L to 136 ng/L, respectively. The WWTP sample results revealed that BPA is not degraded or lost during the wastewater treatment processes. Therefore, significant quantities of BPA enter the receiving waters such as Bee Creek and Clarks River.**

ASSESSING BIOLOGICAL INTEGRITY AND FISH ASSEMBLAGES OF TWO WATERSHEDS LOCATED WITHIN A KARST AGRICULTURAL PLAIN, LOGAN COUNTY, KENTUCKY

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ABSTRACT. **Pleasant Grove Creek is located within the Western Pennyroyal Karst Plain Ecoregion north of Tennessee. The watershed is the focus of several surveys by the Kentucky Division of Water, Environmental Protection Agency, and Austin Peay State University. Pleasant Grove Creek has been identified as an impaired water body on the Environmental Protection Agency's 303(d) list since 2002. Objectives of this study were to assess the environmental health of Pleasant Grove Creek utilizing the Kentucky Index of Biotic Integrity and by comparing historical data with data collected in 2007and 2008. Fish assemblages were compared to habitat changes and an adjacent watershed (Whippoorwill Creek). Whippoorwill Creek is a creek identified by Kentucky as an exceptional water resource. Data indicate that Pleasant Grove Creek continues to be an impaired stream with diminished species richness. Results concluded that total fish density was significantly different between sampling sites.**

EVALUATION OF MICROSATELLITES IN *AMBYSTOMA TIGRINUM NEBULOSUM*

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ABSTRACT. Phenotypic plasticity is the ability of a trait to change in response to an environmental cue. Salamanders are known to exhibit phenotypic plasticity in the form of facultative paedomorphosis, producing a paedomorphic (aquatic) or a metamorphic (terrestrial) body morphology, which provides a unique vertebrate model for understanding the evolution of phenotypic plasticity. Previous research has revealed the mechanisms that produce this polymorphism; however, little is known about the evolutionary mechanisms that maintain it. By studying the fitness consequences of facultative paedomorphosis, we can better understand the evolution of this polymorphism. We have proposed using nuclear markers to assign parentage and to create a pedigree within a closed population of tiger salamanders as a way of measuring fitness differences among morphs. As a first step, we evaluated polymorphism using previously designed *Ambystoma* microsatellite markers in spotted salamanders (*Ambystoma maculatum*). Tissue samples of 55 salamanders were collected from a local population and DNA was amplified using PCR to assess microsatellite variability. In this ongoing study, nine loci have been successfully amplified, six of which are polymorphic and will be used to determine relatedness in this population. The results of this study will eventually be applied to a population of facultatively paedomorphic tiger salamanders to better understand the evolution of phenotypic plasticity.

SEASONAL ACTIVITY AND MOVEMENTS OF WESTERN COTTONMOUTHS (*AGKISTRODON PISCIVORUS LEUCOSTOMA*) ALONG THE CUMBERLAND RIVER BICENTENNIAL TRAIL, ASHLAND CITY, TENNESSEE

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Abstract. The Cumberland River Bicentennial Trail (CRBT) near Ashland City, Tennessee is a popular recreational corridor that bisects the winter and summer habitats of a well established Western Cottonmouths (*Agkistrodon piscivorus leucostoma*) population. The purposes of this study are to determine the seasonal movements of these snakes and any actual or potential negative encounters with people as both traverse the area. To gather data on this question, manual searches are being conducted for snakes on and along the trail. All captured snakes are being measured, weighed, and marked for future identification. In addition, five individuals are being tracked using radio telemetry technology. After 12 months of study, 61 individuals have been encountered and their movements mapped with GIS software. Ingression into hibernacula began in early October at air temperatures around 17 °C, and appeared to be complete by late October. Two snakes were detected leaving their dens the first two weeks of March during an 8-day period when temperatures averaged 15 °C. Egression from hibernation and subsequent movement into summer quarters will be monitored through spring 2009. This project is being supported by Austin Peay State University's Center for Field Biology and the Tennessee Wildlife Resources Agency.

DIFFERENTIAL USE OF CAVE CHAMBERS BY EASTERN PIPISTRELLE, *PERIMYOTIS SUBFLAVUS*, DURING TORPOR AND PRIOR TO MATERNAL ROOST FORMATION

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ABSTRACT. Little quantitative information exists on the differential use of cave chambers by *Perimyotis subflavus* as they utilize cave habitat during torpor or prior to maternal roost formation. Limited published or anecdotal data exists on bat roosting behavior, site fidelity, colonial behavior, and aggregations of species during the emergence period. Ongoing surveys of Dunbar Cave suggest that total number of bats per chamber start to increase before winter torpor as human activity ceases throughout the cave. These numbers remain constant during the winter and early spring months. Monthly surveys recorded each individual's location and the data was integrated into a GIS map of the cave system. Three dimensional analyses of bats for each chamber were developed using microscale GIS mapping. Spacing or aggregation of individuals was evaluated u sing the Morishita Index. Isolation of different species was common during the period of torpor. Incorporating GIS as a tool to track individual species, distinct aggregations, and differential use of habitat, suggests that a significant number of bats are repetitively forming roosts within only a few chambers in Dunbar Cave.

FERAL CATS AS A PRIMARY PREDATOR OF BAT SPECIES

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ABSTRACT. Little quantitative information exists on the percentage of bats as prey by a particular predator. With the exception of a few snakes, bats are documented as an opportunistic or incidental prey and not a primary food source. Most documented incidents of predation on bats by feral cats and other species have occurred at the entrance site of a cave. Feral cat predation has become a focus for conservation biologists, and is deemed detrimental to the native animal populations. The potential for feral cat populations to greatly harm, and in some cases eliminate an entire species has been documented in several studies. Many studies have reported predation on bats by raptors, reptiles, opossum, and some mammals. However, few studies concentrate on the effects of feral cat predation on various bat species. This study provides conclusive data on a single feral cat's predation on bat species at a gated cave entrance. Over the course of three days, one feral cat was able to eradicate over half of the bat population present in the cave system. The cat was observed hunting bats, captured, and obtained by wildlife specialists. No more dead bats were found.

RECENT DECLINE IN CAROLINA CHICKADEE CLUTCH SIZE: A RESPONSE TO GLOBAL WARMING?

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ABSTRACT. **Mean clutch size typically increases from south to north in avian species that have a wide latitudinal distribution. The causes of this variation are not clearly understood, but an inverse correlation with ambient temperature has been noted. For example, Carolina Chickadee clutch size varies from a mean of 4.6 in Louisiana to 6.8 at the northern edge of the range in Illinois. One hypothesized response by chickadees to global warming would be a decrease in clutch size. Mean clutch size of Carolina Chickadees on my northwest Tennessee study area declined from 6.4 in 1976-1983 to 5.8 in 2005-2006. The largest clutch size, 8, made up 17% of the 1976-1983 clutches but 0% of the 2005-2006 clutches. Interpretation of the data is complicated by small sample sizes and the possibility that other factors are responsible, at least in part, for the apparent change.**

MACROINVERTEBRATE BIOASSESSMENT OF PLEASANT GROVE CREEK, LOGAN COUNTY, KENTUCKY

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ABSTRACT. **The Kentucky macroinvertebrate index of biotic integrity (mIBI) and habitat assessments were used to assess water quality in Pleasant Grove Creek. Samples were collected in three reaches of Pleasant Grove Creek and one reach of Whippoorwill Creek, an adjacent watershed that served as a reference stream. The Kentucky mIBI was calculated for each stream reach sampled in this study and for two earlier sets of macroinvertebrate samples collected from Pleasant Grove Creek by Kentucky Department of Water (KDOW). Macroinvertebrate IBI scores for recent samples are somewhat better than scores previously obtained by KDOW indicating continuing improvement of water quality of Pleasant Grove Creek. Improvement in water quality may be even better than indicated because 2007 and 2008 macroinvertebrate samples were collected during a period of severe drought.**

SEASONAL BUTTERFLY SURVEYS AT LAND BETWEEN THE LAKES

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ABSTRACT. Two butterfly sampling methods were used at Land Between The Lakes (LBL) during the period 2003 – 2007. One method involves monitoring butterflies within a predetermined plot circle, and the other is random sampling within the park boundaries. All butterfly species were identified by sight using a close-focus binocular and a field guide. Rare species and unusual sightings were photographed with a digital camera. The first North American Butterfly Association Fourth of July Count was held at LBL – South in 2007. The count circle was 7.5 miles in diameter, with the center at the intersection of Neville Bay Road and The Trace. Observers, number of parties, party hours, distance covered and weather conditions were noted. There were no rare sightings on this count, but there were 28 species noted with butterfly families well represented. (The count was not held in 2008 due to inclement weather.) Random sightings have been documented from 2003-2007 in spring, summer and fall. Again, a variety of habitats were sampled, but some were in the northern portion of the park and not confined to the count circle. During these seasonal surveys, more variety was added to the overall species list because some species are fall migrants, and some only fly in one season. Notable species were the Leonard's Skipper, only found in six counties in Tennessee, the Southern Dogface and the Monarch. There have been over 54 species of butterflies documented for LBL as a result of the count and surveys. Count data go to the North American Butterfly Association where it is compiled by region and published annually. Tennessee county records were sent to Butterflies and Moths of North America (BAMONA) for inclusion on their website. Both sets of data are available for public use.

MACROINVERTEBRATE DIVERSITY AND WATER QUALITY AT A TROUT HATCHERY STREAM ENTERING THE OBEY RIVER, CLAY COUNTY, TENNESSEE

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ABSTRACT. Macroinvertebrates were sampled from the Obey River both above and below a trout hatchery stream effluent and identified to the lowest practical taxon. Numbers of each taxon were entered in a biodiversity program and the following biodiversity indices were obtained for upstream and downstream collections: Simpson's, Shannon, and Species Equitability. Temperature, pH, dissolved oxygen content, and total dissolved solids readings were also taken above and below the hatchery stream. Though it was predicted that the stretch of river below the entrance of the trout hatchery stream would have a lower macroinvertebrate diversity, more species were found below the hatchery effluent. A possible explanation for this result is that the trout stream provides nutrients to support a greater diversity of macroinvertebrates than can be supported upstream and just below the Obey River dam. The results of the macroinvertebrate diversity survey will be compared to previous studies conducted in this region of the Obey River.

TWO FIRST STATE RECORD ODONATES FOR TENNESSEE: *ENALLAGMA DURUM* AND *SOMATOCHLORA ELONGATE*

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ABSTRACT. In 2006 I surveyed odonates for the Tennessee State Parks' All Taxa Biodiversity Inventory and found two species new to the state list. On 3 October 2006, an *Enallagma durum* (Big Bluet) damselfly was observed and photographed along the shore of the Tennessee River (Kentucky Lake) at Paris Landing State Park, Henry County, Tennessee. This species seemed to be common there, as both males and females were observed, with some mating. On 4 October 2006, a male and female were collected as voucher specimens. The species was also found on subsequent surveys south of the park along the Tennessee River in Benton and Hardin counties. In all these locations Big Bluets were found in almost every good patch of Water Willow (*Justicia* sp.) that I checked and represented the dominant odonate species present. It has obviously expanded its previously known range. On 19 July 2006 in Carter County, Tennessee, a *Somatochlora elongata* (Ski-tipped Emerald) was photographed perched, and later captured and photographed in detail. Identification was based on information in Sid Dunkle's dragonfly field guide. Its habitat was a ½-acre, mostly shaded, spring-fed fish pond at an elevation of around 2,000 feet. On August 1, I returned to the site and collected a voucher specimen (a male). I observed two more males, and also observed a female ovipositing along the edge of the pool where the male was collected. *Somatochlora elongata* is known from North Carolina and from farther north. It possibly occurs in other Tennessee counties bordering North Carolina, but has not yet been found elsewhere in Tennessee.