

# Journal of the Arkansas Academy of Science

---

Volume 42

Article 1

---

1988

## Proceedings of the Arkansas Academy of Science - Volume 42 1988

Academy Editors

Follow this and additional works at: <https://scholarworks.uark.edu/jaas>

---

### Recommended Citation

Editors, Academy (1988) "Proceedings of the Arkansas Academy of Science - Volume 42 1988," *Journal of the Arkansas Academy of Science*: Vol. 42 , Article 1.

Available at: <https://scholarworks.uark.edu/jaas/vol42/iss1/1>

This article is available for use under the Creative Commons license: Attribution-NoDerivatives 4.0 International (CC BY-ND 4.0). Users are able to read, download, copy, print, distribute, search, link to the full texts of these articles, or use them for any other lawful purpose, without asking prior permission from the publisher or the author.

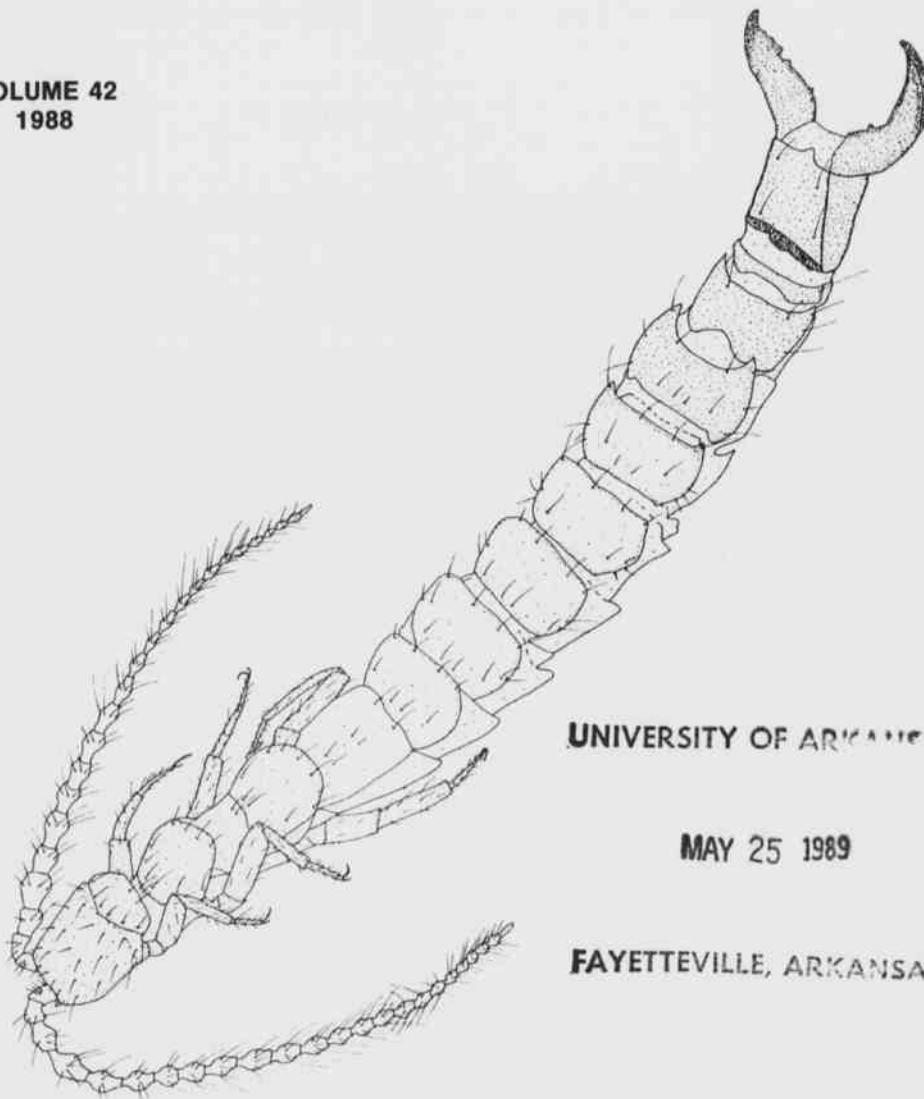
This Entire Issue is brought to you for free and open access by ScholarWorks@UARK. It has been accepted for inclusion in Journal of the Arkansas Academy of Science by an authorized editor of ScholarWorks@UARK. For more information, please contact [scholar@uark.edu](mailto:scholar@uark.edu).

Proceedings of the

CODEN:ARKASO  
ISBN:0097-4374

**ARKANSAS ACADEMY  
OF SCIENCE**

**VOLUME 42  
1988**



**UNIVERSITY OF ARKANSAS**

**MAY 25 1989**

**FAYETTEVILLE, ARKANSAS**

**ARKANSAS ACADEMY OF SCIENCE  
DEPT. OF NATURAL SCIENCE  
MONTICELLO, ARKANSAS 71655**

**Library Rate**

Arkansas Academy of Science, Dept. of Natural Science, University of Arkansas at Monticello  
Monticello, Arkansas 71655

## PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

Charles Brookover, 1917	E. A. Spessard, 1952	M. L. Lawson, 1970
Dwight M. Moore, 1932-33, 64	Delbert Swartz, 1953	R. T. Kirkwood, 1971
Flora Haas, 1934	Z. V. Harvalik, 1954	George E. Templeton, 1972
H. H. Hyman, 1935	M. Ruth Armstrong, 1955	E. B. Whittlake, 1973
L. B. Ham, 1936	W. W. Nedrow, 1956	Clark McCarty, 1974
W. C. Munn, 1937	Jack W. Sears, 1957	Edward Dale, 1975
M. J. McHenry, 1938	J. R. Mundie, 1958	Joe Guenter, 1976
T. L. Smith, 1939	C. E. Hoffman, 1959	Jewel Moore, 1977
P. G. Horton, 1940	N. D. Buffaloe, 1960	Joe Nix, 1978
I. A. Willis, 1941-42	H. L. Bogan, 1961	P. Max Johnston, 1979
L. B. Roberts, 1943-44	Trumann McEver, 1962	E. Leon Richards, 1980
Jeff Banks, 1945	Robert Shideler, 1963	Henry W. Robison, 1981
H. L. Winburn, 1946-47	L. F. Bailey, 1965	John K. Beadles, 1982
E. A. Provine, 1948	James H. Fribourgh, 1966	Robbin C. Anderson, 1983
G. V. Robinette, 1949	Howard Moore, 1967	Paul Sharrah, 1984
John R. Totter, 1950	John J. Chapman, 1968	William L. Evans, 1985
R. H. Austin, 1951	Arthur Fry, 1969	Gary Heidt, 1986
		Gary Tucker, 1987

## INSTITUTIONAL MEMBERS

The Arkansas Academy of Science recognizes the support of the following institutions through their Institutional Membership in the Academy.

ARKANSAS COLLEGE, Batesville  
ARKANSAS STATE UNIVERSITY, State University  
ARKANSAS TECH UNIVERSITY, Russellville  
COLLEGE OF THE OZARKS, Clarksville  
HARDING COLLEGE, Searcy  
HENDERSON STATE UNIVERSITY, Arkadelphia  
HENDRIX COLLEGE, Conway  
JOHN BROWN UNIVERSITY, Siloam Springs  
MISSISSIPPI COUNTY COMMUNITY COLLEGE,  
Blytheville

OUACHITA BAPTIST UNIVERSITY, Arkadelphia  
PHILLIPS COUNTY COMMUNITY COLLEGE, Helena  
SOUTHERN ARKANSAS UNIVERSITY, Magnolia  
UNIVERSITY OF ARKANSAS AT FAYETTEVILLE  
UNIVERSITY OF ARKANSAS AT LITTLE ROCK  
UNIVERSITY OF ARKANSAS FOR MEDICAL  
SCIENCES, Little Rock  
UNIVERSITY OF ARKANSAS AT MONTICELLO  
UNIVERSITY OF ARKANSAS AT PINE BLUFF  
UNIVERSITY OF CENTRAL ARKANSAS, Conway

## EDITORIAL STAFF

EDITOR: JAMES H. PECK, Dept. of Biology, University of Arkansas at Little Rock, 2801 S. University Ave., Little Rock, AR 72204.

NEWSLETTER EDITOR: GARY TUCKER, Biological Sciences Dept., Arkansas Tech University, Russellville, AR 72801.

BIOTA EDITOR: LEO J. PAULISSEN, Botany and Bacteriology Department, University of Arkansas, Fayetteville, AR 72701.

ASSOCIATE EDITORS:

AGRONOMY/PLANT PATHOLOGY: George E. TEMPLETON (UA)  
AQUATIC/ENVIRONMENTAL: John K. Beadles (ASU)  
BIOMEDICAL/PHYSIOLOGY: Earnest J. Peck (UAMS)  
BOTANY: Carol J. Peck (UCA)

CHEMISTRY: Collis R. Geren (UA)  
FISHERIES: Les Torrans (UAPB)  
FORESTRY: Jimmie D. Yeiser (UAM)  
GEOLOGY: John T. Thurmond (UALR)  
PHYSICS: Mustafa Hemmati (ATU)  
SCIENCE EDUCATION: Michael W. Rapp (UCA)  
WILDLIFE MANAGEMENT: Gary A. Heidt (UALR)

COVER: A new species of *Occasjapyx* (Insecta: Diplura: Japygidae) from the Interior Highlands of Arkansas (Newton Co.) that is described by Robert T. Allen in this issue. Proc. Arkansas Acad. Sci. 42:-----.

# PROCEEDINGS ARKANSAS ACADEMY OF SCIENCE

Volume 42

1988

Gary Tucker  
President

Horace Marvin  
President-Elect

Dave Chittenden  
Vice-President/President-Elect

Walt Godwin  
Secretary

Robert Wiley  
Treasurer

James Fribourgh  
NAAS Delegate

Henry Robison  
Historian

## Secretary's Report

### MINUTES OF THE SEVENTY-SECOND ANNUAL MEETING, 1-2 APRIL 1988

#### FIRST BUSINESS MEETING

Gary Tucker, President, called the meeting to order.

Dick Cohoon, Dean of Physical and Life Sciences, welcomed the Academy to the Annual Meeting. Cohoon made several announcements including mentioning the banquet and an open house at the mining institute on campus. He introduced Dr. Jim Ed McGehee, Vice President for Academic Affairs who welcomed the group to Arkansas Tech University.

Walter Godwin, Secretary, presented the minutes of the Seventy-First Annual Meeting. He stated that there were copies in the *Proceedings* and extras at the back of the room. He asked for any corrections to be presented in writing before the Second Business Meeting.

Bob Wiley, Treasurer, presented the Financial Report. He briefly discussed the report and indicated that the Academy is in good financial shape. He indicated that expenses were low for the previous year since no volume of the *Proceedings* was published. An Audit Committee consisting of Leon Richards (Chairman), and Eric Sundell will examine the report. A copy of the report follows.

#### ANNUAL FINANCIAL STATEMENT

##### SUMMARY

(15 MARCH 1987 TO 17 MARCH 1988)

Balance Approved by Audit on 4 April 1987		\$10,495.45
Total Income (Page 2)	6741.60	
Total Expenses (Page 3)	2124.21	
Balance for the Year	4617.39	
<b>TOTAL FUNDS AS OF 17 MARCH 1988</b>		<b>\$15,112.84</b>

##### DISTRIBUTION OF ACCOUNTS

Interest Bearing Checking Account (Union Bank and Trust Co., Monticello, AR)	9180.03
Certificates of Deposit	
Dwight Moore Endowment (1st National Bank of Conway - No. 78940 - 7% Interest)	1077.25
Life Membership Endowment (Heritage Federal Savings and Loan - Monticello - No. 502440 - 7% Interest)	4855.56
Arkansas Academy of Science Endowment - Matured at \$2760.92 on 18 February 1988 - A new CD to be purchased soon. Monies currently in interest bearing checking account.	
<b>TOTAL</b>	<b>\$15,112.84</b>

#### INCOME: 15 March 1987 to 17 March 1988

1. ANNUAL MEETING: RIVERFRONT HILTON, NLR, 3-4 APRIL 1987		768.98
2. INDIVIDUAL MEMBERSHIPS		
a. Regular (191)	2280.00	
b. Sustaining (21)	320.00	
c. Sponsoring (9)	325.00	
d. Life (6)	500.00	
e. Associate (5)	25.00	
Total	3450.00	3450.00
3. INSTITUTIONAL MEMBERSHIPS (14)		700.00
4. PROCEEDINGS, LIBRARY SUBSCRIPTIONS		75.00
5. BIOTA RECEIPTS		130.00
6. INTEREST		
a. Interest Bearing Checking Account	257.87	
b. Dwight Moore Endowment	75.40	
c. AAS Endowment	259.66	
d. Life Membership Endowment	224.69	
Total	817.62	817.62
7. ENDOWMENTS		730.00
8. MISCELLANEOUS		70.00
<b>TOTAL INCOME</b>		<b>\$6741.60</b>

#### EXPENSES: 15 March 1987 to 17 March 1988

1. AWARDS		
a. Kyle J. Weld (#227)	35.00	
b. Seth M. Lovrey (#223)	30.00	
c. Deidra M. Schuckman (#229)	25.00	
d. Hal Palmer (#230)	50.00	
e. Belinda Paybol (#231)	50.00	
f. Arkansas Science Talent Search (#232)	20.00	
g. Arkansas Junior Academy of Science (#233)	200.00	
h. Arkansas Science Fair Association (#234)	200.00	
Total	610.00	610.00
2. MEETING EXPENSES (RIVERFRONT HILTON) (#502)		131.25
3. OPERATING EXPENSES		
a. Secretary's Office (#224, #236)	250.00	
b. Treasurer's Office (#501, #504)	168.66	



## Arkansas Academy of Science

4. NEWSLETTER			
a. Gloria's Printing & Office Supply (#505, #507)	589.74		
b. UALR Biology Department (#506, #508)	126.11		
	-----		
	715.85	715.85	
5. DUES - National Association of Academies of Science (#509)			40.00
6. BIOTA EXPENSES (#237)			126.45
7. MISCELLANEOUS (#225, #226, #235)			82.00
			-----
TOTAL EXPENSES			\$2124.21

## ENDOWMENTS

NAME: DWIGHT MOORE ENDOWMENT  
 PLACE: 1st National Bank of Conway  
 NUMBER: 78940  
 AMOUNT: \$1077.25  
 DATE PURCHASED: 2 January 1987  
 INTEREST RATE: 7% (Interest paid to AAS semiannually)  
 DURATION: 30 Months  
 MATURITY DATE: 2 July 1990

The funds for this CD are derived from money contributed by members and friends of the AAS in memory of Dwight Munson Moore 1891-1985. It is intended that the interest generated from this capital be used to give awards in the name of the honoree. There is no obligation to use all of the interest so that the fund can grow. No provision has as yet been made as to what the awards might be other than they would be in education and would honor outstanding work in the sciences.

NAME: ARKANSAS ACADEMY OF SCIENCE ENDOWMENT  
 PLACE: 1st State Bank and Trust (Conway)  
 NUMBER: 0007-769-4  
 AMOUNT: \$2052.89  
 DATE PURCHASED: 18 February 1985  
 INTEREST RATE: 10% (Interest compounded quarterly)  
 DURATION: 36 Months  
 MATURITY DATE: 18 February 1988

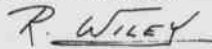
The majority of funds in this CD are unrestricted as to their use. However some funds within the Arkansas Academy of Science Endowment were donated with restrictions as to their use within the following categories: Student Research Awards/Grants, Publications, and Other.

NAME: LIFE MEMBERSHIP ENDOWMENT  
 PLACE: Heritage Federal Savings and Loan Assn. (Monticello)  
 NUMBER: 502440  
 AMOUNT: \$4855.56  
 DATE PURCHASED: 11 March 1988  
 INTEREST RATE: 7% (Interest compounded quarterly)  
 DURATION: 12 months  
 MATURITY DATE: 11 March 1989

The funds for this CD are derived from money paid by members of the AAS for Life Memberships (\$200.00). It is thought that these monies should be kept separate from other monies and perhaps earmarked for some special purpose. As individuals become life members they no longer pay annual dues. Thus it may be desirable to annually remove from this endowment an amount equal to the number of life members x the annual dues and deposit it in the checking account. The additional interest earned would be used for other purposes (education and research). Life members would thus be contributing to the Arkansas Academy of Science long after they have become inactive. Life Memberships would have value not only for the life of the individual, but for the life of the Arkansas Academy of Science.

(NOTE: When CD's mature additional monies collected for that particular CD since investment are added to the maturity amount and reinvested in a new CD.)

Respectfully Submitted,



Robert W. Wiley, AAS Treasurer

Annual Meeting: 1-2 April 1988  
 Arkansas Tech University, Russellville, AR

Jim Peck, Editor of the *Proceedings*, indicated that volume 41 of the *Proceedings* was available. He stated that this volume contained 20 articles and 20 notes of great diversity. He also reminded section chairs be sure to collect papers at the sessions and to turn in those papers. He also indicated that numerous assistant editors were now being used. He mentioned that Volume 40 should go to the printer soon. He presented the following motion:

Mr. President, I move that the Academy appropriate \$500.00 for editorial assistance and \$120.00 for travel for preparation of Volume 42 of the *Proceedings* for the year 1988.

The motion was seconded and will be voted on at the Second Business Meeting.

John Rickett, Editor of the Newsletter, indicated he will be retiring after the Second Business meeting. He thanked the members for their support. He stated that the Executive Committee has voted to continue the "membership drive" with the additional copies of the Fall Newsletter. He presented the following motion:

Mr. President, I move that the Arkansas Academy of Science commit \$750.00 to the production and mailing of the two Newsletter issues for the Academic Year 1988-89.

The motion was seconded and will be voted on at the Second Business Meeting.

Mike Rapp, Director of the Arkansas Science Fair Association, reported on the Science Fair. He stated that there were seven regional fairs and the state fair held this year. He thanked the Academy for both judging assistance and financial support. He presented the following motion:

Mr. President, I move that the Arkansas Academy of Science provide \$200.00 support to the Arkansas Science Fair Association for distribution among the seven regional science fairs and the state science fair.

The motion was seconded and will be voted on at the Second Business Meeting.

Mike Rapp reported for Paul Krause concerning the Arkansas Junior Academy of Science. He described the activities of the Junior Academy and mentioned that the Junior Academy now has an Executive Committee. He presented the following motion:

Mr. President, I move that the Arkansas Academy of Science provide \$250.00 support to the Arkansas Junior Academy of Science.

The motion was seconded and will be voted on at the Second Business Meeting.

John Peck, Director of the Arkansas Science Talent Search, reported on the results of this year's Talent Search. His report follows.

Following is the list of high school seniors who placed in the 37th Annual Arkansas Science Talent Search 1987-88, held in conjunction with the 47th Annual Westinghouse Science Talent Search.

## First Place

David Pearce Gillson  
 7500 Dover Place  
 Fort Smith, AR 72903

Improving Air Flow Uniformity  
 in a Lumber Predryer  
 Fort Smith Christian School  
 Sponsored by Mr. John Deaton  
 and Mr. Charles Besancon

## Second Place

Jeffery Chi Wei Koay  
 P.O. Box 1842  
 Pine Bluff, AR 71601

Newcomb's Paradox and Its  
 Implications on Free Will  
 Pine Bluff High School  
 Sponsored by Mr. Jerrel Boast

## Third Place

Dionne Leigh Baxter  
 Route 1, Box 699R  
 Batesville, AR 72501

Is Curia Creek Really Polluted?  
 Batesville High School  
 Sponsored by Mr. Paul Reynolds

## Secretary's Report

He presented the following motion:

Mr. President, I move that the Arkansas Academy of Science provide up to \$120.00 to the Arkansas Science Talent Search for the purpose of plaques for the three award winners for 1987-88.

The motion was seconded and will be voted on at the Second Business Meeting.

President Tucker reported for Tom Palko, Director of the Arkansas Junior Science and Humanities Symposium. He stated that the Symposium went very well this year with good participation.

President Tucker reported that Horace Marvin, President-Elect, had resigned due to health reasons. The Executive Committee has moved Dave Chittenden, Vice President, to President-Elect. Tucker expressed regret that Marvin had found it necessary to resign and also expressed appreciation for his service this year.

Glynn Turnipseed, Chairman of the Nominating Committee, presented the nominees for Vice President and President-Elect. The nominees for Vice President were Peggy Rae Dorris, Henderson State University, and Arthur Johnson, Hendrix College. The nominees for Vice President were Robert Watson, UALR, and George Harp, Arkansas State University.

Leo Paulissen reported on the Biota Survey. Combined checklists are available for \$10.

President Tucker announced that the Resolutions Committee will consist of Bill Shepherd and Rick McDaniel.

President Tucker announced that the location of the 1989 meeting will be the University of Arkansas for Medical Sciences and that the location of the 1990 Meeting will be Arkansas State University. There is also a tentative invitation from the University of Arkansas at Fayetteville for 1991.

Robbin Anderson, Chairman of the Science Education Committee, reported that there would be a committee meeting later in the afternoon.

President Tucker asked for old business and none was presented.

President Tucker asked for new business. Dick Spears expressed two ideas for Academy consideration. First, he asked if there were any representatives from 2-year institutions present. There were none. He suggested that the Executive Committee should try to generate more involvement from 2-year institutions. Secondly, he suggested that the Academy should have a representative at meeting of the Board of Higher Education. No action was taken on these suggestions.

President Tucker encouraged section chairs to keep their sections on time and to be sure to pick up papers for publication. He also stated that judges were needed for the undergraduate papers and asked for volunteers.

President Tucker adjourned the First Business Meeting.

### SECOND BUSINESS MEETING

Gary Tucker, President, called the meeting to order.

Walter Godwin, Secretary, moved the approval of the minutes of the Seventieth Annual Meeting as distributed with no corrections. The motion was seconded and passed.

President Tucker repeated his statement from the first meeting that Horace Marvin had resigned and that Dave Chittenden had been

moved from Vice President to President-Elect by the Executive Committee. He also repeated the report from Glyn Turnipseed, Chairman of the Nominating Committee, indicating that the nominees for Vice President were Peggy Rae Dorris, Henderson State University, and Arthur Johnson, Hendrix College and that the nominees for Vice President were Robert Watson, UALR, and George Harp, Arkansas State University. Arthur Johnson asked that his name be removed from consideration and nominated Richard Spears. The nomination was seconded. It was moved, seconded and passed that the nominations cease. Ballots were distributed and collected. A report of the results appears later in these minutes.

Robert Wiley, Treasurer, indicated that the additional copies of the Treasurer's Report were available and discussed it briefly. He moved that the Treasurer's Report be approved. The motion was seconded. Edward Richards, Chairman of the Audit Committee, presented the following report from the Audit Committee.

The Audit Committee on reviewing the Treasurer's Financial Statement, books and records for 1987-88 find everything to be in order and correct. We recommend the Treasurer's Report be accepted and extend to Dr. Robert Wiley our thanks and congratulations for excellent and accurate record keeping.

Respectfully submitted,  
Edward L. Richards, Chairman  
Eric Sundell

It was moved and seconded to accept the report of the Audit Committee. The motion passed. The initial motion concerning acceptance of the Treasurer's Report passed.

The motion presented at the First Business Meeting by Jim Peck, Editor of the *Proceedings*, to allocate \$500 for editorial assistance and \$120 for travel for the *Proceedings* for next year was passed.

The motion presented at the First Business Meeting by John Rickett, Editor of the Newsletter, to allocate \$750 for the Newsletter for next year was passed.

The motion presented at the First Business Meeting by Mike Rapp, Director of the Arkansas Science Fair Association, to provide \$200 support to the Arkansas Science Fair Association for next year was passed.

The motion presented at the First Business Meeting by Mike Rapp for Paul Krause, Director of the Arkansas Junior Academy of Science, to provide \$250 support to the Arkansas Junior Academy of Science for next year was passed.

The motion presented at the First Business Meeting by John Peck, Director of the Arkansas Science Talent Search, to provide up to \$120 to the Arkansas Science Talent Search for the purpose of plaques for the three award winners for 1987-88 was passed.

Henry Robinson, Historian, reported that this was the 72nd Annual Meeting and that it was the fourth time the Academy had been hosted by the Arkansas Tech University.

Ed Bacon reported for the Development Committee. He mentioned the Development Brochure which had been developed and distributed the past year. He reported that there was \$5000 in the general Endowment Fund and \$1100 in the Dwight Moore Endowment Fund. He thanked members for their support and encouraged additional contributions. He stated that development efforts would continue.

Leo Paulissen reported on the Biota Survey. A compilation of about 50 checklists is now available.

Robbin Anderson, Chairman of the Science Education Committee, mentioned increasing needs in the education area and especially in

## Arkansas Academy of Science

teacher education. He stated that the committee had no specific recommendations but that it will keep in contact with the Academy.

President Tucker reported on the undergraduate awards. He reported that the awards had been won by:

## Physical Sciences:

J.G. Ross - UCA

Measurements of the Drag on Spheres Falling Through the Air.

## Life Sciences: tie

Luke Eggering - Arkansas Tech University

Autumn Diets of White-Tailed Deer in Arkansas

Yvette Randle - UAPB

*Strongyloides stercoralis*: Immunobiological Studies of an Unusual Worm.

Dick Spears reexpressed two ideas for Academy consideration. First, he asked if there were any representatives from 2-year institutions present. There were none. He stated that there are 10 such schools in the state, three of which are affiliated with 4-year schools. He suggested that a project be undertaken to encourage participation from these schools. Secondly, he suggested that the Academy should have a representative at meeting of the Board of Higher Education since the board directs education in the state. It was decided that the Executive Committee should consider these proposals.

Dave Saughey stated that a preliminary list of herptiles of the State Parks had been completed. Copies of this list are available.

President Tucker announced the results of the election. Robert Watson was elected Vice President and Dick Spears was elected President-Elect.

Bill Shepherd, Chairman of the Resolutions Committee, moved the adoption of the following resolution.

Be it resolved:

The members of the Arkansas Academy of Science express their gratitude to Arkansas Tech University for hosting the Academy's 1988 meeting. In particular, the Academy thanks Richard Cohoon, Dean of Physical and Life Sciences, who was in charge of local arrangements, and the entire faculty of Cohoon's school, who assisted in various ways. Appreciation is expressed to all who helped provide comfortable and convenient facilities and an excellent banquet. Dr. Warren H. Wagner's outstanding banquet address on endangered species was a highlight of the meeting, and the Academy is grateful to the ATU office of Academic Affairs for underwriting the cost of bringing him to Russellville.

The Academy appreciates the work of the various section chairmen and recognizes the important role they played in the conduct of the meeting. They are as follows: O. D. Smith (Agronomy/Forestry), Harlan McMillan (Aquatic/Environmental I), John Martin (Biomedical/Microbiology I), Gerald Hutchinson (Botany), Robert Allen (Chemistry I), Victor Vere (Geology/Earth Science), Robbin Anderson (Science Education I & II), Glyn Turnipseed (Vertebrate Zoology I), Bruce Shackelford (Aquatic/Environmental II), Scott Kirkconnel (Biomedical/Microbiology II), William Trigg (Chemistry II), Raymond Couser (Invertebrate Zoology), Mostafa Hemmati (Physics/Mathematics), and Tom Nelson (Vertebrate Zoology II).

The Academy expresses gratitude to the various directors of the science youth activities supported by the Academy:

Robbin Anderson, the Science Education Committee; Mike Rapp, Director of the Arkansas State Science Fair; Tom Palko, Director of the Junior Science and Humanities Symposium; Paul Krause, the Arkansas Junior Academy of Science; John Peck, Director of the Arkansas Science Talent Search; Leo Paulissen, the Biota Committee; and Ed Bacon, the Development Committee.

The Academy is only as successful as its leadership in planning, working, and directing the various activities. To Gary Tucker, President; David Chittenden, President-Elect; Walter Godwin, Secretary; Robert Wiley, Treasurer; Ed Bacon, Past-President; Jim Peck, *Proceedings* Editor; John Rickett, outgoing Newsletter Editor; and Henry Robison, Historian, the Academy expresses gratitude and thanks for an excellent year.

The Academy expresses thanks and encouragement to continue in Advanced Scientific, Inc., the Arkansas Geological Commission, Jacobs Instrument Co., the Ozark Interpretive Association, S & S Scientific Co., and Sargent-Welch Scientific Co. for their exhibition booths at the meeting.

The Academy recognizes with appreciation the work of Ed Bacon, Rose McConnell, and Mike Rapp for their efforts on the Student Awards Committee, Glyn Turnipseed, William Evans, and Henry Robison for their work on the Nominating Committee, and Victor Vere and William Guest as tellers.

The Academy is appreciative for design and art work to the ATU Art Department, program cover; Jim Edson, plaques; and Calvin Cotton, calligraphy on student awards.

Finally, the Academy expresses fond remembrance and regret in the deaths of two of its members, Maxine Clark and Delzie Demaree.

The motion was seconded and passed.

President Tucker announced that there would be a group picture taken after adjournment of the business meeting.

President Tucker announced that meetings have been scheduled for the next three years. The Academy will meet at the University of Arkansas for Medical Sciences in 1989, at Arkansas State University in 1990, and tentatively at the University of Arkansas at Fayetteville in 1991.

President Tucker expressed appreciation for the help he has received in the past year.

President Tucker presented a plaque to John Rickett in recognition of six years service as Newsletter Editor.

President Tucker called on President-Elect Dave Chittenden and passed the gavel to him.

President Chittenden invited all members to UAMS for next year's meeting.

President Chittenden presented Past-President Tucker with a plaque in recognition of his year of service.

President Chittenden asked that a representative from each institution or organization pick up copies of the *Proceedings* for those not in attendance.

It was moved, seconded and passed to adjourn the meeting.

Respectfully submitted,

Walter E. Godwin  
Secretary

## Secretary's Report

## REGULAR

- Stephen R. Addison  
Syed M. Aljaz  
Bob Allen  
Robert T. Allen  
Silke Huffnagel Allen  
John T. Annulis  
Robert K. Bacon  
Owen Barber  
Sara Mills Barnett  
Adolphina M. Basford  
John Kenneth Beadles  
Ann Marie Benson  
C. Bhuvaneshwara  
Veryl V. Board  
Harilyn D. Bocksnick  
Laurence J. Boucher  
William R. Bowen  
Robert E. Bowling  
Leo H. Bowman  
Jitemy D. Bragg  
Marge A. Brewster  
John F. Bridgman  
Arthur V. Brown  
Connell J. Brown  
Helen G. Brown  
Richard H. Brown  
Charles T. Bryant  
Charles T. Bryant, Jr.  
Neal D. Buffalo  
Michael Cartwright  
John S. Choiniski, Jr.  
Frances E. Clayton  
Malcolm K. Cleaveland  
Lorris G. Cockerham  
Richard R. Cohoon  
George W. Colton  
Robert M. Cordova  
Bob W. Cowling  
Fred Dalske  
James J. Daly  
James T. Daniels  
Stanley N. David  
Leo Carson Davis  
Robert H. Dillard  
Peggy Rea Dorris  
Lee Lee Doyle  
Benjamin T. Duhart  
Danny J. Ebert  
Tammy Kay Ebsen  
Rudolph J. Eichenberger  
Thomas K. Ekman  
Hudson B. Eldridge  
Don England  
Lawana England-Whaley  
Carole R. Engle  
Claude E. Epperson  
Wilbur W. Everett  
Steve Filipek  
Sheldon Fitzpatrick  
E. P. Floyd  
Thomas L. Foti  
Paul B. Francis  
Winefred Fraser  
Jack Gaiser  
Joe P. Gentry  
Thomas E. Goodwin  
D. Leroy Gray  
Donald C. Greenland  
B. R. Griffin  
Gaston Griggs  
Tyrrel C. Grohman  
Mark Gross  
William C. Guest  
Jim Gullden  
Rao P. Gullapalli  
Paul D. Gwinup  
Bruce Haggard  
Earl L. Hanabrink  
B. J. Hankins  
Richard H. Hanson  
George L. Harp  
Jarvis Harper  
John L. Harris  
Calvin J. Haskins  
Mustafa Hemmati  
Larry Hinck  
Maxine R. Hite  
Art Hobson  
John R. Hodges  
Kathy M. Holobar  
Kay Holtman  
E. E. Hudson  
Jim Huey  
Joe Jeffers  
Michael I. Johnson  
Jay Justice  
Phillip L. Kehler  
Scott Kirkconnell  
Maurice G. Kleve  
Richard Klueder  
University of Central Arkansas  
University of Arkansas at Pine Bluff  
Arkansas Tech University  
University of Arkansas  
Hendrix College  
University of Arkansas at Monticello  
University of Arkansas  
University of Central Arkansas  
Texas Education Agency & UT-Austin  
Henderson State University (Retired)  
Arkansas State University  
University of Arkansas for Medical Sciences  
University of Arkansas for Medical Sciences  
Arkansas College  
Arkansas Tech University  
Arkansas Tech University  
University of Arkansas at Little Rock  
University of Arkansas for Medical Sciences  
Arkansas Tech University  
Henderson State University  
University of Arkansas for Medical Sciences  
University of the Ozarks  
University of Arkansas  
University of Arkansas  
University of Arkansas  
Ouachita Baptist University  
Water Resources Associates of Arkansas  
Water Resources Associates of Arkansas  
University of Central Arkansas  
Arkansas Game & Fish Commission  
University of Central Arkansas  
University of Arkansas  
NCTR Associated Universities  
Arkansas Tech University  
Arkansas Geological Commission  
Cordco Consulting  
University of Central Arkansas  
University of Arkansas for Medical Sciences  
SAU - Tech  
Arkansas State University  
Southern Arkansas University  
Univ. of Ark. Cooperative Extension Service  
Henderson State University  
University of Arkansas for Medical Sciences  
University of Arkansas at Pine Bluff  
U. S. Forest Service  
University of Arkansas at Little Rock  
Southern Arkansas University  
Southern Arkansas University  
University of Central Arkansas  
Harding University  
Arkansas State University Alumnus  
University of Arkansas at Pine Bluff  
University of Arkansas for Medical Sciences  
Ouachita Baptist University  
Arkansas Game & Fish Commission  
University of Arkansas at Pine Bluff  
U. S. Public Health Service (Retired)  
Arkansas Natural History Commission  
University of Arkansas at Monticello  
Arkansas College  
University of Central Arkansas  
Arkansas Science & Technology Authority  
Hendrix College  
Univ. of Ark. Cooperative Extension Service  
U. S. Fish & Wildlife Service  
U. S. Fish & Wildlife Service  
John Brown University  
University of Arkansas for Medical Sciences  
University of Arkansas Graduate Institute of  
University of Arkansas  
University of Arkansas at Monticello  
University of Arkansas at Little Rock - GIT  
Arkansas State University  
Hendrix College  
Arkansas State University  
Univ. of Ark. Cooperative Extension Service  
University of Arkansas at Little Rock  
Arkansas State University  
Alcoa  
Arkansas Highway & Transportation Department  
Arkansas Game & Fish Commission  
Arkansas Tech University  
Arkansas State University  
University of Arkansas  
University of Arkansas at Little Rock  
Everglades National Park  
University of Arkansas at Little Rock  
Arkansas Tech University  
University of Arkansas at Monticello  
Ouachita Baptist University  
Nettleton High School  
Arkansas Dept. of Pollution Control & Ecology  
University of Arkansas at Little Rock  
Arkansas Tech University  
University of Arkansas at Little Rock  
University of Arkansas at Monticello  
Richard A. Komoroski  
Randall A. Kopper  
Walter A. Korfmacher  
Timothy M. Kral  
Jack C. Krele  
Timothy T. Ku  
Forrest E. Lane  
Danny L. Lattin  
Kwang Lee  
Linda A. Lee  
Thomas J. Lynch  
Chris T. McAllister  
Clark W. McCarty  
Rose McConnell  
Harlan McMillan  
Walter E. Meshaka, Jr.  
Lawrence A. Mink  
Richard S. Mitchell  
Leland F. Morgans  
G. J. Musick  
Paul Hove  
Nathaniel Nehus  
Thomas Nelson  
W. Donald Newton  
William F. Nicholson  
Joe Nix  
Timothy J. O'Brien  
Kelly H. Oliver  
Derrick M. Osterhuis  
Tom Palko  
Bryan D. Palmer  
Leo J. Paulissen  
Mark A. Paulissen  
John E. Pauly  
Ernest J. Peck  
John D. Peck  
Carlos W. Pennington  
Jacob R. Phillips  
Robert A. Pierce  
Albert B. Pittman  
Michael V. Plummer  
Harold Pray  
Denver L. Prince  
Paul L. Raines  
Michael W. Rapp  
Derik J. Reed  
Ruby S. Reynolds  
Edward L. Richards  
Donald Rickard  
Peggy Root  
Perry C. Rothrock, III  
S. Jeffery Scott  
John A. Sealander  
Elwood B. Shade  
William H. Shepherd  
Samuel Siegel  
Dewey H. Sifford  
Buria J. Sims  
Sidney Skinner  
Tom Slattton  
Erwin B. Smith  
Kimberly G. Smith  
Roy J. Smith, Jr.  
Frederick W. Spiegel  
Kenneth F. Steele  
Stan Steight  
Ann H. Steinmeir  
T. W. Steward  
Nathan Stone  
Joseph Sylvester  
Sandy Tedder  
Lyell Thompson  
Dan Timmerman  
Les Torrans  
Stanley E. Trauth  
William W. Trigg  
Renn Tumison  
Tom Turner  
Glyn Turnipseed  
Victor Vere  
Tito Viswanathan  
David L. Vosburg  
George H. Wagner  
Joel T. Walker  
Robert L. Watson  
G. J. Weidemann  
Wendy Welch  
Laurin Wheeler  
Marion C. Wicht, Jr.  
T. Bentley Wigley  
James T. Willcutt  
William M. Willingham  
Rebecca L. Willis  
Edmond W. Wilson, Jr.  
Duane C. Wolf  
Robert D. Wright  
William V. Wyatt  
Chia C. Yang  
Jimmie D. Yeiser  
David A. Young  
University of Arkansas for Medical Sciences  
Hendrix College  
National Center for Toxicological Research  
University of Arkansas  
Fayetteville Public Schools  
University of Arkansas at Monticello  
University of Arkansas  
University of Arkansas for Medical Sciences  
University of Arkansas at Pine Bluff  
Pocahontas High School  
University of Arkansas at Little Rock  
Dallas VA Medical Center  
Ouachita Baptist University  
University of Arkansas at Pine Bluff  
Arkansas Tech University  
Arkansas State University  
Arkansas State University  
Arkansas State University  
University of Arkansas at Little Rock  
University of Arkansas  
Arkansas State University  
Arkansas Dept. of Pollution Control & Ecology  
Arkansas Tech University  
Arkansas State University  
University of Arkansas at Monticello  
Ouachita Baptist University  
University of Arkansas for Medical Sciences  
Henderson State University  
University of Arkansas  
Arkansas Tech University  
Henderson State University  
University of Arkansas  
University of Arkansas  
University of Arkansas for Medical Sciences  
Arkansas State University  
University of Central Arkansas  
USAE Waterways Experiment Station  
University of Arkansas  
Univ. of Ark. Cooperative Extension Service  
Arkansas Natural History Commission  
Harding University  
University of Central Arkansas  
University of Central Arkansas  
Arkansas State University  
University of Arkansas at Monticello  
University of the Ozarks  
Arkansas State University  
Arkansas Tech University  
Southern Arkansas University  
University of Arkansas for Medical Sciences  
University of Arkansas  
University of Arkansas  
University of Arkansas at Monticello (Retired)  
Arkansas Natural History Commission  
University of Arkansas  
Arkansas State University  
University of Arkansas at Little Rock  
USDA - ARS  
University of Arkansas at Little Rock  
University of Arkansas  
University of Arkansas  
U. S. Department of Agriculture  
University of Arkansas  
University of Arkansas  
Arkansas State Parks  
Baptist Medical Center  
Arkansas State University  
Cooperative Extension Service  
Arkansas Cooperative Fish Project  
University of Arkansas  
University of Arkansas  
Arkansas State University  
University of Arkansas at Pine Bluff  
Arkansas State University  
Arkansas Tech University  
Oklahoma State University  
Ouachita Baptist University  
Arkansas Tech University  
Arkansas Tech University  
University of Arkansas at Little Rock  
Arkansas State University  
University of Arkansas  
University of Arkansas at Little Rock  
University of Arkansas  
Arkansas Highway & Transportation Department  
University of Arkansas  
Arkansas College  
University of Arkansas at Monticello  
Arkansas Tech University  
University of Arkansas at Pine Bluff  
Southern Arkansas University  
Harding University  
University of Arkansas  
University of Central Arkansas  
Arkansas State University  
Arkansas Tech University  
University of Arkansas at Monticello  
North Arkansas Community College - Rogers



## Arkansas Academy of Science

## ASSOCIATE

Diana Garland	University of Arkansas at Little Rock	Robin Matthews	University of Arkansas at Little Rock
David Goad	University of Arkansas at Little Rock	Stephen W. Miller	University of Arkansas
Kevin D. Golden	Henderson State University	Michael Murphy	University of Arkansas
Phoebe A. Harp	Arkansas State University	Michael E. Scheinost	University of Arkansas
William Brian Harrod	University of Arkansas	Charlene Shrock	University of Arkansas at Pine Bluff
Brett Hobbs	Henderson State University	Bruce M. Whitney	University of Arkansas
John Marr	University of Central Arkansas		

## SUSTAINING

Judith A. Bean	University of Central Arkansas	Horace N. Marvin	University of Arkansas for Medical Sciences
John B. Bennett	Arkansas State University	Daniel M. Mathews	University of Arkansas for Medical Sciences
David Chittenden	Arkansas State University	V. Rick McDaniel	Arkansas State University
Joseph M. Clark	Arkansas State University	Alex R. Nisbet	Quachita Baptist University
Donald Culwell	University of Central Arkansas	Lance Peacock	The Arkansas Nature Conservancy
Edward E. Dale, Jr.	University of Arkansas	Ervin W. Powell	University of Arkansas for Medical Sciences
Edmond E. Griffin	University of Central Arkansas	Eric Sundell	University of Arkansas at Monticello
Lester C. Howick	University of Arkansas	Richard B. Walker	University of Arkansas at Pine Bluff
Leslie E. Mack	University of Arkansas	James O. Wear	Veterans Administration Medical Center
Daniel L. Marsh	Henderson State University		

## SPONSORING

David L. Davies	University of Arkansas for Medical Sciences	Gary A. Heidt	University of Arkansas at Little Rock
Jim Edson	University of Arkansas at Monticello	Ray Kinser	University of Central Arkansas
Daniel R. England	Southern Arkansas University	John Rickett	University of Arkansas at Little Rock
Arthur Fry	University of Arkansas	Paul C. Sharrah	University of Arkansas
Collis R. Geren	University of Arkansas	Gary Tucker	Arkansas Tech University
Walter E. Godwin	University of Arkansas at Monticello	Robert W. Wiley	University of Arkansas at Monticello

## LIFE MEMBERS

Robbin C. Anderson	University of Arkansas	Carol J. Peck	University of Arkansas at Pine Bluff
Edmond J. Bacon	University of Arkansas at Monticello	James H. Peck	University of Arkansas at Little Rock
Mark Draganjac	Arkansas State University	Henry M. Robison	Southern Arkansas University
William L. Evans	University of Arkansas	David A. Saugey	U. S. Forest Service
James H. Friborough	University of Arkansas at Little Rock	Stephen A. Sewell	USDA-SCS
Joe M. Guenter	University of Arkansas at Monticello	Betty M. Speairs	Quachita Mountains Biological Station
Douglas James	University of Arkansas	Richard K. Speairs, Jr.	Louisiana State University Shreveport
Arthur A. Johnson	Hendrix College	George E. Templeton	University of Arkansas
Robert T. Kirkwood	University of Central Arkansas - Retired	James L. Wickliff	University of Arkansas
Clementine Moore	Rudy, AR		

# PROGRAM

## Arkansas Academy of Science

Seventy-Second Annual Meeting

ARKANSAS TECH UNIVERSITY

Russellville, Arkansas

Meeting concurrently with sessions of

The Collegiate Academy of Science

*Friday, 1 April, 1988*

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SENIOR ACADEMY -- Executive Board Meeting

SENIOR ACADEMY -- First General Business Meeting

Lunch

SENIOR AND COLLEGIATE ACADEMIES: Registration

SENIOR AND COLLEGIATE ACADEMIES: Papers [Concurrent Sessions]:

Agronomy-Forestry  
Aquatic and Environmental I  
Biomedical-Microbiological I  
Botany  
Chemistry I  
Geology-Earth Science  
Science Education I  
Vertebrate Zoology I

SENIOR AND COLLEGIATE ACADEMIES -- Banquet

POST BANQUET SPEAKER -- Dr. Warren H. Wagner, Jr.  
University of Michigan  
Ann Arbor, MI

*Saturday, 2 April, 1988*

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SENIOR AND COLLEGIATE ACADEMIES -- Papers [Concurrent Sessions]:

Aquatic and Environmental II  
Biomedical-Microbiological II  
Chemistry II  
Invertebrate Zoology  
Physics-Mathematics  
Vertebrate Zoology II

ARKANSAS SCIENCE TALENT SEARCH

SENIOR ACADEMY -- Second General Business Meeting

## SECTION PROGRAMS

### AGRONOMY - FORESTRY

Session Chairperson: O. D. Smith (Timber Staff Officer,  
Ozark-St. Francis National Forests, Russellville, AR)

ADVENTURES IN FORESTRY - THE TAIWAN CONNECTION.  
Timothy T. Ku, R. Scott Beasley, and James M. Guldin, Dept.  
of Forest Resources, Arkansas Agric. Exp. Sta., UAM, Monticello,  
AR 71655.

FORESTRY ON THE ISLAND OF TAIWAN, REPUBLIC OF  
CHINA - THE STATE OF THE ART.

James M. Guldin, R. Scott Beasley, and T. T. Ku. Dept. Forest  
Resources, Arkansas Agric. Exp. Sta., UAM, Monticello, AR  
71655.

ARKANSAS' FORESTS: YESTERDAY, TODAY, AND  
TOMORROW.

Richard A. Kluender and R. Larry Willett. Dept. of Forest  
Resources, Ark. Agric. Exp. Sta., UAM, Monticello, AR 71655;  
Extension Forester, Arkansas Cooperative Extension Service, Mon-  
ticello, AR 71655.

A FOUR YEAR ANALYSIS OF WILDFIRES IN SOUTHEASTERN  
ARKANSAS.

Richard A. Kluender, Gregory W. Callahan, and Lynne C. Thomp-  
son. Department of Forest Resources, UAM, Monticello, AR  
71655.

INFLUENCE OF NITROGEN FERTILITY ON MILLING YIELD  
OF RICE (*Oryza sativa*).

R. H. Dilday, USDA-ARS, Box 287, Stuttgart, AR 72160.

IMPACTS OF SILVICULTURAL ALTERNATIVES ON NUTRIENT  
EXPORT VIA STREAMFLOW IN THE OUACHITA MOUNTAINS.

R. S. Beasley, E. L. Miller, and E. R. Lawson. Department of  
Forest Resources, UAM, Monticello, AR 71655; Dept. of Forestry,  
OSU, Stillwater, OK 74078; Forest Hydrology Lab, US Forest Ser-  
vice, Oxford, MS 38655.

STANDARD AND SEMIDWARF RICE (*Oryza sativa*) CULTIVARS  
AND THE ASSOCIATION OF PLANT HEIGHT, SEEDLING  
VIGOR, AND MESOCOTYL/COLEOPTILE ELONGATION.

S. L. Skinner, R. H. Dilday, M. A. Mgonja, and S. A. Amonsilpa,  
USDA-ARS, 287, Stuttgart, AR 72160.

SEEDLING GROWTH RESPONSE IN A GREENHOUSE TO FOUR  
RATES OF OLD AND NEW PAPER MILL SLUDGE.

J. L. Yeiser, Department of Forest Resources, UAM, Monticello,  
AR 72655.

HERBICIDE TREATMENTS FOR CONTAINER-GROWN SEED-  
LINGS IN PROGENY TESTS.

J. L. Yeiser (UAM), J. W. Boyd (Extension), and D. J. Reed  
(UAM). Dept. of Forest Resources, UAM, Monticello, AR 72655;  
Arkansas Cooperative Extension Service, Little Rock, AR 72203.

SURVIVAL AND GROWTH TWO YEARS AFTER CONTROL OF  
HERBACEOUS COMPETITORS IN NEWLY PLANTED SEED-  
LINGS OF LOBLOLLY PINE.

J. L. Yeiser and J. W. Boyd. Department of Forest Resources,  
UAM, Monticello, AR 71655; and UA Cooperative Extension  
Service, Little Rock, AR 72203.

THE EFFECTS OF ANTHROPOGENIC STRESSES ON SOIL  
WATER CHEMISTRY OF SOUTHERN PINE FORESTS.

G. L. Wheeler, T. T. Ku, and R. J. Colvin; Dept. of Horticulture  
and Forestry, UA, Fayetteville, AR 72701; Dept. of Forestry  
Resources, UAM, Monticello, AR 71665; and SW Research and  
Extension Center, UA, Hope, AR 72801.

### AQUATIC - ENVIRONMENTAL I

Session Chairperson: Dr. Harlan McMillan (Biology, ATU)

PCB CONTAMINATION IN LAKE PINE BLUFF.

Bruce Shackelford, Arkansas Department of Pollution Control &  
Ecology, 8001 National Drive, Little Rock, AR 72209.

DISTRIBUTION AND HABITAT OF DARTERS AS FOUND  
IN REPRESENTATIVE STREAMS OF CLARK COUNTY,  
ARKANSAS.

Thomas Brett Hobbs, HSU, Arkadelphia, AR 71923.

RAPID BIOASSESSMENTS OF MACROINVERTEBRATE  
COMMUNITIES IN ARKANSAS STREAMS.

Bruce Shackelford, Arkansas Dept. of Pollution Control and  
Ecology, 8001 National Drive, Little Rock, AR 72209.

A PRACTICAL WATER SAMPLER.

Richard S. Mitchell and Edward L. Richards, Depts. of Chemistry  
and Biological Sciences, ASU, State University, AR 72467.

PHYTOTOXICITY OF SOIL RESIDUES OF JP-4 AVIATION FUEL.

Richard H. Brown, Biology Department, OBU, Box 3686,  
Arkadelphia, AR 71923.

CATFISH (*Ictalurus punctatus*) AQUACULTURE AND OFF-  
FLAVOR RELATED TO BLUE-GREENS.

Richard S. Mitchell and Edward L. Richards, Depts. of Chemistry  
and Biological Sciences, ASU, State University, AR 72467.

BIOLOGICAL RESPONSE TO HABITAT ALTERATION IN A  
SMALL OZARK STREAM.

Danny J. Ebert and Stephen P. Filipek. U.S. Forest Service, 605  
W. Main, Russellville, AR 72801; and Arkansas Game and Fish  
Commission, #2 Natural Resources Drive, Little Rock, AR 72201.

### BIOMEDICAL - MICROBIOLOGY I

Session Chairperson: Dr. John Martin (Chemistry, ATU)

PLASMA CORTICOSTERONE CONCENTRATION DECREASES  
WITH INCREASE OF BODY TEMPERATURE IN BACTERIAL  
LIPOPOLYSACCHARIDE-INJECTED RABBITS.

Stanley N. David and Lawrence W. Hinck. Department of  
Biological Sciences, ASU, State University, AR 72467.

THE EFFECT OF METRONIDAZOLE ON THE MURINE IMMUNE  
RESPONSE TO PNEUMOCOCCAL POLYSACCHARIDE AND  
*Plasmodium yoelli*.

Dale Ferguson (UALR), Steve Koeller (UALR), and Jim Daly  
(UAMS). UALR, Little Rock, AR 72204; and UAMS, Little Rock,  
AR 72205.

ATTEMPTED SYNTHESIS OF ENKEPHALIN ANALOGUES AS  
OPIATE RECEPTOR LABELS.

Danny L. Lattin (UAMS), John Moix (UAMS), and Eric Pierce  
(SAU). College of Pharmacy, UAMS, Little Rock, AR 72204; and  
SAU, Magnolia, AR 71753.

MALATE DEHYDROGENASE KINETICS OF AN ANAEROBIC  
VERTEBRATE.

J. M. Walters, D. A. Baeyens, and W. G. Smith. Biology Dept.,  
UALR, Little Rock, AR 72204.

*Strongyloides stercoralis*: IMMUNOBIOLOGICAL STUDIES OF AN  
UNUSUAL WORM.

Yvette Randle and Robert Genta. Dept. of Biology, UAPB, Pine  
Bluff, AR 71601; Laboratory for Infectious Diseases, Cincinnati  
Veterans Hospital, Cincinnati, OH 45219.



## Program

### ISOLATION OF SODIUM FLUORIDE RESISTANT MUTANTS OF *Streptococcus sanguis* AND *S. salivarius*.

Hamid R. Janloo and Timothy R. Kral. Dept. of Botany and Microbiology, UA, Fayetteville, AR 72701.

### COMPARISON OF FLUORIDE RESISTANCE LEVELS OF *Streptococcus Mutans* MUTANTS GROWING ON DIFFERENT CARBOHYDRATE SOURCES.

Ralf Krahe, Michael E. Scheinost, and Timothy A. Kral, Dept. of Botany and Microbiology, UA, Fayetteville, AR 72701.

### CYCLIC AMP PHOSPHODIOESTERASE ACTIVITY IN THE HAPLOID STAGE (MYXAMOEBIA) OF THE MYXOMYCETE *Physarum flavicomum*.

Tammy K. Ebsen and Thomas J. Lynch. Dept. of Biology, UALR, Little Rock, AR 72204.

### FURTHER STUDIES OF A HEAT STABLE NUCLEAR CYCLIC-GMP AND CYCLIC-AMP PHOSPHODIOESTERASE FROM THE PLASMODIUM OF *Physarum flavicomum*.

C. Kay Holtman (UALR), Judith A. Bean (UCA), and Thomas J. Lynch (UALR). Dept. of Biology, UALR, Little Rock, AR 72204; and Dept. of Biology, UCA, Conway, AR 72032.

### DEVELOPMENT OF MONOCLONAL ANTIBODIES TO THE MUCOID EXOPOLYSACCHARIDE OF *Pseudomonas aeruginosa*.

John T. Stine, James M. Saunders, and R. Mark Wooten. Dept. of Botany and Microbiology, UA, Fayetteville, AR 72701.

### ANTIMICROBIAL PROPERTIES FROM LAND SNAIL EGGS.

Winifred Fraser, Arkansas College, Batesville, AR 72501.

### BOTANY

Session Chairperson: Dr. Gerald Hutchinson  
(Mining and Mineral Resources Research Institute, ATU)

### GIBBERELLIN FUNCTION IN CASTOR BEAN IS ASSOCIATED WITH CHANGES IN TISSUE SENSITIVITY.

James G. Taylor and John S. Choinski, Jr. Dept. of Biology, UCA, Conway, AR 72032.

### SPECIES BIOLOGY OF *Lindera melissifolia*, PONDBERRY, A FEDERALLY LISTED SPECIES, IN NORTHEAST ARKANSAS.

Robert D. Wright, Dept. of Biology, UCA, Conway, AR 72032.

### A SURVEY OF THE VASCULAR PLANTS OF CARROLL COUNTY, ARKANSAS.

Michael E. Murphy. Dept. of Biological Sciences, ASU, State University, AR 72467.

### IDENTIFICATION, SURVEY, AND EVALUATION OF POTENTIAL HABITATS OF *Geocarpon minimum* MACKENZIE IN ARKANSAS.

Albert B. Pittman. Arkansas Natural Heritage Commission, The Heritage Center, Suite 200, 225 E. Markham, Little Rock, AR 72201.

### SELECTED SPECIES OF NATIVE PLANTS FOR USE ON HIGHWAY RIGHT OF WAY.

Don Culwell and Wendy Welch. Dept. of Biology, UCA, Conway, AR 72032; and Arkansas Highway and Traffic Department, Environmental Division, Box 2261, Little Rock, AR 72203.

### LITERATURE TO ARKANSAS FIELD BOTANY.

James H. Peck and Carol J. Peck. Department of Biology, UALR, Little Rock, AR 72204.

### IN MEMORIAM: MAXINE CLARK, 1905-1988.

Gary Tucker. Biological Sciences Dept., ATU, Russellville, AR 72801.

### POPULATIONS AND SUCCESSION OF PROTOSTELIDS ON *Zea mays*.

S. W. Miller and F. W. Spiegel. Dept. of Botany and Microbiology, UA, Fayetteville, AR 72701.

### STATUS AND REPRODUCTION OF LOG FERNS (*Dryopteris*) IN ARKANSAS.

James H. Peck and Carol J. Peck. Dept. of Biology, UALR, Little Rock, AR 72204.

### DELZIE DEMAREE, BOTANIST, 1889-1987.

Gary Tucker. Biological Sciences Dept., ATU, Russellville, AR 72801.

### CHEMISTRY I

Session Chairperson: Dr. Robert Allen (Chemistry, ATU)

### SYNTHESIS OF CARBOHYDRATE-DERIVED CHIRONS FROM D-ARABINOSE.

Heidi E. Mills and Thomas E. Goodwin. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### REACTION OF ALLYLIC SULFIDE ANIONS WITH CARBOHYDRATE-DERIVED EPOXIDES.

Angela K. Wilson, Belinda Shirkey, and Thomas E. Goodwin. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### SYNTHESIS OF NOVEL PRIMAQUINE ANALOGUES.

John C. Byrd, Warren A. Tucker, and Thomas E. Goodwin. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### SYNTHESIS AND SUBSEQUENT TRANSFORMATION OF CARBOHYDRATE-DERIVED ENZYMES.

Michele N. Rothaman and Thomas E. Goodwin. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### SYNTHESIS, REARRANGEMENT AND SUBSEQUENT TRANSFORMATIONS OF ISOXAZOLIDINE TOSYLATES.

Cheryl F. Lichti, Van Anh Pham, James E. Montgomery, and Thomas E. Goodwin. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### NOVEL APPLICATIONS OF THE STETTER REACTION.

Sam Clark, and Thomas E. Goodwin. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### THE X-RAY CRYSTALLOGRAPHY RESEARCH PROGRAM AT UALR.

A. F. Gremillion and S. E. Wallace. Dept. of Chemistry, UALR, Little Rock, AR 72204.

### SECONDARY STRUCTURE IN OVALBUMIN mRNA AND ITS PRECURSORS.

Paul M. Henry and Randall A. Kopper. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### METAL ION COFACTOR REQUIREMENTS OF ALKALINE PHOSPHATASE.

Jennifer R. Thompson and Randall A. Kopper. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### ISOLATION AND IDENTIFICATION OF PRECURSOR mRNAs.

Frances Suria and Randall A. Kopper. Dept. of Chemistry, Hendrix College, Conway, AR 72032.

### ENZYME KINETICS IN HYDROPHOBIC SOLVENTS.

Tonya L. Scruggs and Randall A. Kopper. Dept. of Chemistry, Hendrix College, Conway, Ar 72032.

## Arkansas Academy of Science

## THE SYNTHESIS AND CHARACTERIZATION OF ANTINEOPLASTIC AND SUPEROXIDE DISMUTASE-MIMETIC MANGANESE(II) COMPLEXES.

LaWanda d. Jones, Richard A. West, Kenneth Foster, and William M. Willingham, Department of Chemistry, UAPB, Pine Bluff, AR 71601.

## FLUORESCENCE-FREE RAMAN SPECTROSCOPY.

Skip Williams. Chemistry Dept. UALR, Little Rock, AR 72204.

## GEOLOGY - EARTH SCIENCES

Session Chairperson: Dr. Victor Vere (Geology, ATU)

## ATYPICAL RAINFALL EVENTS IN NORTHEAST ARKANSAS, 1987.

David M. Chittenden II. Chemistry Dept., ASU, State University, AR 72467.

## THE WILCOX GROUP OF UNION COUNTY, ARKANSAS: STRATIGRAPHY AND GEOHYDROLOGIC APPLICATIONS.

Lesli J. Wood. Dept. of Geology, UA, Fayetteville, AR 72701.

## GAMMA RAY MEASUREMENTS IN HOT SPRINGS NATIONAL PARK ARKANSAS.

Claude E. Epperson and Noel R. Rhodes. College of Pharmacy, UAMS, Little Rock, AR 72205.

## COMPARISON OF EARTHQUAKE MITIGATION IN SMALL COMMUNITIES VS. URBAN CENTERS.

David L. Vosburg, Dept. of Chemistry, ASU, State University, AR 72467.

## TREETHROW AS A MASS WASTING PROCESS IN THE BOSTON MOUNTAINS OF NORTHERN FRANKLIN COUNTY, ARKANSAS.

John D. Hall. Dept. of Geography, UA, Fayetteville, AR 72701.

## EVOLUTION OF THE MISSISSIPPI RIVER FLOOD PLAIN NEAR BLYTHEVILLE, ARKANSAS.

M. J. Guccione. Dept. of Geology, UA, Fayetteville, AR 72701.

## SCIENCE EDUCATION I

Session Chairperson: Dr. Robbin Anderson (Chemistry, UA)

## UNDERGRADUATE RESEARCH AS SCIENCE EDUCATION.

Frank Millett, Dept. of Chemistry, UA, Fayetteville, AR 72702; Thomas J. Lynch, Dept. of Biology, UALR, Little Rock, AR 72204; Thomas E. Goodwin, Dept. of Chemistry, Hendrix College, Conway, AR 72032.

## VERTEBRATE ZOOLOGY I

Session Chairperson: Dr. Glyn Turnipseed (Biology, ATU)

FOOD HABITS OF THE NINE-BANDED ARMADILLO (*Dasypus noveminctus*) IN SOUTHWESTERN ARKANSAS.

Robert S. Sikes (MSU), Gary A. Heidt (UALR), Joni L. Matthews, (UALR), and Douglas Elrod (UALR). Dept. of Biology, MSU, Memphis, TN 38152; and Dept. of Biology, UALR, Little Rock, AR 72204.

## USE OF FOREST OPENINGS BY WILD TURKEYS ON THE OZARK NATIONAL FOREST.

Thomas A. Nelson (ATU), Lowell Aberson (ATU), and Gary Hartman (USFS). Biological Sciences Dept., ATU, Russellville, AR 72801; and USFS, Ozark-St. Francis National Forests, Russellville, AR 72801.

## THE BATS OF HOT SPRINGS NATIONAL PARK.

David A. Saugey (USFS), Dianne G. Saugey (USFS), Gary A. Heidt, (UALR), and Darrell R. Heath (UALR). USFS, Ouachita National Forest, Hot Springs, AR 72902; Dept. of Biology, UALR, Little Rock, AR 72204.

## AUTUMN DIETS OF WHITE-TAILED DEER IN ARKANSAS.

Thomas A. Nelson (ATU), Luke Eggering (ATU), and Danny Adams (IPC). Biological Sciences Dept., ATU, Russellville, AR 72801; and International Paper Company, Arkadelphia, AR 71923.

EFFECT OF FIRE ON POPULATIONS OF THE PRAIRIE VOLE (*Microtus ochrogaster*) ON THE GRAND PRAIRIE IN CENTRAL ARKANSAS.

Mark Kirchner, Belinda Raybon, and Gary Heidt. Dept. of Biology, UALR, Little Rock, AR 72204.

## AN ANALYSIS OF BARN OWL PELLETS FROM A SINGLE LOCATION.

T. W. Steward (ATU), J. D. Wilhide (ASU), V. R. McDaniel (ASU), and Dan England (SAU). Dept. of Biological Sciences, ASU, State University, AR 72467; Biology Dept., SAU, Magnolia, AR 71753.

DISTRIBUTION AND ASPECTS OF REPRODUCTION AND NATURAL HISTORY OF THE BRAZILIAN FREE-TAIL BAT, *Tadarida brasiliensis cynocephala*, IN ARKANSAS.

David A. Saugey (USFS), Tim W. Steward (ASU), Daniel R. England (SAU), V. R. McDaniel (ASU), and Gary A. Heidt (UALR). U. S. Forest Service, Ouachita National Forest, Hot Springs, AR 71902; Dept. of Biological Sciences, ASU, State University, AR 72467; Biology Dept., SAU, Magnolia, AR 71753; and Dept. of Biology, UALR, Little Rock, AR 72204.

REPRODUCTIVE CHARACTERISTICS OF SOUTH FLORIDA *Sternotherus odoratus* AND *Kinosternon baurii* (TESTUDINES: KINOSTERNIDAE).

Walter E. Meshaka, Dept. of Biological Sciences, ASU, State University, AR 72467.

EGGTOOTH DEVELOPMENT AND MORPHOLOGY IN THE SIX-LINED RACERUNNER, *Cnemidophorus sexlineatus* (SAURIA: TEIIDAE) USING SCANNING ELECTRON MICROSCOPY.

Stanley E. Trauth, Dept. of Biological Sciences, ASU, State University, AR 72467.

A COMPARISON OF EIGHT AGING TECHNIQUES OF WHITE-TAILED DEER (*Odocoileus virginianus*) IN ARKANSAS.

Bruce Shackelford. Biology, UCA, Conway, AR 72032.

## SURFACE TOPOGRAPHY OF THE TONGUE IN THE NINE-BANDED ARMADILLO.

Douglas Elrod (UALR), William R. Bowen (UALR), Gary A. Heidt (UALR), Robert Sikes (MSU), and Tina Green (UALR). Dept. of Biology, UALR, Little Rock, AR 72204; Dept. of Biology, MSU, Memphis, TN 38152.

## UNUSUAL HUMMINGBIRDS IN ARKANSAS.

William Shepherd, Joseph Neal, Thomas Foti, and Douglas James. Arkansas Natural Heritage Commission, Little Rock, AR 72201; and Dept. of Zoology, UA, Fayetteville, AR 72701.

## AQUATIC - ENVIRONMENTAL II

Session Chairperson: Bruce Shackelford  
(Arkansas Department of Pollution Control and Ecology)

## REPRODUCTION AND HABITAT SELECTION IN TWO SPECIES OF DARTERS (OSTEICHTHYES: PERCIDAE) IN THE UPPER SALINE RIVER, SALINE COUNTY, ARKANSAS.

John Rickett and Diana Garland, Biology Department, UALR, Little Rock, AR 72204.

## Program

### THE EFFECTS OF BARITE MINING ON THE SOUTH FORK OF THE CADDO RIVER.

George L. Harp and Paul L. Raines, Department of Biological Sciences, ASU, State University, AR 72467.

### SPAWNING FREQUENCY AND FECUNDITY OF BLUE TILAPIA.

Thomas J. Aureli and Les Torrains. Arkansas Power and Light Co., 9005 Penrose Lane, Little Rock, AR 72205; and Dept. of Agriculture, UAPB, Pine Bluff, AR 71601.

### COMPARATIVE FEEDING HABITS OF CREOLE (*Etheostoma collettei*) AND REDFIN (*E. whipplei*) DARTERS IN THE UPPER SALINE RIVER, SALINE COUNTY, ARKANSAS.

Diana Garland and John Rickett, Biology Department, UALR, Little Rock, AR 72204.

### HOUSEHOLD CHEMICALS AND SEPTIC TANK.

Rao P. Gullapalli and Mark A. Gross, Graduate Institute of Technology, UALR, 2801 South University, Little Rock, AR 72204.

### BENTHIC INVERTEBRATES OF THE SALINE RIVER.

John C. A. Marr, Department of Biology, UCA, Conway, AR 72032.

### BIOMEDICAL - MICROBIOLOGY II

Session Chairperson: Dr. Scott Kirkconnell (Biology, ATU)

### A NEW LOOK AT GRANULOPHOIESIS IN MOUSE BONE MARROW.

Bonnie L. Wright and William C. Guest. Arkansas Children's Hospital, Little Rock, AR 72205; Dept. of Zoology, UA, Fayetteville, AR 72701.

### SURVIVAL AND GROWTH OF *Trichomonas vaginalis* IN HUMAN SEMEN.

Lynn Green, Jerome Sherman, Terry Hostetler, and James Daly. Dept. of Chemistry, MSU, Memphis, TN 38152; Dept. of Anatomy, UAMS, Little Rock, AR 72204; and Dept. of Microbiology and Immunology, UAMS, Little Rock, AR 72204.

### RADIOPROTECTION OF MICE BY MANGANESE(II)(3,5-DIISOPROPYLSALICYLATE).

William M. Willingham (UAPB), LaWanda D. Jones (UAPB), Kyle B. Bond (UAMS), Ahmid Salari (UAMS), and John R. J. Sorenson (UAMS). Dept. of Chemistry, UAPB, Pine Bluff, AR 71601; Dept. of Biopharmaceutical Sciences, College of Pharmacy, UAMS, Little Rock, AR 72205.

### ALTERATIONS IN TUMOR BINDING BY SPLEENOCYTES AND PERITONEAL EXUDATE CELLS FROM cis-DIAMINEDICHLOROPLATINUM(II) TREATED L1210 TUMOR-BEARING MICE.

Bruce M. Whitney Dwight Talburt, Dept. of Botany and Bacteriology, UA, Fayetteville, AR 72701.

### SCANNING ELECTRON MICROSCOPIC DEMONSTRATION OF THE BACTERIAL GLYCOLALYX.

W. Bowen (UALR), M. Kleve (UALR), B. Good (UALR), M. Bartelt (UAMS), R. Evans (UAMS), C. Nelson (UAMS), and B. Harrison (UAMS). UALR, Little Rock, AR 72204; UAMS, Little Rock, AR 72205.

### CORRELATION BETWEEN ISOLATION pH AND LEVELS OF RESISTANCE IN FLUORIDE-RESISTANT MUTANTS OF *Streptococcus mutans*.

David W. Clay, Susan M. Brussock, Karen A. Lau, and Timothy A. Kral. Dept. of Botany and Microbiology, UA, Fayetteville, AR 72701.

### ANTIVIRAL MANGANESE(II) COMPLEX WITH SUPEROXIDE DISMUTASE-MIMETIC ACTIVITY.

R. West, L. W. Jones, K. Foster, and W. M. Willingham. Dept. of Chemistry, UAPB, Pine Bluff, AR 71601.

### TESTING A MODEL FOR ISOCHROMATID DEPLETION PRODUCTION RESULTING FROM UV IRRADIATION OF G1 PHASE HAMSTER CELLS.

Dana Roberts, Laura Fratzke, Tim Gryder, and Gaston Griggs. Biology Dept., John Brown University, Siloam Springs, AR 72761.

### CHEMISTRY II

Session Chairperson: Dr. William Trigg (Chemistry, ATU)

### HIGH TEMPERATURE CHEMISTRY OF ETHANOL-FIRED MAGNETOHYDRODYNAMICS. I. COMBUSTION STUDIES.

J. Edward Bennett, Michael Martin, and Colin Hester. Dept. of Chemistry, ASU, State University, AR 72467.

### HIGH TEMPERATURE CHEMISTRY OF ETHANOL-FIRED MAGNETOHYDRODYNAMICS. II. EXPERIMENTAL SYSTEM FOR CHARACTERIZATION OF THERMAL IONIZATION.

J. Edward Bennett, Michael Martin, and Colin Hester. Dept. of Chemistry, ASU, State University, AR 72467.

### THE MASS SPECTRA OF OXAZOLIDINES FORMED BY CONDENSATION OF EPHEDRINE AND PSEUDOEPHEDRINE.

Don S. Moore, Michael D. Massey and Richard B. Walker. Dept. of Chemistry, UAPB, Pine Bluff, AR 71601.

### RUTHENIUM MERCAPTAN COMPLEXES.

D. Minick (ASU), M. Draganjac (ASU), F. Evans (NCTR), and A. W. Cordes (UA), Dept. of Chemistry, ASU, State University, AR 72467; National Center for Toxicological Research, Jefferson, AR 72079; and Dept. of Chemistry and Biochemistry, UA, Fayetteville, AR 72701.

### RING-OPENING AND RING-FORMING POLYMERIZATIONS: POLYAMINES AND POLYAMIDES FROM DIALLYLAMINE AND ETHYLOXAZOLINE.

Harper Wood and Tito Viswanathan. Chemistry Dept., UALR, Little Rock, AR 72204.

### THE OXIDATION OF ALCOHOLS WITH CHROMIUM TRI-OXIDE IN ACETONITRILE.

Paul M. Nave and D. B. Holt, Dept. of Chemistry, ASU, State University, AR 72467.

### MONITORING SURFACE WATER FOR ORGANOCHLORINE PESTICIDES AND PCBs FROM 121 SAMPLE SITES OF THE NORTHEAST ARKANSAS ENVIRONMENTAL QUALITY GRID.

William V. Wyatt and Paul D. Gwinup. Dept. of Chemistry, ASU, State University, AR 72467.

### LICHENS AS AIR QUALITY MONITORS.

William V. Wyatt, Paul D. Gwinup, and Johnny W. Cude. Dept. of Chemistry, ASU, State University, AR 72467.

### PHOTOCHEMISTRY OF CYCLOPENTADIENYL BRIDGED DINUCLEAR COMPLEXES.

E. F. Askew and B. Durham. Dept. of Chemistry and Biochemistry, UA, Fayetteville, AR 72701.

### INVERTEBRATE ZOOLOGY

Session Chairperson: Dr. Raymond D. Couser (Biology ATU)

### TWO NEW SPECIES OF DIPLURA FROM THE OUACHITA MOUNTAINS OF ARKANSAS.

Robert T. Allen, Department of Entomology, UA, Fayetteville, AR 72701.



Arkansas Academy of Science

CORTICAL SINGLET MICROTUBULES AND MOTILITY OF THE AFLAGELLATE SPERMATOOZON OF *Hydrolimax*.

W. Donald Newton, Department of Biological Sciences, ASU, State University, AR 72467.

ADDITIONS TO THE KNOWN ENDEMIC FLORA AND FAUNA OF ARKANSAS.

Robert T. Allen, Department of Entomology, UA, Fayetteville, AR 72701.

NOTES ON THE BIOLOGY OF *Thyanta calceata* (HEMIPTERA: PENTATOMIDAE) ON *Tephrosia virginiana* (LEGUMINOSAE), A NEW HOST PLANT.

Phoebe A. Harp and Harvey E. Barton, Department of Biological Sciences, ASU, State University, AR 72467.

PHYSICS - MATHEMATICS

Session Chairperson: Dr. Mostafa Hemmati, Physics, ATU

ON THE APPLICABILITY OF STOKES' LAW.

Stephen R. Addison, Physics Dept., UCA, Conway, AR 72032.

MEASUREMENTS OF THE DRAG ON SPHERES FALLING THROUGH THE AIR.

J. G. Ross, N. O. Gaiser, and Stephen R. Addison, Physics Dept., UCA, Conway, AR 72032.

ANALYSIS OF HIGH TEMPERATURE SERIES IN CRITICAL PHENOMENA USING FIRST ORDER ORDINARY DIFFERENTIAL APPROXIMANTS.

M. J. George, Dept. of Computer Science, ASU, State University, AR 72467.

X-RAY WOOD DENSITOMETER.

Hudson B. Eldridge, Bruce A. Yee, and Harold L. Pray, Physics Dept., UCA, Conway, AR 72032.

EQUATIONS OF VARIATION FOR ORDINARY DIFFERENTIAL EQUATIONS ON MANIFOLDS.

John B. Bennett, Dept. of Computer Science, Mathematics, and Physics, ASU, State University, AR 72467.

THERMAL DIFFUSIVITY OF YITTRIUM ALUMINUM GARNET AND YITTRIUM ALUMINATE BETWEEN 20 AND 200 DEGREES CELSIUS.

John Beasley and Pradip Bandyopadhyay, Department of Physics, Hendrix College, Conway, AR 72032.

X-RAY SPECTROMETER APERTURE MEASUREMENT.

M. Fields and Hudson B. Eldridge, Physics Dept., UCA, Conway, AR 72032.

AN EXPERIMENTAL INVESTIGATION OF EXCITED STATE ABSORPTION OF DIVALENT EUROPIUM IN ALKALI HALIDES.

Stephen Fenno and Pradip Bandyopadhyay, Department of Physics, Hendrix College, Conway, AR 72032.

X-RAY FLUORESCENCE ANALYSIS OF TREATED WOOD.

Bruce A. Yee, Hudson B. Eldridge, and Harold L. Pray, Physics Dept., UCA, Conway, AR 72032.

IONIZING WAVES MOVING INTO A PREIONIZED MEDIUM: SOLUTIONS OF THE ELECTRON FLUID DYNAMIC EQUATIONS FOR QUASI-NEUTRAL REGION (CLASS II WAVES).

Mostafa Hemmati, Physical Sciences Dept., ATU, Russellville, AR 72801.

SCIENCE EDUCATION II

Session Chairperson: Dr. Robbin Anderson (Chemistry, UA)

STATUS REPORT AND PROJECTIONS: NEW ARKANSAS STANDARDS SEEN IN EFFECT.

R. C. Anderson, Dept. of Chemistry and Biochemistry, UA, Fayetteville, AR 72701.

LAB SAFETY - BUSINESS AS USUAL?

Michael W. Rapp, Dept. of Chemistry, UCA, Conway, AR 72032.

AN ACADEMIC SCIENTIST'S ROLE IN ECONOMIC DEVELOPMENT: ONE PERSON'S VIEW.

Collis Geren, Dept. of Chemistry and Biochemistry, and the Arkansas Biotechnology Center, UA, Fayetteville, AR 72701.

NSF UNDERGRADUATE SUPPORT PROGRAMS.

Karl David Straub, John L. McLellan VA Hospital, Little Rock, AR 72204; and Richard Anderson, Physics Dept., UA, Fayetteville, AR 72701.

A SIMPLE EXERCISE TO ILLUSTRATE UNCERTAINTY OF MEASUREMENT AND SIGNIFICANT FIGURES.

Syed M. Aijaz, Chemistry Dept., UAPB, Pine Bluff, AR 71601.

COMPUTER AIDED INSTRUCTION AND STUDENT REMEDIATION: A PROPOSAL FOR ARKANSAS.

J. Edward Bennett and Tom Barber, Dept. of Chemistry, ASU, State University, AR 72467.

THE VETERANS ADMINISTRATION ENGINEERING TRAINING CENTER.

J. O. Wear, Eng. Trn. Ctr. (10A4A), VA Medical Center, North Little Rock Division, North Little Rock, AR 72114.

VERTEBRATE ZOOLOGY II

Session Chairperson: Dr. Tom Nelson (Fisheries and Wildlife Management, ATU)

IDENTIFYING FACTORS AFFECTING ANNUAL DEER HARVEST IN ARKANSAS.

R. A. Kluender (UAM), T. B. Wigley (UAM), and M. E. Cartwright (AG&FC), Dept. of Forest Resources, Arkansas Agric. Exp. Sta., UAM, Monticello, AR 71655; Arkansas Game and Fish Commission, Rt. 1, Box 56, Calico Rock, AR 72519.

COMMENTS ON ESTIMATING RATE OF INCREASE FROM AGE FREQUENCY DATA.

Renn Tumilson and V. R. McDaniel, Dept. of Zoology, OSU, Stillwater, OK 74078; and Dept. of Biological Sciences, ASU, State University, AR 72467.

FOREST HABITAT USE BY WHITE-TAILED DEER IN THE ARKANSAS COASTAL PLAIN.

T. B. Wigley and M. E. Garner, Dept. of Forest Resources, Arkansas Agric. Exp. Sta., UAM, Monticello, AR 71655.

FEEDING BEHAVIOR, FOOD, SEX RATIOS AND MEASUREMENTS OF THREE SPECIES OF WATER SNAKES COLLECTED IN NORTHEASTERN ARKANSAS.

Walter Meshaka, William Byrd, and Earl Hanebrink, Dept. of Biological Sciences, ASU, State University, AR 72467.

MANDIBULAR DENTITION IN SIX SPECIES OF SALAMANDERS, GENUS *Plethodon* (CAUDATA: PLETHODONTIDAE), FROM ARKANSAS USING SCANNING ELECTRON MICROSCOPY.

Richard A. Atwill and Stanley E. Trauth, Dept. of Biological Sciences, ASU, State University, AR 72467.

## Program

---

**TOE TIP SURFACE MORPHOLOGY IN SIX SALAMANDER SPECIES, GENUS *Ambystoma* (CAUDATA: AMBYSTOMATIDAE), FROM ARKANSAS USING SCANNING ELECTRON MICROSCOPY.**

Stanley E. Trauth and J. D. Wilhide. Dept. of Biological Sciences, ASU, State University, AR 72467.

**SEX RATIOS IN BOBCAT POPULATIONS.**

Renn Tumblison and V. R. McDaniel. Dept. of Zoology, OSU, Stillwater, OK 74078; and Dept. of Biological Sciences, ASU, State University, AR 72467.

**A PRELIMINARY INVESTIGATION OF HERPTILES INHABITING THE STATE PARKS OF ARKANSAS.**

Darrell R. Heath (UALR), Glyn Turnipseed (ATU), and David A. Saugey (USFS). Dept. of Biology, UALR, Little Rock, AR 72204; Biological Sciences Dept., ATU, Russellville, AR 72801; and USFS, Ouachita National Forest, Hot Springs, AR 71902.

**SURVEY OF BATS IN THE OUACHITA MOUNTAINS OF ARKANSAS.**

David A. Saugey (USFS), Gary A. Heidt (UALR), and Darrell R. Heath (UALR). U.S. Forest Service, Hot Springs, AR 71902; Dept. of Biology, UALR, Little Rock, AR 72204.

## IN MEMORIAM: LOWELL F. BAILEY, 1911-1988

LEO J. PAULISSEN  
Dept. Botany and Microbiology  
University of Arkansas  
Fayetteville, AR 72703



Dr. Lowell F. Bailey passed away on December 5, 1988. He was a long-time member of the Arkansas Academy of Science serving as its President in 1965. He was born June 15, 1911 at Holton, Kansas. He was graduated from Southern Illinois State Teachers College in 1932 and received his Ph.D. from the University of Michigan in 1939. He then held faculty positions at the Universities of Kentucky and Tennessee before coming to the University of Arkansas where he was a Professor of Botany and Bacteriology from 1951 until he retired in 1978. He was Chairman of the department from 1963 until 1975. He was a plant physiologist with research interests in plant chemistry and growth regulators. He directed research for graduate students and taught general botany and plant physiology. He was an inspiring and innovative teacher having installed the audio-tutorial laboratory for general botany courses at the University of Arkansas.

Lowell had the greatest concern for science education in the secondary schools as well. After Sputnik was launched in 1957, he was one of the first to apply for and obtain NSF grants for Summer Science Institutes for high school teachers. Science education in Arkansas was helped tremendously by these programs. He was also a major force in the establishment and organization of science fairs for high school students and gave encouragement to the Arkansas Science Talent Search programs for high school seniors. He had a major role in keeping the Academy alive and active during slack years in the late fifties and sixties.

He was greatly concerned about environmental problems at this time and participated in national and state forums in that regard. He also encouraged pursuit of ecological studies within the department and served on the committee that developed the curriculum for the environmental science degree program at the University of Arkansas, Fayetteville.

During the many years of his tenure he personally took care of the botany greenhouse as if it was his balliwick. He put in long hours and

did not shirk from performing even menial tasks to keep it in operations when money was short and trained help unavailable. When the department was moved from Old Main to the present Science Engineering Building, he was the person most involved in the planning and construction of the new greenhouse. The result of his effort is a very fine facility which serves both teaching and research activities today. It is a fitting monument to his care and commitment of time and effort which went into it.

Lowell's life was one of total dedication having its greatest impact while he was chairman of the department. He once stated that as chairman he considered it his responsibility to provide his faculty with the most time and best facilities possible for them to pursue their teaching duties and research. So he shouldered all of the usual departmental administrative duties he could to spare his colleagues. Even so he was always ready to listen to people and help them when he could. His colleagues who knew and served with him were aware of how hard he worked, but he was such a quiet and unassuming man that many did not know the extent of his dedication. His wise counsel and commitment sustained the department and university exceedingly well during the time of rapid growth for the university in the late sixties and early seventies.

In addition to his service as department chairman, he was chairman or member of numerous university committees. He was the University's council representative to the Oak Ridge Institute of Nuclear Sciences, a fellow of the American Association for the Advancement of Science, and a member of Sigma Xi and other professional organizations.

He is survived by his wife Alice of Fayetteville, a son Jack of Madison, Wisconsin, and a brother Ralph Bailey of Haddonfield, New Jersey.

# IN MEMORIAM: MAXINE CLARK, 1905-1988

GARY E. TUCKER

Biological Sciences Department  
Arkansas Tech University  
Russellville, AR 72801

Maxine Clark, longtime student of plants in Oklahoma and Arkansas, died at Fayetteville, Washington County, Arkansas, on 11 January 1988 at the age of 82. In her last years she was debilitated by Alzheimer's disease, the effects of that condition first appearing in 1978. The ravages of Alzheimer's advanced rapidly to the point that the loss of memory forced her to abandon almost all things botanical. Thus, the botanical community lost in premature fashion one of its most enthusiastic practitioners.

The daughter of Alexander Thomas and Iva Jane (Bradford) McMurtrey, she was born in Salem, Missouri, on 17 October 1905. She married Joseph Marsh Clark, at Steelville, Missouri, on 3 November 1929. She is survived by her husband and two sons, Joseph Henry Clark, of Dallas, Texas, and Thomas McMurtrey Clark, of Lafayette, Louisiana, as well as five grandchildren and six great-grandchildren. Burial was at Fairview Memorial Gardens, Fayetteville.

The Clark family lived for many years at Tulsa, Oklahoma, where Joe worked as a professional geologist. Maxine studied botany under Dr. Ralph Kelting at University of Tulsa, where she received her M.A. degree in Botany in 1959. Her thesis, entitled *A Study of the Flowering Plants of Tulsa County, Oklahoma Exclusive of the Grasses, Sedges, and Rushes*, was a fine floristic study and gave her a depth of experience and appreciation for all plant groups. The collections from that study are deposited at the herbarium of University of Tulsa. Maxine was a long-time friend there of Dr. Harriet G. Barclay and credited Dr. Barclay for stimulating her interest in field botany.

Following retirement Joe and Maxine moved to Fayetteville, Arkansas, and they quickly became actively involved in many aspects of Arkansas' natural history. His interests in geology and hers in botany took them to the outdoors, always working together as a team. They were charter members of the Ozark Society and served as editors of the award-winning *Ozark Society Bulletin* during 1967-1981. During their tenure with the *Bulletin* they helped make all aspects of natural history come alive to many people. Active canoeists and hikers, they made many treks into the Arkansas backcountry, always with a camera and a plant press. Maxine's feature column, called *Botanical Notes*, appeared in the *Ozark Society Bulletin* during the period of 1967-1981. Her column was of high quality and gave insight into the depth of her botanical understanding.

Her many years in Oklahoma gave her an appreciation of prairie and prairie plants. She was one of the first to recognize the few Lindley Prairie remnants in Benton County, Arkansas, and studied them for years. Her observations on two of the small prairie remnants were recorded in a 1977 paper (Clark, M. B. 1977. Remnant prairie plots of Benton County, Arkansas. *Proc. Ark. Acad. Sci.* 31:112-114.)

She was fascinated by ferns and one of her significant Arkansas finds was a Boston Mountain station for the Filmy Fern (Clark, M. B. 1962. *Trichomanes boschianum* in Madison County, Arkansas. *Amer. Fern J.* 52:85-86). Her collection served as a stimulus in the successful search for other stations in northwest Arkansas.

Maxine loved plants and she loved to make botanical specimens. She accumulated a sizeable collection of specimens and regularly worked with them. The specimens were stored at her home for many years until finally they were transferred to the herbarium at Arkansas Tech. Many of them were badly damaged by insect and water damage, but many more were salvaged. The collections are probably strongest in the prairie species, but she also collected many specimens from forest communities in the Ozarks and Ouachitas.

She was a member of the Arkansas Academy of Science, a charter member of the Arkansas Native Plant Society, and an honorary member of the Ft. Smith Geological Society. In addition, she was an active member of the Fayetteville Garden Club.

Maxine was a real botanist, familiar with botanical literature and the plants themselves. Those of us in the Arkansas botanical community who knew her well will miss her. Those who came along too late to know her will never know the curious mix of gentility and grit that she was. One of her closest friends has confided that she always saw many parallels between Maxine and the late artist Georgia O'Keefe. Maxine, too, had the eye of an artist and always appreciated the beauties of all of nature. A visit to her home was something like being in a combination of gallery and natural history museum. But, whereas the world of O'Keefe defied convention, Maxine always worked within the realm of that which was proper. In the words of a popular song — "she was a lady." And what a remarkable lady she was.



## IN MEMORIAM: DELZIE DEMAREE, 1889-1987

GARY E. TUCKER  
Biological Sciences Department  
Arkansas Tech University  
Russellville, AR 72801

Delzie Demaree, American botanist and noted plant collector, was born at Benham, Indiana, on 15 September 1889. A longtime Arkansas resident, he had lived at Avery, Texas, since 1981. He died in Texas on 2 July 1987 at the age of 97. This paper presents a glimpse of Demaree as seen from the eyes of a friend and field companion. Delzie Demaree was a friend who was bigger than life to me. Some of this assessment of his life and work may appear to be less than objective, but Demaree was a person who touched the emotions of anyone who knew him. Often I've heard him say "if I had to *work* to make a living it would be as a forester," but field botany was the discipline that kept him busy for many years. One had the feeling in talking with him that teaching was a vehicle allowing for field work, but wasn't of great significance in itself. Learning for him was to be found in the field.

An important era in the history of Arkansas botany passed with Delzie Demaree. His death, combined with that of Dwight Moore just slightly more than two years earlier, leaves us with no one else from that generation. Their lives were intertwined, both professionally and personally, for many years, and it is difficult to discuss one without the other. They were very different personalities and yet their capabilities complimented each other well.

Demaree's life was remarkable in several respects, but particularly in that it spanned so many changes in science and education. He was perhaps a man who came too late. Had he worked two hundred years earlier he would have been recorded as one of the world's great botanical explorers. Of that I am certain. No explorer of the classical age of botany ever worked harder, longer, or more diligently in the field than he. Many summer days in the field with him in Arkansas convinced me of that.

A full account of Demaree's biographical data has been given elsewhere (Sida 9:269-286, 1982.). Academy members should know, though, that he taught at several Arkansas institutions. His first job was at Hendrix college, 1922-26; he loved to say he was the only person in the state teaching evolution legally at that time and in a church school at that. Later he taught at the University of Arkansas, Fayetteville, 1926-30; Arkansas A. and M., Monticello, 1936-46; and Arkansas State, Jonesboro, 1946-53. Following retirement from Arkansas State University he moved to Hot Springs, where he lived until 1981. The last few years of his life were spent in east Texas, near the home of his daughter, Martha Davis.

During his lifetime Demaree devoted unceasing effort toward collecting, seemingly in search of at least one of everything he could find. That meant plants, but it also meant petrified wood, shark's teeth and other fossils, novaculite, and snakes. He started collecting plants in 1922, when at Hendrix, and by his death had amassed a total of over 75,000 collection numbers in his ledgers. He collected throughout the United States, but more extensively in Arkansas than anywhere else. He is said to have collected more Arkansas specimens than any other collector. Those numbers were important to him, and the field of botany owes him a debt of gratitude for them. Countless graduate students across the country were assisted by him in their dissertation and thesis work. Who can say how many thousands of specimens, both living and preserved, were mailed to students and others involved in research?

One of Demaree's peculiarities relating to plant specimen labels should be mentioned. He had an old multi-volume set of books that gave post offices and elevation readings for each. When he distributed specimens his label data listed the closest post office (within the county) to the collection site. Unfortunately, the label usually gives only the post office without specific mileage or directions to the site. That is a source of consternation to those trying to re-locate rare plant localities, but one must remember that Demaree came from an era when exact localities seldom were noted on labels. In early years of collecting he took elevation readings from his books but in later years always carried an altimeter with him and was forever checking altitudes to see if it agreed with the books. Labels included an elevation reading wherever possible.

I well remember meeting Demaree for the first time. When I was a botany graduate student at the University of North Carolina, Chapel

Hill, he visited there each spring. He knew Harry Ahles, Herbarium Curator, and regularly sent him plants for identification. It was a departmental joke that the arrival of Demaree's huge boxes would cause Ahles to laughingly say, "Here comes another bale of hay from Demaree." Demaree and I met at the herbarium in the spring of 1966 and spent much of that day together. Later that spring I accepted a position at Arkansas Tech, but thought little more about my new Arkansas acquaintance, Demaree. In September, with the task of settling in at Russellville far from complete, plant collecting was not a high priority on my list. But that first week on the job I received a postcard from Demaree, saying simply: "Meet me at Benton bus station, Saturday morning, 9:00. Bring lots of press material and I'll show you some plants." That was the first of many trips to the field with Demaree.

On his second trip to Russellville Demaree dug deep into his boxes and came up with what looked like something very special. Wrapped in numerous layers of newspaper and held together with layers of red plastic tape was a copy of his famous little publication: *Taxodium*, Vol. 1, No. 1. I was unaware of this 1943 checklist of Arkansas plant species, so he told me the story of its production and distribution. He had initiated the journal, named it after his favorite tree, had it privately printed, and tightly controlled its limited distribution. No one in Arkansas, he said, had personal copies but him and me! And it was to stay a secret! Later he showed me his cache of copies in a dresser drawer at his home. How many other people had copies I don't know.

The 1943 checklist apparently was many years in the making. In a letter to Carleton Ball, dated 15 July 1936, Demaree wrote: "I am working on a report of a checklist of Arkansas plants combining the Branner and Coville list, the Palmer and Buchholz supplement of 1926 to the above, plus my collections since 1926 and any others that I can find." (Letter in manuscript collections at Hunt Institute, Pittsburgh.)

The story of a supposed feud between Demaree and Dwight Moore has been told for years. Demaree himself said things to support the feeling they were less than close friends. Ultimately I came to know both well but basically heard only Demaree's side of the story. On a single occasion Moore made passing reference to Demaree's displeasure with him due to a misunderstanding over a teaching position. I knew what he referred to, because Demaree had told me the story many times. In his later years, Demaree had come to the conclusion that Moore was guilty of two things: (1) causing Demaree to lose his Fayetteville position and end up with only a temporary job in Oklahoma, and (2) taking Demaree's discoveries and publishing them under his own name. As evidence, Demaree said he published a woody checklist in 1933, only to have Dr. Moore publish another one in the 1941 Academy Proceedings. At that point Demaree would say the reason he published his *Taxodium* checklist privately and without state distribution was to keep Moore from seeing it and publishing it as his own.

One of my fond memories relates to Demaree's 85th birthday party. On 14 September 1974 a group of his friends held a birthday party at Hot Springs, a beautiful affair with many in attendance. After blowing out the candles on the cake he went to the microphone and presented each guest with a small remembrance. Under the head table Demaree had a box full of copies of his *Taxodium* checklist, each copy personally inscribed to each in attendance. Dwight Moore received his copy graciously and in the dim light of the setting had little chance of reading the title page to see how old it was. I heard him compliment Demaree on "finally getting this job done" and Demaree's reply was, "Hell, Doc, I did that back in 1943."

So — often I've wondered about Demaree's story that Moore had wrestled his Fayetteville teaching position away from him. Demaree had gone to Stanford to seek a doctorate and was to return to Fayetteville upon completion of the degree. On his return he found the job had been given to someone else, but Moore had arranged for an Oklahoma job. On his arrival at Oklahoma, however, he found the job was only temporary.

Recently, while assisting Mrs. Moore in sorting Dr. Moore's personal

## Gary E. Tucker

papers I had the chance to examine and copy correspondence from the period involved (all correspondence now part of the Dwight Moore collection, Special Collections, University of Arkansas Library). Moore's correspondence to and from Demaree was extensive and indicates that Demaree's whereabouts were unknown to Moore for many months following completion of his doctoral program. Moreover, the correspondence clearly indicated that Demaree did not personally notify Moore of completion of the doctoral requirements. Moore's contention that another person finally was appointed to Demaree's position when he couldn't be found is confirmed by the correspondence.

Demaree completed his doctoral work at Stanford in 1932, but in a letter dated 7 March 1934 Moore wrote: "You never let us know about the completion of your doctor's work, but I have heard of it in an indirect way and would like to congratulate you on it." Demaree replied on 11 March 1934: "Thanks for the degree congratulations. I never tell anyone unless I have to. So few are really interested in education."

The Oklahoma position was discussed in a letter from Demaree to Moore on 8 April 1936. Demaree wrote: "When I received your letter I wired them that I would accept the proposition on Friday morning. Saturday they wired me that due to changes the position would be for only three months. On the following Wednesday they wired me to decline or accept by six o'clock. I accepted. I arrived here on Sunday and Dr. Cross was making mention of two telegrams and finally asked him what he meant about two. Then he asked me if I had not received two. Well, I did not get the first one as it did not leave the Norman office. About this time the operator was fired and in Texas. Since the U. does not have a copy of the telegram the W. U. [presumably Western Union] is free. Dr. Cross is trying to fix it for me to stay but I think the chances are slim." There was absolutely no animosity expressed in the letter.

Correspondence between Demaree and Moore continued regularly over a period of many years and generally was lengthy, detailed, and warm and cordial in nature. In a letter of 19 November 1941, Demaree wrote to Moore: "My list of ligneous plants is no good because it was published before I had it ready . . . Even my name was spelled wrong . . . I never did distribute it."

Whatever the nature of any difference between the two men, it would appear that time may have altered if not exaggerated the original circumstances. That, to me, changes nothing, but only adds to the mystique of the man Demaree.

What a pity so few of today's graduate students get the chance to work with people of Demaree's genre. It is sad, but true, that too many botanists have been reared in a new age and with a new set of values. It hurts to see papers saying such things as, "In the history of Arkansas botany, the ultimate unworkable and untenable floristic list for the state is that by Demaree (1943), which includes every imaginable type of error in compilation and judgment." (*Phytologia* 64:82. 1987). Such a comment serves as proof that some of our botanists are sadly lacking

in courtesy and tact if not ethics. Moreover, such comments show little appreciation or depth of understanding of the nature of pioneering work. Any person who collects over 75,000 numbers of plant specimens in a lifetime (without owning or driving a car) has to be doing something right. Moreover, those 75,000 numbers were accumulated without an expense account or grant money. Anyone failing to recognize the value of the 1943 checklist reveals a lack of understanding of the basic workings of science.

The author of a 1973 paper (*Castanea* 38:79. 1973.) included a statement critical of Demaree's failure to distribute his 1943 checklist to libraries and the Arkansas scientific community. The article stated, ". . . this was an unfortunate choice . . . since it delayed the work on a Manual or Flora for the state of Arkansas . . ." That comment hurt Demaree deeply and he considered it an indictment of his character. And yet, probably there is a good deal of accuracy in the statement. It is interesting to contrast that author's assessment ("delayed work on a state Flora") against the more recent comments ("ultimate unworkable and untenable floristic list for the state").

Any pioneering work will have its deficiencies. Hindsight always is better than foresight, though, and it always is easier to have a strawman to knock down than to erect the strawman in the first place. Somewhere I recall hearing the phrase "walking on the shoulders of giants." It seems appropriate in this discussion.

In conclusion, Arkansas botany is richer for having experienced the life and work of Delzie Demaree. The tributes paid to him in the special section of *Sida* (*Sida* 9:269-289. 1982.) are ample indication that professionals across the country recognized his contributions. To his few detractors I would hope that age and maturity may mend the imperfections of intellect and ego. This state can be proud of its adopted son, Delzie Demaree. When and if a state flora is produced for Arkansas the totality of Demaree's work of a lifetime will stand for what it was — a monumental pioneering effort of permanent value.

## ACKNOWLEDGEMENTS

The following persons provided assistance critical to the preparation of this paper: Ellen Shipley, Special Collections, University of Arkansas Library, Fayetteville; Anita Karg, Archivist, Hunt Institute for Botanical Documentation, Carnegie-Mellon University, Pittsburgh, Pennsylvania; and Mrs. Dwight Moore, Rudy, Arkansas. Additionally, appreciation is extended to Arkansas Tech University for providing a travel grant enabling me to examine the manuscript collections at Hunt Institute for Botanical Documentation.

# ADDITIONS TO THE KNOWN ENDEMIC FLORA AND FAUNA OF ARKANSAS

ROBERT T. ALLEN  
University of Arkansas  
Department of Entomology  
Fayetteville, AR 72701

## ABSTRACT

Robison and Smith's (1982) list of endemic species of Arkansas rendered a valuable service to the community of biologists interested in the endemic biota of the state. These authors listed seven species of plants and forty species of animals endemic to Arkansas. This paper stimulated my interest in the endemic biota of the Ozark/Ouachita Mountain region of Missouri, Arkansas, and Oklahoma. During the course of compiling a list of Ozark/Ouachita endemic species several references were found that listed Arkansas endemic taxa inadvertently overlooked by Robison and Smith. Most notable among these references was Chamberlin and Hoffman (1958), *Checklist of the Millipeds of North America*. This paper chronicles the work of N. B. Causey and R. V. Chamberlin who describe thirty-two species of endemic Arkansas Millipeds. These records as well as a few additional records for other animal and plant taxa are presented in this paper.

## INTRODUCTION

Various workers have discussed the taxonomic and geographic relationships between the biota of Arkansas and possible relatives in other areas of eastern North America (Tucker, 1976; Williams, 1954; Heighton, 1962; Ross, 1956; Ross and Ricker, 1971; Allen and Carlton, 1988). These papers and others leave no doubt that the Arkansas biota does have distinct affinities with the biota of eastern North America, especially at the species level. But if one considers higher and more inclusive taxa such as genera, tribes, and/or families, taxonomic and geographic relationships with western North America also become evident. For example, the salamander genus *Plethodon* has a distinct endemic western element which is closely related to the eastern *Plethodon* species (Heighton, 1972). The ground beetle tribe Aniliini in which the genus *Anilinus* occurs in eastern North America has sister genera in west Texas and California. The lace bug genus *Acalypta* has both eastern and western endemic sister groups including an Arkansas species known only from Logan County. This paper also notes one example in the millipedes, *Cibularia profuga*, whose nearest relative occurs in the southwest.

If we consider the origin and evolution of the biota of North America as a whole, the place of the Arkansas biota, especially the endemic biota of the Interior Highlands of Arkansas and Missouri, becomes a critical and important element. We might pose the question, "In America is there a western biota, a mid-continent (Interior Highlands) biota and an eastern biota whose various elements will show a repetitive sister group relationship or relationships?" When we consider the possibility of searching for an answer to the question just posed a knowledge of the endemic biota of Arkansas becomes crucial. And the answer to the question has far greater implications than just listing species that occur within the boundaries of the state. As we study the endemic biota of Arkansas we would be well advised to consider seriously not only the eastern affinities the various taxa might exhibit, but also the possibility that western North America has played some role in the evolution of this rich biota.

## ANNOTATED LIST

### I. VASCULAR PLANTS.

Order Papaverales

Family Cruciferae — Mustard Family

1. *Cardamine angustata* O. E. Schulz var. *ouachitana* E. B. Smith, 1982:379. Type: University of Arkansas Herbarium. Type locality: Arkansas, Polk Co.: 12.1 miles south of the junction of highways 375 and 8 near Mena; 19 March 1982. Collector, E. B. Smith. Distribution: AR: Howard, Montgomery, and Polk counties. Remarks: Smith presents a discussion of this variety comparing it with the typical *C. angustata angustata*. He notes that the populations of nominate species and the new variety are disjunct by some "400 air Km" from popula-

tions in northeastern Mississippi and central Tennessee. There are five eastern species in the subgenus *Dentaria* to which Smith assigns this variety.

Order Rubiales

Family Rubiaceae — Madder Family

2. *Galium arkansanum* Gray var. *pubiflorum* E. B. Smith, 1979:281.

Type: University of Arkansas Herbarium. Type locality: Arkansas, Montgomery Co., Albert Pike Recreation Area, 1.3 miles south of Highway 8, 31 May, 1978. Collector, E. B. Smith, Distribution: AR: Montgomery county. Remarks: See Smith (1979) for a discussion of the variety *arkansanum* and the "Mixed phase" and the distribution of these forms.

### II. ANIMALS

Phylum Arthropoda

Class Myriapoda — Millipedes

Order Polydesmida

Family Desmonidae

1. *Desmonus pudicus* (Bollman), 188:3. Type: United States National Museum, No. 154. Type locality: Arkansas, Pulaski county, Little Rock. Distribution: AR: Clark and Pulaski counties. Remarks: This species was originally described and placed in the genus *Sphaeriodesus*. There is one additional species in the genus, *D. earlei*, from Alabama, Tennessee, and Kentucky.

Family Eurydesmidae

2. *Cibularia profuga* Causey, 1955:29. Type: American Museum of Natural History. Type locality: Arkansas, Montgomery Co., Mt. Ida, 5 miles south of the Ouachita River bridge; 14 April, 1954. Distribution: Known only from the type locality. Remarks: The type specimens, three males, three females, one larva, were collected under rocks. The area from which this species was collected is a mixture of pine and hardwoods. There is one additional species in the genus, *C. tuobita* (Chamberlin), from Otero and Lincoln counties in central New Mexico.

3. *Mimuloria davidcauseyi* (Causey), 1950:194. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Newton Co., Jasper, about 3 miles northwest. Distribution: Known only from the type locality. Remarks: This species was originally placed in the genus *Nannaria*. Causey states that the "two recently molted males and two larvae were collected by Dr. David Causey on 25 August 1950 from an oak-hickory woodland on an east hillside." There are five species in this genus, three from the Ozark Mountains and one each from Ohio and Indiana.



## Robert T. Allen

4. *Mimuloria depalmaei* (Causey), 1950:1. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Carroll County, 2 mi. S. of Lake Leatherwood. Lake Leatherwood is east of Eureka Springs on Hwy. 62. Distribution: Known only from the type locality. Remarks: This species was originally placed in the genus *Castanaria*. Also see *M. davidcauseyi*.

5. *Pleurolooma miribilia* (Causey), 1951:85. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Clay County, 12 mi. NE of Piggott, on highway 62. Distribution: Known only from the type locality. Remarks: Causey notes that the habitat of this species was "rather dry litter on a north oak-hickory covered hillside." This species was originally placed in the genus *Zinaria*. Chamberlin and Hoffman note that there are twelve species in the genus and "most of which will probably be shown to be only geographic races of *P. flavipes*." All of the species are eastern in distribution.

## Family Euryuridae

The family is divided into two subfamilies. The Aphelidesminae is predominately Neotropical with one species known from Kerr county, Texas. The Euryurinae are known only from eastern North America.

6. *Auturus florus* Causey, 1950:37. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Newton County, Compton, Hemmed-in Hollow. Distribution: Known only from the type locality. Remarks: The type locality is now within the Buffalo National River Park. A special collecting permit is required. There are ten species in this eastern genus. One species *A. mimetes* Chamberlin is endemic to the Christian and Jefferson counties in Missouri.

## Family Eurymerodesmidae

7. *Eurymerodesmus angularis* Causey, 1951:69. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Prairie County. Distribution: Known only from the type locality. Remarks: There are twenty-one species in the genus. All of the species are found in eastern North America.

8. *Eurymerodesmus bentonus* Causey, 1950:268. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Benton County, Monte Ne. Distribution: Known only from the type locality. Remarks: Much of the area around the Monte Ne community has been flooded by the impoundment of Beaver Lake Reservoir.

9. *Eurymerodesmus compressus* Causey, 1952:169. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Union County, Junction City. Distribution: Known only from the type locality. Remarks: See *E. angularis*.

10. *Eurymerodesmus dubius* Chamberlin, 1943:38. Type: Field Museum of Natural History, Chicago. Type locality: Arkansas, Pike County, Delight; 16 April 1941. Collected by K. P. Schmidt. Distribution: AR: Clark, Dallas, Hot Spring, Pike, Saline, Sevier counties. Remarks. See *E. angularis*.

11. *Eurymerodesmus goodi* Causey, 1952:3. Type: R. V. Chamberlin Collection. Type locality: Arkansas, Polk County, 16 miles southeast of Mena. Distribution: Known only from the type locality. Remarks: See *E. angularis*.

12. *Eurymerodesmus newtonius* Chamberlin, 1942:6. Type: R. V. Chamberlin Collection. Type locality: Arkansas, Newton County, 12 miles south of Jasper. Distribution: Known only from the type locality. Remarks: See *E. angularis*.

13. *Eurymerodesmus oliphantus* Chamberlin, 1942:6. Type: R. V. Chamberlin collection. Type locality: Arkansas, Jackson County,

Oliphant, 15 miles south. Distribution: Known only from the type locality. Remarks: See *E. angularis*.

14. *Eurymerodesmus schmidtii* Chamberlin, 1943:38. Type: Field Museum of Natural History, Chicago. Type locality: Arkansas, Polk County, Rich Mountain, elevation 2400 feet; 22 March 1958. Collected by K. P. Schmidt. Distribution: AR: Carroll, Polk, Washington. Remarks: See *E. angularis*.

15. *Eurymerodesmus wellesleybentonius* Causey, 1952:171. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Phillips County, Helena. Distribution: Known only from the type locality. Remarks: See *E. angularis*.

16. *Paresmus columbus* Causey, 1950:272. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Columbia County, Magnolia. Distribution: Known only from the type locality. Remarks: There are four additional species in the genus: two from type localities in Arkansas and one each from Louisiana and Texas.

17. *Paresmus polkensis* Causey, 1952:5. Type: American Museum of Natural History. Type locality: Arkansas, Polk County, 11 miles north of Mena. Distribution: Known only from the type locality. Remarks: See *P. columbus*.

18. *Paresmus pulaski* Causey, 1950:271. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Pulaski County, Sweet Home. Distribution: AR: Grant and Pulaski counties. Remarks: See *P. columbus*.

Order Chordeumida  
Family Cleidogonidae

19. *Cleidogona arkansana* Causey, 1954:66. Type: American Museum of Natural History. Type locality: Arkansas, Dallas County, 4 miles east of Princeton at a picnic site on Arkansas State Route No. 8; 7 January 1954. Distribution: Known only from the type locality. Remarks: There are about 25 species in the genus of which 17 occur in North America.

20. *Cleidogona aspera* Causey, 1951:78. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Lawrence County, Imboden, 6 miles east. Distribution: AR: Dallas, Lawrence, and Randolph counties. Remarks. A doubtful Interior Highland species. Also see *C. arkansana*.

21. *Ofcoogogona alia* Causey, 1951:121. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Union County, Junction City. Distribution: Known only from the type locality. Remarks: There are two species in the genus, both described from Arkansas by Causey (1951). *O. alia* was collected from a pine-hardwood forest on 25 December 1950 in Union County near Junction City.

22. *Ofcoogogona stewartae* Causey, 1951:121. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Sebastian County, Greenwood; 26 November 1950. Distribution: Known only from the type locality. Remarks: See *O. alia*.

23. *Ozarkogona glebosa* Causey, 1951:82. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Washington County, Fayetteville. Distribution: AR: Benton, Johnston, and Washington counties. Remarks: There are two species in the genus, both described from Arkansas by Causey.

24. *Ozarkogona ladymani* Causey, 1952:114. Type: United States National Museum. Type locality: Arkansas, Clay County, Rector. Distribution: Known only from the type locality. Remarks: See *O. glebosa*.

25. *Tiganogona moesta* Causey, 1951:82. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Carroll County, Blue Spring.

## Additions to the Known Endemic Flora and Fauna of Arkansas

Distribution: AR: Carroll and Washington Counties. Remarks: The type locality, Blue Spring, is now a commercial tourist venture. It is located west of Eureka Springs on Highway 62.

## Family Conotyliidae

26. *Trigenotyia parca* Causey, 1951:118. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Carroll County, Blue Spring. Distribution: AR: Carroll and Washington counties. Remarks: This is a monotypic genus described by Causey (1951) and known only from northwest Arkansas. Blue Spring is now a commercial tourist attraction west of Eureka Springs on Highway 62.

27. *Craspedosoma flavidum* Bollman, 1888:2. Type: United States National Museum. Type locality: Arkansas, Clark County, Okolona. Distribution: Known only from the type locality. Remarks: The types have apparently been lost. It should be noted that other species described in this genus by Bollman have either been synonymized or transferred to another genus, *Branneria*.

## Order Julida

## Family Paraiulidae

28. *Aliulus carrollus* Causey, 1950:45. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Carroll County, Blue Spring. Distribution: AR: Carroll and Washington counties. Remarks: There are two other species in the genus: *A. caddoensis* from Oklahoma; *A. rugosus* from Pennsylvania, Ohio, Indiana, and Illinois. The type locality, Blue Spring, is now a commercial venture on Highway 62, west of Eureka Springs.

29. *Okliulus beveli* Causey, 1953:152. Type: American Museum of Natural History. Type locality: Arkansas, Union County, Junction City. Distribution: Known only from the type locality. Remarks: This genus was described by Causey for two species, *O. beveli* from Arkansas, and *O. carpenteri* Causey from Latimer County in Oklahoma.

30. *Oriulus grayi* Causey, 1950:50. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Prairie County, DeValls Bluff. Distribution: Known only from the type locality. Remarks: This genus contains eight additional species ranging throughout eastern North America with one species reaching as far west as Colorado and Utah.

## Order Cambalida

## Family Cambalidae

31. *Cambala arkansana* Chamberlin, 1942:3. Type: R. V. Chamberlin Collection. Type locality: Arkansas, Randolph County, Pocahontas. Distribution: Known only from the type locality. Remarks: There are 10 additional species in the genus, all occurring in eastern North America.

## Order Polyzoiiida

## Family Polyzoiiidae

32. *Polyzonium bikermani* Causey, 1951:138. Type: Philadelphia Academy of Sciences. Type locality: Arkansas, Washington County, Devil's Den State Park. Distribution: Known from the type locality only. Remarks: There are two additional, eastern North American species in the genus. The staphylinid beetle *Derops divialis* Sanderson was also described from Devil's Den State Park and is an Ozark endemic.

## Class Symphyla — Symphylids

## Order Symphyla

## Family Neobisiidae

33. *Microcreagris ozarkensis* Hoff, 1945:34. Type: Illinois Natural History Survey. Type locality: Arkansas, Washington County, Devil's

Den State Park; 3 October 1941. Distribution: AR: Washington county. Remarks: The allotype female was collected in Farmington which is also in Washington County. Both specimens were collected in "woody, leafy debris" (Hoff, 1958).

## Family Chernetidae

34. *Pseudozoaona occidentalis* Hoff & Bosterli, 1956:170. Type: Illinois Natural History Survey. Type locality: Arkansas, Washington County, Fincher Cave. Distribution: AR: Washington county. Remarks: The type series of this species was composed of a number of specimens from three caves in Washington County: Fincher Cave, Carrol Cave, and Stevenson's Cave. There is one additional species in the genus, *P. mirabilis* (Banks) known from Indian Cave Barren County, Kentucky.

## Class Insecta

## Order Diplura — Diplurans

## Family Japygidae

35. *Catajapyx ewingi* Fox, 1941:28. Type: United States National Museum, Catalogue No. 54834. Type locality: Arkansas, Howard County, Peach Orchard; 7 April 1937. Distribution: Known only from the type locality.

## Class Insecta

## Order Coleoptera — Beetles

## Family Scaphidiidae

36. *Scaphisoma arkansana* Casey. Type: United States National Museum. Type locality: Arkansas. Distribution: Known only from the type locality. Remarks: The original description only listed the state of Arkansas as the area from which this species came. Other records have not been reported in the literature.

## ACKNOWLEDGEMENTS

I thank the following colleagues for reviewing this manuscript: C. E. Carlton, J. R. Phillips, and W. C. Yearian.

## LITERATURE CITED

- ALLEN, R. T. and C. E. CARLTON. 1988. Two new *Scaphinotus* from Arkansas with note on other Arkansas species (Coleoptera: Carabidae: Cychnini). J. New York Ent. Soc. In Press.
- BOLLMAN, C. H. 1888. A preliminary list of the Myriapoda of Arkansas, with descriptions of new species. Entomol. Amer. 4:1-8.
- CASEY, T. L. 1893. Notes on the Coleoptera. Ann. New York Acad. Sci. 7:510-533.
- CAUSEY, N. B. 1950a. Two new polydesmoid diplopods. Entomol. News 61:37-39.
- CAUSEY, N. B. 1950b. Five new Arkansas millipeds of the genera *Eurymerodesmus* and *Paresmus* (Xystodesmidae). Ohio J. Sci. 50:267-272.
- CAUSEY, N. B. 1950c. A new genus and species of diploid (Family Xystodesmidae). Chicago Acad. Sci. Nat. Hist. Misc. No. 73:1-3.
- CAUSEY, N. B. 1950d. New genera and species of millipeds — Paraiulidae (Juloidea). Proc. Ark. Acad. Sci. 3:45-58.

## Robert T. Allen

- CAUSEY, N. B. 1950e. On four new polydesmoid millipeds. *Entomol. News* 61:193-198.
- CAUSEY, N. B. 1951a. On Eurymerodesmidae, a new family of Diplopoda (Strongylosomidea), and a new Arkansas species of *Eurymerodesmus*. *Proc. Ark. Acad. Sci.* 4:69-71.
- CAUSEY, N. B. 1951b. The milliped assembly *Zinaria butlerii* isogen (*Xystodesmidae*). *Proc. Ark. Acad. Sci.* 4:73-88.
- CAUSEY, N. B. 1951c. New genera and species of chordeumoid millipeds in the United States, and notes on some established species. *Proc. Biol. Soc. Wash.* 64:117-124.
- CAUSEY, N. B. 1951d. On two new colobognath millipeds and records of some established from east of the Rocky Mountains. *Proc. Biol. Soc. Wash.* 64:137-140.
- CAUSEY, N. B. 1952a. Some records and descriptions of polydesmoid millipeds from the United States. *Chicago Acad. Sci. Nat. Hist. Misc. No.* 106:1-11.
- CAUSEY, N. B. 1952b. On three new eurymerodesmoid millipeds and notes on *Paresmus impurus* (Wood). *Entomol. News* 63:169-176.
- CAUSEY, N. B. 1952c. Four chordeumoid millipeds from the United States. *Proc. Biol. Soc. Wash.* 65:111-118.
- CAUSEY, N. B. 1953. On five new North American millipeds and records of some established species. *Amer. Midl. Nat.* 50:152-158.
- CAUSEY, N. B. 1954. Three new species and new records of southern millipeds. *Tulane Stud. Zool.* 2:63-68.
- CAUSEY, N. B. 1955. New records and descriptions of polydesmoid millipeds (Order Polydesmida) from the eastern United States. *Proc. Biol. Soc. Wash.* 68:21-30.
- CHAMBERLIN, R. V. 1942. New southern millipeds. *Bull. Univ. Utah, Biol. Ser.* 6:1-19.
- CHAMBERLIN, R. V. 1943. On nine North American polydesmoid millipeds. *Proc. Biol. Soc. Wash.* 56:35-40.
- CHAMBERLIN, R. V. and R. L. HOFFMAN. 1958. Checklist of the millipeds of North America. *Bull. USNM No.* 212, 236 pp.
- CHAMBERLIN, R. V. 1958. List of the pseudoscorpions of North America North of Mexico. *Amer. Mus. Nat. Hist. Novitates No.* 1875, 50 pp.
- FOX, I. 1941. New or little known American Japygidae (Thysanura). *Canad. Entomol.* 73:28-31.
- HIGHTON, R. 1962. Revision of North American Salamanders of the genus *Plethodon*. *Bull. Fla. St. Mus.* 6:235-367.
- HOFF, C. C. 1945. New species and records of pseudoscorpions from Arkansas. *Trans. Amer. Micros. Soc.* 64:34-57.
- HOFF, C. C. and J. E. BOLSTERLI. 1956. Pseudoscorpions of the Mississippi River drainage basin area. *Trans. Amer. Micros. Soc.* 75:155-179.
- REDDELL, J. R. 1983. A checklist of the Japygidae (Insecta:Diplura) of North America, Central America, and the West Indies. *Texas Mem. Mus., Pearce-Sellards Ser.*, No.37, 41 pp.
- ROBISON, H. W. and K. L. SMITH. 1982. The endemic flora and fauna of Arkansas. *Proc. Ark. Acad. Sci.* 36:52-57.
- ROSS, H. H. 1956. Evolution and classification of the mountain caddisflies. *Univ. of Ill. Press, Urbana.* 213 pp.
- ROSS, H. H. and W. E. RICKER. 1971. The classification, evolution and dispersal of the winter stonefly genus *Allocapnia*. *Ill. Biol. Monog.*, No. 45, 167 pp.
- TUCKER, G. E. 1976. A guide to the woody flora of Arkansas. Ph.D. dissertation, University of Ark., Fayetteville, AR. 356 pp.
- SMITH, E. B. 1979. A new variety of *Galium arkansanum* (Rubiaceae) endemic to the Ouachita Mountains of Arkansas. *Brittonia* 31:279-283.
- SMITH, E. B. 1982. A new variety of *Cardamine angustata* (Cruciferae) from the Ouachita Mountains of Arkansas. *Brittonia* 34:376-380.
- WILLIAMS, A. B. 1954. Speciation and distribution of the crayfishes of the Ozark Plateaus and Ouachita Provinces. *Univ. Kan. Sci. Bull.* 36:803-918.

# A NEW SPECIES OF *OCCASJAPYX* FROM THE INTERIOR HIGHLANDS (INSECTA: DIPLURA: JAPYGIDAE)

ROBERT T. ALLEN  
Entomology Department  
University of Arkansas  
Fayetteville, AR 72701

## ABSTRACT

A new species of Japygidae, *Occasjapyx carltoni* is described from the Ozark Mountains of the Interior Highlands. This is the first record of the genus outside of California in North America. The genus is also known from China and Japan.

## INTRODUCTION

The eyeless, soil dwelling insects of the family Japygidae in the order Diplura have received scant attention from North American entomologists. Only the California fauna has been studied in detail in a series of papers by Smith from 1959 through 1964. In one of these papers, Smith (1959) discussed the genus *Occasjapyx*. Smith characterized the genus as follows: (1) antennae 24 segmented, (2) first lamina of lacina falciform, (3) tergite VII with posterolateral angles directed posteriorly, (4) forceps asymmetrical with two prominent teeth, (5) body without plumose body setae. These characters also serve to place the genus in the subfamily Japyginae.

*Occasjapyx* presently includes four California species, *O. americanus* (MacGillivray), *O. californicus* Silvestri, *O. koboldi* (Silvestri), and *O. sierrensis* Smith, five species from Japan, and four species from China (Reddell, 1983). This paper describes *Occasjapyx carltoni* new species from the Ozark Mountains of the Interior Highlands. The terminology used here follows that of Smith (1959) used for other species in the genus.

### *Occasjapyx carltoni* new species

Holotype. Female. Arkansas, Newton County, Indian Creek near Kyle's Landing, 7 March, 1988, under rocks along creek bank, C. E. Carlton collector. Slide mount in CMC medium. University of Arkansas Insect Collection. Paratype. Male. Same data as Holotype.

Etymology. This species is named in honor of my colleague and friend and the collector of the specimens, Mr. C. E. Carlton.

## DESCRIPTION

**HEAD.** Dorsal surface with 24 M setae and numerous secondary setae, Fig. 1. Antennae: 24 segments; segment IV with two elongate hair-like sensillae Fig. 17; segment VI, length 0.27 mm., width 0.23 mm., longest data seta on segment VI 0.35 mm.; terminal segment, length 0.12 mm., width 0.06 mm., without placoid sensillae. Maxillae: first lamina of lacina falciform, lamina 2-5 pectinate, Fig. 13; lateral margin of galea with 4 primary setae, 3 additional primary setae, in a row, near the midline, about 10 secondary setae present; thumb of galea bilobed, inner lobe rounded, with 6 sensory cones apically, 2 primary setae towards the base near the lateral margin, outer lobe broadly rounded, asetose, Fig. 14; labial palpi evenly narrowed from base to apex, length 0.20 mm., width at base 0.08 mm., Fig. 15; mandible with 4 teeth, Fig. 16.

**THORAX.** Pronotum: 5 + 5 M, Fig. 2. Meso and metanotum, prescutum: 1 + 1 M, Fig. 3. Scutum: 5 + 5 M, Fig. 4.

**ABDOMINAL TERGITES.** Figures 5-12. Segments I-VII with a median anterior pair of distinct setae, not decreasing in size posteriorly and a small pair of posterior median setae. I: 1 + 1 M; II: 3 + 3 M; III: 4 + 4 M; IV-VII: 5 + 5 M; VIII: 2 + 2 M; IX: 0; X: 2 + 2 M.

**ABDOMINAL STERNITES.** I: prescutum, 3 + 3 M; scutum, 15 + 15 M; II-VI: 16 + 1 + 16 M, 1 decreases in size posteriorly; VII: 18 + 18 M; VIII: 6 + 6 M; IX: 0; X: 13 + 13 M.

**LEGS.** Femur: with several primary and secondary setae. Tibia: setae more numerous in apical  $\frac{1}{4}$ . Tarsi: evenly narrowed base to apex; claws unequal, longest claw 2 Xs length short claw, empodium sclerotized,  $\frac{1}{4}$  length or less of the longest claw; tarsal length, base to apex of longest claw 0.50 mm., width at base 0.11 mm.

**SUBCOXAL ORGANS.** Lateral: with 2-3 rows of glandular setae; sensory setae not evident; median subcoxal organ with about 13 short setae on each side of the organ; median area without disculi or setae.

**FEMALE GENITALIA.** Orifice elongate, transverse opening with narrow anterior and posterior flaps; anterior margin with about 20 setae, posterior margin with about 30 setae; papillae and/or sensory setae absent.

**MALE GENITALIA.** Gonopore: a narrow longitudinal slit; an anterior or posterior flap not evident; anterior margin with about 34 long setae in 2 (possibly 3) rows; posterior margin with about 37-40 small setae arranged in 2-3 rows, posterior to which are 14-16 longer setae arranged in 2 rows. Papillae: one each side, broadly rounded apically, with 40 + longer setae irregularly arranged, Fig. 18.

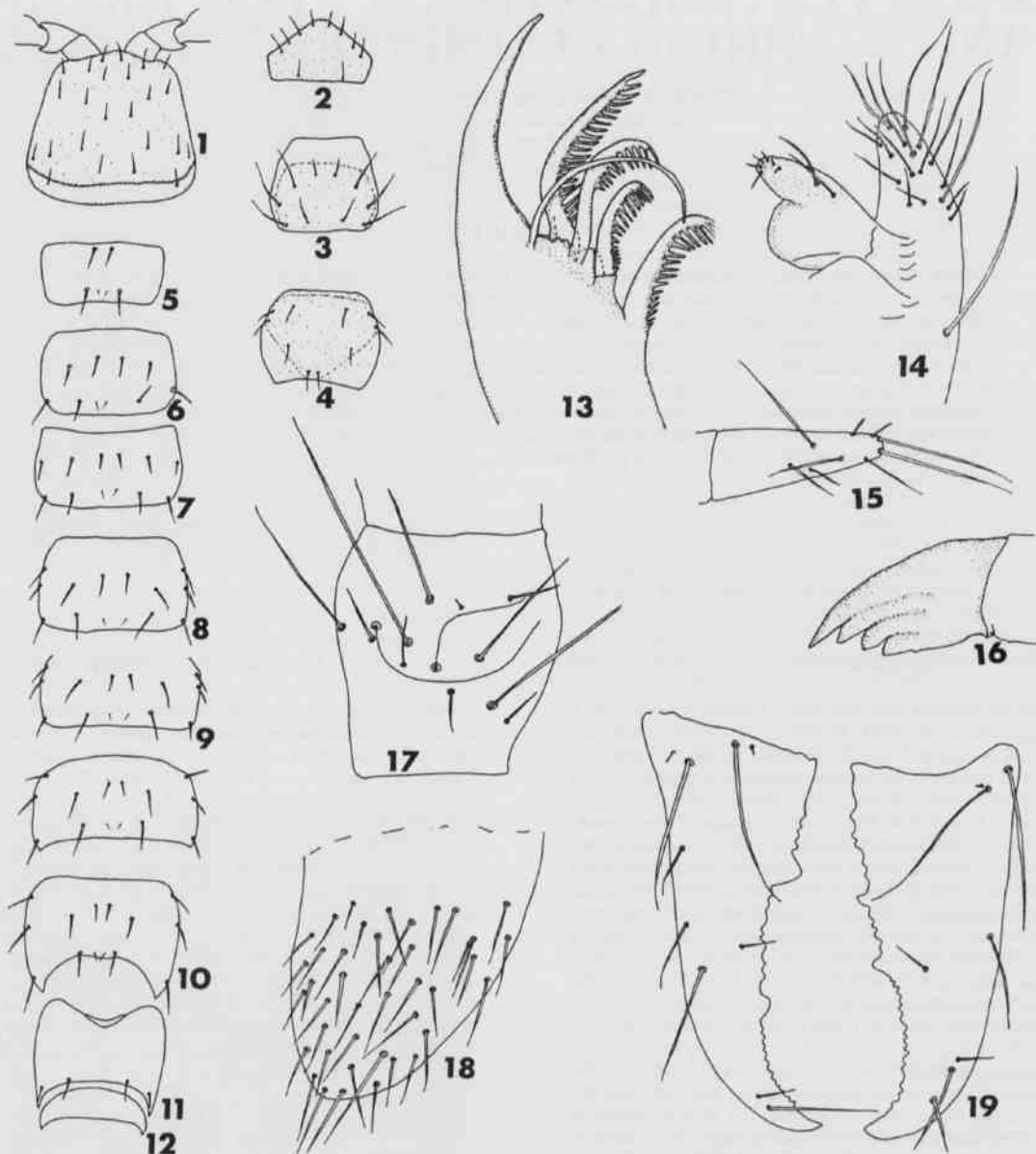
**FORCEPS.** Left cercus: 1 premedian and one post median tooth; preidental tubercles 4, interdental tubercles 7, postidental tubercles 10. Right cercus: one premedian and one post median tooth; preidental tubercles 5, interdental tubercles 3-4, postidental tubercles 14, Fig. 19.

## DISCUSSION

The discovery of the genus *Occasjapyx* in the Interior Highlands presents an interesting distributional disjunction between the central and western United States. The majority of the Interior Highland endemic taxa have their closest affinities with taxa east of the Mississippi River. Smith (1960) also described a japygid, *Eojapyx pedis* Smith, from Missouri whose closest relatives in the subfamily Provalljapyginae are found only along the west coast of North America. However, since collections of Japygidae are rare and thus we know so little about the distribution of these insects, any definitive statement about this disjunct pattern would be premature.



Robert T. Allen



Figures 1-19: *Occasjapyx carltoni*. Figures 1-12: Dorsal surface showing position and number of major (M) setae on segments; 1 head, 2 pronotum, 3 mesonotum, 4 metanotum, 5-12 abdominal segments I - IX. Figure 13: lacinia. Figure 14: galea. Figure 15: labial palpi. Figure 16: mandible. Figure 17: antennal segment IV. Figure 18: male lateral papillae. Figure 19: terminal abdominal cerci.

## ACKNOWLEDGEMENTS

The author would like to thank C. E. Carlton, D. E. Foster, and L. O. Warren for reviewing the manuscript and offering constructive criticism. This paper is published with the approval of the Director, Arkansas Agricultural Experiment Station, Fayetteville, AR 72701.

## LITERATURE CITED

- REDDELL, J. R. 1983. A checklist and bibliography of the Japygoidea (Insecta: Diplura) of North America, Central America, and the West Indies. The Pearce-Sellars Series, No. 37, 41 pp. Texas Memorial Museum, Austin, Texas.
- SMITH, L. M. 1959. The Japygidae (Diplura) of North America, 3. *Occasjapyx* Silvestri and *Hecajapyx* n. gen. Ann. Entomol. Soc. America, 52:363-368.
- SMITH, L. M. 1960. Japygidae of North America, 7. A new genus of Provalljapyginae from Missouri. Proc. Biol. Soc. Washington, 73:261-266.

# MANDIBULAR DENTITION IN SIX SPECIES OF SALAMANDERS, GENUS *PLETHODON* (CAUDATA: PLETHODONTIDAE), FROM ARKANSAS USING SCANNING ELECTRON MICROSCOPY

RICHARD A. ATWILL and STANLEY E. TRAUTH

Department of Biological Sciences  
Arkansas State University  
State University, AR 72467

## ABSTRACT

The mandibular (dentary) dentition of six species of *Plethodon* (*P. caddoensis*, *P. dorsalis*, *P. fourchensis*, *P. glutinosus*, *P. ouachitae*, and *P. serratus*) from Arkansas was studied using scanning electron microscopy. In all species, the mandibular teeth were bicuspid, and each tooth possessed a prominent labial cusp and a well-developed, inward-curving lingual cusp. All species showed similar tooth crown features, except *P. caddoensis* which exhibited a reduced tooth height and a reduced lingual cusp (only slightly larger than the labial cusp). We compared our data with other studies on premaxillary, maxillary, and palatal teeth in *Plethodon* and found overall similarities in tooth types. Tooth morphology does not appear to be an effective tool for taxonomic purposes in our *Plethodon* species because of the range of morphological variation in tooth structure.

## INTRODUCTION

Amphibian teeth are divided into two parts, a basal pedestal and a distal crown or apex (Lawson, 1965; Moury *et al.*, 1987). Teeth can be either monocuspid or bicuspid with the bicuspid condition being considered primitive and can be either monostichous, in a single row, or polystichous, in multiple rows (Wake, 1963; 1966; 1976). Within the family Plethodontidae, Coss (1974) found that the shape of the premaxillary and maxillary teeth of *Plethodon ouachitae* and *P. glutinosus* were bicuspid with a well-developed labial cusp. He also noted that these teeth in *P. dorsalis* were bicuspid and uniform in size with the labial cusp being more reduced in males (an indication of sexual dimorphism). Stewart (1958) stated that the maxillary and dentary teeth were similar in morphology in *Eurycea bislineata* with the exception of a gradual decrease in size and height posteriorly. Moury *et al.* (1987) studied the ultrastructural and histochemical features of monostichous teeth of the jawbones in *P. cinereus* and compared them to the palatal (polystichous) teeth. They found that the apices, or crowns, were similar in both kinds of teeth with the basal pedestals being heterogenous. Coss (1974) also found that the crowns were similar in external morphology with the Yonahlossee group, the Glutinosus group, and the Wehrlei group in *Plethodon*. He stated that in the Yonahlossee group, the species *P. yonahlossee*, *P. ouachitae*, and *P. caddoensis* had similar tooth morphologies as were *P. glutinosus* and *P. jordani* of the Glutinosus group. Highton and Larson (1979), using electrophoretic analysis of protein variation, revised the grouping of *Plethodon* and placed *P. ouachitae*, *P. caddoensis*, *P. glutinosus*, and *P. fourchensis* into the Glutinosus group, *P. wehrlei* and *P. punctatus* in the Wehrlei Group, *P. serratus* in the Cinereus group, and *P. dorsalis* in the Welleri group.

Although several studies have compared the morphology of premaxillary, maxillary, and vomerine (palatal) teeth in *Plethodon*, few have mentioned anything other than general morphology of the mandibular or dentary teeth (see Moury *et al.*, 1987). No study using scanning electron microscopy (SEM) has been performed on the mandibular dentition of *Plethodon* species from Arkansas. Herein, we describe the mandibular teeth of six species of *Plethodon* (*P. caddoensis*, *P. dorsalis*, *P. fourchensis*, *P. glutinosus*, *P. ouachitae*, and *P. serratus*) from Arkansas using SEM. We also wished to determine interspecific differences and whether mandibular tooth morphology could be used as a reliable taxonomic tool. Lastly, we compare our observations with the current knowledge pertaining to premaxillary and maxillary teeth in *Plethodon*.

## MATERIALS AND METHODS

The mandibular teeth of six species of *Plethodon* (N = 29) were examined (*P. caddoensis*—1 female, 3 males; *P. dorsalis*—1 female, 4 males; *P. fourchensis*—3 females, 2 males; *P. glutinosus*—2 females, 3 males; *P. ouachitae*—3 females, 2 males; *P. serratus*—3 females, 2 males). All specimens were collected in Montgomery, Polk, and Stone counties. Animals were sacrificed using a dilute chloroform solution, fixed within 24 hr of collection in 10% formalin, and stored in 70% ethanol. Specimens were then measured and sexed. Lower jaws were excised and placed into vials of 70% ethanol. For SEM, mandibles were dehydrated in a graded series of ethanol and amyl acetate, dried in a critical point dryer, coated with gold/palladium, and viewed with a JEOL 100 CXII TEM/SCAN electron microscope at an accelerating voltage of 40 kV. Jaw teeth were counted after preparation for SEM using a dissecting microscope at 30X. All specimens and preparations are deposited in the Arkansas State University Museum of Zoology. When means are given, they are accompanied by  $\pm$  two standard errors.

## RESULTS

All mandibular teeth examined during this study were bicuspid and exhibited an elongate lingual cusp (except *P. caddoensis*) and a prominent, well-developed labial cusp. Teeth showed basic similarities among all species, and some degree of intraspecific variation was evident.

In *P. dorsalis* and *P. serratus*, teeth showed a well-developed labial cusp with a long inward-curving lingual cusp (Fig. 1A & B). Each tooth also exhibited a posterior curvature as seen in dorsal view (Fig. 2A).

In *P. ouachitae* and *P. glutinosus*, the teeth exhibited a prominent labial cusp with the lingual cusp being curved sharply inward (Fig. 2D-F). The labial cusp was almost vertical (anterior-to-posterior), or slightly curved posteriorly as observed in labial view (Fig. 1F).

*Plethodon fourchensis* exhibited a reduced labial cusp and a slightly incurving lingual cusp (Fig. 1D; 2B). The labial cusp was either vertical or slightly curved posteriorly.

In *P. caddoensis*, the teeth showed slightly-developed lingual and labial cusps with the lingual cusp being greatly reduced to such a degree that the lingual cusp was only slightly larger than the labial cusp (Fig. 1C; 2C). The teeth exhibited no inward curvature and were nearly vertical in anterior-to-posterior position. Although some variation was evident, both cusps showed a blunt to moderately tapering crest.

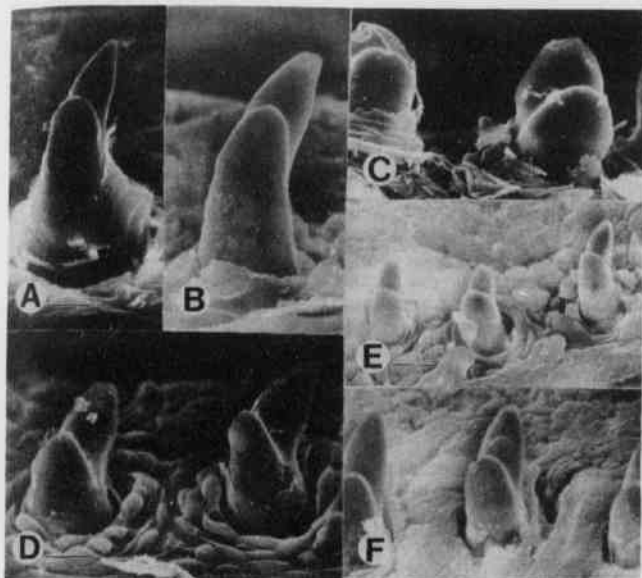


Figure 1. Scanning electron micrographs of mandibular teeth in species of *Plethodon* from Arkansas. All observations are labial views. A. *P. serratus*, 500X; line = 20  $\mu$ m for A - C. B. *P. dorsalis*. C. *P. caddoensis*. D. *P. fourchensis*, 300X; line = 35  $\mu$ m. E. *P. dorsalis*, 200X; line = 50  $\mu$ m for E & F. F. *P. glutinosus*.

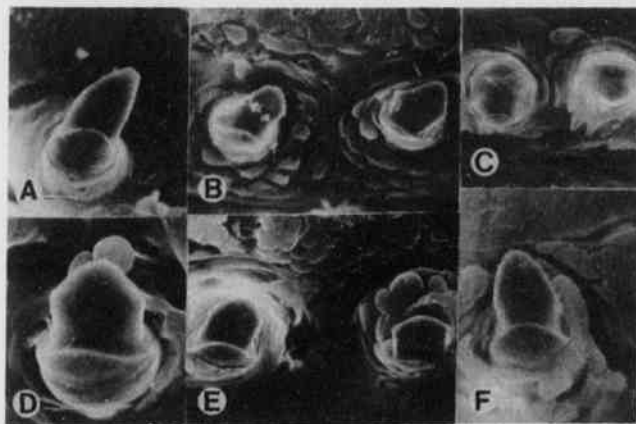


Figure 2. Scanning electron micrographs of mandibular teeth in species of *Plethodon* from Arkansas. All observations are dorsal views. A. *P. serratus*, 300X; line = 35  $\mu$ m for A - C, E & F. B. *P. fourchensis*. C. *P. caddoensis*. D. *P. ouachitae*, 500X; line = 20  $\mu$ m. E. *P. ouachitae*. F. *P. glutinosus*.

Within the tribe Plethodontini, tooth number may either increase as body length increases (a primitive condition), or decrease as body length increases (an advanced or specialized condition). In our study, the highest average mandibular tooth counts (including empty sockets) were found in the larger species (*P. caddoensis*,  $74.8 \pm 4.6$ ; *P. fourchensis*,  $77.4 \pm 3.9$ ; *P. glutinosus*,  $77.6 \pm 3.7$ ; *P. ouachitae*,  $77.6 \pm 3.3$ ). The two smaller species, *P. dorsalis* and *P. serratus*, averaged  $46.6 \pm 2.7$  and  $41.6 \pm 3.7$ , respectively.

## DISCUSSION

Our results confirm that mandibular tooth morphology in *Plethodon* is basically similar in structure to premaxillary and maxillary teeth as reported by Coss (1974) and Wake (1963, 1966). The teeth were bicuspid with the cusps showing varying degrees of development. The mandibular teeth of *P. glutinosus* and *P. ouachitae* possess the same morphological characteristics as their premaxillary and maxillary teeth. The only visible difference between these teeth was the width of the base of the tooth (widest in *P. ouachitae*). *Plethodon fourchensis* (not studied by Coss, 1974) was similar to *P. glutinosus* and *P. ouachitae*, except for the lingual cusp being sharply curved posteriorly. Although within the same phylogenetic grouping as *P. fourchensis*, *P. glutinosus*, and *P. ouachitae* (Duncan and Highton, 1979; Highton and Larson, 1979), *P. caddoensis* exhibited a distinctive mandibular tooth morphology with the lingual cusp being greatly reduced. This reduction in size of the lingual cusp would be a specialization for the Glutinosus group.

The tooth counts for the mandibular teeth in *P. glutinosus* and *P. ouachitae* were similar to the maxillary tooth numbers reported by Coss (1974). The mandibular tooth number in *P. dorsalis* and *P. serratus* were also very similar to the premaxillary/maxillary combined counts (Coss, 1974). Although *P. glutinosus* is considered a primitive species while *P. dorsalis* represents an advanced form (see Coss, 1974), the significance of mandibular tooth number and the correlation between body size and tooth number was not assessed during the present study.

Because of the range of variation, mandibular tooth morphology does not appear to be an effective taxonomic tool in *Plethodon* salamanders. The only species that possesses a distinctive cusp morphology is *P. caddoensis*. Otherwise, *Plethodon* species generally exhibit similar tooth structure among the various sets of teeth.

## LITERATURE CITED

- COSS, H. T. 1974. Maxillary and premaxillary dentition of salamanders of the tribe Plethodontini (Family Plethodontidae). Ph.D. Dissertation. Clemson University. 70 pp.
- DUNCAN, R., and R. HIGHTON. 1979. Genetic relationships of the eastern large *Plethodon* of the Ouachita Mountains. *Copeia* 1979:95-110.
- HIGHTON, R., and A. LARSON. 1979. The genetic relationships of the salamanders of the genus *Plethodon*. *Syst. Zool.* 28:579-599.
- LAWSON, R. 1965. The teeth of *Hypogeophis rostratus* (Amphibia, Apoda) and tooth structure in the Amphibia. *Proc. Zool. Soc. Lond.* 145:321-326.
- MOURY, J. D., S. K. CURTIS, and D. I. PAV. 1987. Structural heterogeneity in the basal regions of the teeth of the red-backed salamander, *Plethodon cinereus* (Amphibia, Plethodontidae). *J. Morph.* 194:111-127.
- STEWART, M. M. 1958. Seasonal variation in the teeth of the two-lined salamander. *Copeia* 1958:190-196.
- WAKE, D. B. 1963. Comparative osteology of the plethodontid salamander genus *Aneides*. *J. Morph.* 113:77-118.
- WAKE, D. B. 1966. Comparative osteology and evolution of the lungless salamanders, Family Plethodontidae. *Mem. S. California Acad. Sci.* 4:1-111.
- WAKE, M. H. 1976. The development and replacement of teeth in viviparous caecilians. *J. Morph.* 148:33-64.



# EFFECT OF NITROGEN FERTILIZER ON MILLING QUALITY OF RICE (*ORYZA SATIVA*)

R. H. DILDAY  
USDA-ARS-SPA  
P.O. Box 287  
Stuttgart, AR 72160

## ABSTRACT

The effect of nitrogen fertilizer on milling quality or milling yield of rice (*Oryza sativa*) was tested for two cultivars, 'Lemont' and 'Newbonnet'. This was an increase in the percentage of broken kernels and a decrease in head rice yield when no nitrogen fertilizer was applied as compared to applying all of the nitrogen at pre-flood or in split applications. The greater effect was on Lemont, a cultivar that requires a high amount of nitrogen fertilizer for maximum grain yields. Data showed that the percentage of head rice can be reduced by as much as 7 to 22 percent in Lemont and from 2 to 6 percent in Newbonnet when no nitrogen is applied as compared to applying all of the nitrogen at pre-flood or in split applications. Also, these data show that the percentage of broken kernels can increase from 8 to 19 percent for Lemont and from 4 to 11 percent for Newbonnet when no nitrogen fertilizer is applied as compared to applying all of the nitrogen at pre-flood or in split applications.

## INTRODUCTION

Milling quality of rice (*Oryza sativa*) is determined by the percentage of whole kernels (head rice), broken kernels, and total milled rice. In fact, the United States standards for rough rice and milled rice is based on the quantity of whole kernels and total milled rice (whole and broken kernels combined) that is produced in the milling of rough rice to a well milled degree (Morse *et al.*, 1967). Rice producers received more than twice as much money for whole kernels as they did for broken kernels in 1988 (Anonymous, 1988). Therefore, it is imperative that producers understand the variables that influence milling quality of rice. The effects of moisture content of the grain at harvest on milling yield has been well documented. For example, Smith *et al.* (1938) showed in Arkansas and Texas in the 1930's that rice harvested between 23 to 28% moisture content of the grain, after drying, resulted in maximum grain yield and the highest percentage of head rice yields. In the 1940's and 1950's McNeal (1950) of Arkansas showed that the highest milling quality of dried paddy rice occurred when the grain was threshed between 16 to 24% moisture content. Kester *et al.* (1963) of California showed in the 1960's that the highest head rice yield after drying, was obtained at harvest moisture contents between 25 to 32%. Also, Morse *et al.* (1967) of California showed that the maximum head rice yield was obtained when the grain was harvested between 28-30% moisture content. In the 1970's Calderwood *et al.* (1980) of Texas found that the percentage of total milled rice increased with delays in harvest date but the percentage of head rice reached a maximum at an intermediate harvest date then declined rapidly with delays in harvesting.

Dilday (1987) showed significant differences between cylinder speed, germplasm, and moisture content of the grain at harvest on milling yield. For example, the percentage of broken kernels approximately doubled when the cylinder speed of the thresher was increased from 600 to 1000 RPM. 'Newbonnet' produced the fewest broken kernels (5.7, 11.0) while 'Leah' had the most broken kernels (22.6, 30.6) at 600 and 1000 RPM, respectively. Also, 'Lemont' produced the highest total milling yield (69.5, 70.6); whereas, 'L202' produced the lowest total milling yield (63.4, 66.3) at 600 and 1000 RPM, respectively.

The objective of this study was to determine the effect of nitrogen fertilizer on milling quality of two rice cultivars, Lemont and Newbonnet.

## MATERIALS AND METHODS

Nitrogen fertility experiments were conducted during a two-year period, 1986 and 1987. Field trials with two cultivars were conducted at the Rice Research and Extension Center Stuttgart, Arkansas, on a Crowley silt loam soil which is a fine montmorillonitic, thermic Typic Albaqualf. The experimental design for each of the tests was a randomized block design with four replications. Rice was drill-seeded in plots that were 14 row wide and 4.57 m long with a 0.191 m row spacing on April 23, 1986 and 1987. The seedlings emerged on May 4, 1986

and May 8, 1987, respectively. Plots of the two cultivars were harvested each year at 10 separate harvest dates. Harvesting started at a moisture content of approximately 25% and the harvest continued twice a week for five weeks. The number of days after heading was noted for each harvest sample.

A single row 3.66 m long was hand-harvested from the center 10 rows of each plot generally between the hours of 1100 and 1400 when the kernels were free of dew and surface moisture. The outer 2 rows on each side of each plot were not harvested. The amount of rice harvested from the 3.66 m row generally ranged from 450 to 750 grams. A vogue thresher [Mention of trade names or proprietary products is for information only and does not necessarily imply their endorsement by the USDA, Riceland Cooperative, or the Arkansas Agric. Exp. Stn.] was used to separate kernels from straw. The samples were passed through a screen to remove the larger leaves and stems. Samples were weighed in the laboratory and the moisture content was determined with a DICKEY-john Model Gac II grain analysis moisture meter. The samples were immediately placed in a zipper-top plastic bag and taken to Riceland Cooperative, Stuttgart, Arkansas the following day for drying to about 12% moisture and analysis. Samples were cleaned over a Carter-Day dockage machine with FGIS approved sieves and determinations of milling yield were carried out in accordance with the standard procedure of rice graders (Anonymous, 1982, 1983), (Smith, 1972), except that the samples processed were smaller (162 g) than the normal 1,000 grams.

The test plots were flushed two times in 1986 and three times in 1987 to obtain uniform seedling emergence and a permanent flood (5-10 cm) was established at about the fifth true leaf stage and maintained until maturity. The four nitrogen treatments were 0, 3-way split, 6-way split and all pre-flood. A total of 135 and 180 lbs./A of nitrogen were applied as urea to Newbonnet and Lemont, respectively. The 3-way split application of nitrogen was applied at a rate of 75-30-30 and 120-30-30 lbs./A of nitrogen on Newbonnet and Lemont, respectively. The 75 and 120 units were applied prior to the first flood, the first 30 units at  $\frac{1}{2}$ " to " internode elongation and the second 30 units were applied 10 days later. All of the nitrogen was applied immediately prior to the first flood in the pre-flood treatment. Head rice, total milled rice, and percentage of broken kernels for each cultivar were analyzed using the General linear models procedure. The LSD procedure was used for mean separation.

## RESULTS AND DISCUSSION

The combined analysis (Table 1) for 1986 and 1987 showed that the greatest percentage of broken kernels and the lowest head rice yields occurred when no nitrogen fertilizer was applied. Conversely, the fewest broken kernels and the highest head rice yields were obtained when nitrogen fertilizer was applied. Furthermore, the fewest broken kernels were observed when all of the nitrogen was applied at pre-flood in both 1986 and 1987. Also, the greatest head rice yield was obtained where all of the nitrogen was applied at pre-flood in 1987. The greatest numerical head rice yield also occurred where all of the nitrogen was

## R. H. DILDAY

Table 1. Influence of Nitrogen Fertilizer on Milling Yield (Combined analysis - Lemont and Newbonnet)

Treatment	Head Rice		Broken	
	1986	1987	1986	1987
0	59.8 b	43.4 c	10.4 a	24.4 a
3-way split	61.9 a	53.8 b	7.2 b	15.7 c
6-way split	61.7 a	51.4 b	7.2 b	18.0 b
All Preflood	62.2 a	57.1 a	6.8 c	13.0 d

Means within a column followed by the same letter are not significantly different at the P < 0.05.

Table 2. Influence of Nitrogen Fertilizer on Milling Yield of Lemont.

Treatment	Head Rice		Broken	
	1986	1987	1986	1987
0	55.9 c	35.0 d	15.2 a	33.3 a
3-way split	60.5 b	52.0 b	8.7 b	18.5 b
6-way split	61.2 ab	49.3 c	8.9 b	21.4 c
All Preflood	62.6 a	56.8 a	7.3 c	14.2 d

Means within a column followed by the same letter are not significantly different at the P < 0.05.

Table 3. Influence of Nitrogen Fertilizer on Milling Yield of Newbonnet.

Treatment	Head Rice		Broken	
	1986	1987	1986	1987
0	63.7 a	51.7 d	5.6 ns	15.6 a
3-way split	62.9 ab	55.6 b	5.7	13.0 c
6-way split	62.6 ab	53.5 c	5.5	14.6 b
All Preflood	61.8 b	57.3 a	6.2	11.9 d

Means within a column followed by the same letter are not significantly different at the P < 0.05.

applied at preflood in 1986 but the preflood treatment was not significantly different from the 3-way or 6-way split applications.

Data from each cultivar, Lemont and Newbonnet, were analyzed independently and the analysis showed that the highest percentage of broken kernels in Lemont occurred when no nitrogen was applied and the fewest broken kernels occurred where all of the nitrogen was applied at preflood both in 1986 and 1987 (Table 2). Also, the lowest head rice yield occurred where no nitrogen was applied both in 1986 and 1987. The highest head rice yields in 1987 occurred where all of the nitrogen was applied at preflood; furthermore, the largest numerical head rice yield in 1986 was where all of the nitrogen was applied at preflood but the preflood treatment was not significantly different from the 6-way split. There was no significant difference among nitrogen treatments for broken kernels in Newbonnet in 1986 but in 1987 the zero and all preflood treatments caused the milling yield of Newbonnet to react the same as the milling yield for Lemont in 1986 and 1987 (Table 3). Furthermore, the head rice yields of Newbonnet and Lemont reacted the same for all four treatments in 1987. The greatest head rice yield of Newbonnet occurred at the zero level of nitrogen in 1986 and there were no significant differences among the treatments where nitrogen was applied. The 1986 head rice yield data for Newbonnet was not consistent with the head rice yield data for Lemont in 1986 and 1987 or for Newbonnet in 1987. This suggests that further studies are needed to delineate the affects among nitrogen treatments on head rice yields, especially for Newbonnet.

Non uniform applications of nitrogen fertilizer (streaking), which are usually due to improper aerial applications, are common in producer fields of rice. Furthermore, uneven distribution of nitrogen fertilizer can have an adverse affect on milling yield in rice. For example, these data show that the percentage of broken kernels will approximately double when no nitrogen is applied as compared to proper nitrogen application at preflood or in split applications, especially for Lemont. Also, these data suggest that Newbonnet reacts in the same manner as

Lemont, although the affect of increasing the percentage of broken kernels in the streaked (no nitrogen) area will not be as pronounced in Newbonnet as it is in Lemont, a variety which requires a higher level of nitrogen for maximum grain yields (Norman and Wells, 1985).

## SUMMARY

These data show that nitrogen fertilizer has an influence on milling yield in rice, especially on Lemont. Furthermore, these data show that the percentage of broken kernels can essentially double, especially for Lemont (14 to 33%), in those areas of the field which receives no nitrogen as compared to areas that receive all of the nitrogen at preflood or in split applications. The percentage of broken kernels of Newbonnet (12 to 16%) were affected about like the percentage of broken kernels of Lemont but the affect was not as pronounced. Also, the head rice yield can be reduced by as much as 7-22% percent for Lemont in areas where zero nitrogen is applied as compared to all of the nitrogen being applied at preflood or in split applications.

## ACKNOWLEDGEMENTS

The assistance of D. W. Bickerstaff and T. R. Hays, Vice-President-Comodity Operations and Manager-Appraisal Office, respectively, for Riceland Cooperative, Stuttgart, Arkansas for the grain drying and analysis of the rice samples is gratefully acknowledged.

## LITERATURE CITED

- ANONYMOUS. 1982. Rice Inspection Handbook. Fed. Grain Insp. Ser., Washington, D.C.
- ANONYMOUS, 1983. United States Standards for Rice. Fed. Grain Insp. Ser., Washington, D.C.
- ANONYMOUS. 1988. Rice Marketing News. USDA, AMS, San Francisco, CA. March, Volume 69 No. 11.
- CALDERWOOD, D. L., C. N. BOLLICH and J. E. SCOTT. 1980. Field drying of rough rice: Effect on grain yield, milling quality, and energy saved. Agron. J. (70):649-653.
- DILDAY, R. H. 1987. Influence of thresher cylinder speed and grain moisture at harvest on milling yield of rice. Proc. Ark. Academy of Sci. 41:35-37.
- KESTER, E. B., H. C. LUKENS, R. E. FERREL, A. MOHAMMED, and D. C. FINFROCK. 1963. Influences of maturity on properties of western rices. Cereal Chem. 40:323-326.
- MCNEAL, X. 1950. When to harvest rice for best milling quality and germination. Arkansas Agric. Exp. Stn. Bull. 504. p. 41.
- MORSE, M. D., J. H. LINDT, E. A. OELKE, M. D. BRANDON, and R. E. CURLEY. 1967. The effect of grain moisture at time of harvest on yield and milling quality of rice. Rice J. 70(11):16-20.
- NORMAN, R. J., and B. R. WELLS. 1985. Yield response to nitrogen of four new rice cultivars. Ark. Farm Res., 34:6:4.
- SMITH, W. D. 1972. United States standards for rough rice, brown rice for processing, milled rice. Agric. Market. Serv., Washington, D.C.
- SMITH, W. D., J. J. DEFFES, C. H. BENNETT, R. C. ADAIR, and H. M. BEACHELL. 1938. Effect of date of harvest on yield and milling quality of rice. USDA, Circ. No. 484.

# RESPONSE OF FISH COMMUNITIES TO HABITAT ALTERATION IN A SMALL OZARK STREAM

DANNY J. EBERT  
US Forest Service  
605 W. Main St.  
Russellville, AR 72801

and

STEPHEN P. FILIPEK  
Arkansas Game and Fish Commission  
#2 Natural Resources Dr.  
Little Rock, AR 72205

## ABSTRACT

From 1984 to 1986, the Arkansas Highway and Transportation Department reconstructed and upgraded a portion of St. Hwy. 123 west of St. Hwy. 7 at Pelsor, Arkansas. As a result of the construction, portions of Haw Creek, Johnson County, Arkansas, a third order stream in the Boston Mountains Ecoregion, were straightened and channelized. In reconstructing specific stream reaches, stream banks were riprapped and vegetated, gabions constructed and positioned, stream substrates and pool-riffle ratios altered. Instream and riparian habitat and fish biomass and diversity in altered reaches were radically altered. Channelized reaches became wide and shallow, lacking overstory cover and pools. Substrate particle size changed from boulder/rubble to rubble/gravel/sand and velocity increased. Fish communities in channelized reaches simple; *Campostoma anomalum*, *Notropis boops*, and *Etheostoma spectabile* accounted for more than 80 percent of all fish captured. This represented a shift from piscivore and insectivore-piscivore to herbivore and insectivore dominated feeding guilds. Natural channel reaches had more complex fish communities and greater abundance of centrarchids and ictalurids, primarily deeper water groups. Immediately after channelization, altered reaches had a larger biomass than natural reaches (0.43-0.26 g/m<sup>2</sup>). The summer following alteration, channelized segments were basically dewatered, and biomass decreased dramatically (0.06-0.11 g/m<sup>2</sup>). One year post channelization, altered reaches had eroded, scoured and deepened at their headwaters, and embedded. Fish community composition in altered reaches stabilizing to a riffle-type assemblage dominated by the herbivore *Campostoma anomalum*.

## INTRODUCTION

Stream channelization is one of the most destructive activities that man imposes on riparian ecosystems. Over 300,000 km of stream channels have been modified in the United States (Schoof, 1980). Specific impacts of channelization upon stream ecosystems are multidimensional and interrelated. Two aspects of channelization of prime importance are habitat changes due to channelization and the resulting biological response.

Hubbard *et al.* (1988) in their review of channelization listed gradient, velocity, depth, channel meander, flow regime, substrate, instream structure, temperature, turbidity, water chemistry, and terrestrial and riparian habitats as being affected by channel alteration. Immediate impacts on instream and riparian biota result from the physical destruction of the biota and their habitat. Delayed impacts may occur as habitats continue to be altered due to land use changes or unstable conditions. The magnitude and duration of particular impacts depend on the type of stream system involved, length and timing of channelization, and the impacted biological species.

Early studies of channelization effects on fishes were conducted by Schneberger and Funk (1971), Barton *et al.* (1972), Wilkienson (1973), and Moyle (1976). More recently, channelization impacts on fish have been well documented, but mitigation of losses has not been adequately addressed (Edwards *et al.*, 1984).

Channelization and subsequent shifts in fish species composition were identified as early as the 1900's (Shelford, 1911; 1917). Trautman and Gartman (1974) reported that during an 86-year period, relative abundance of fishes in Gordon Creek, Ohio, decreased and the fish fauna reverted from smallmouth bass associations to typical headwater or brook associations comprised of beach-nosed dace, red-sided dace, creek chub and silver-jawed minnow. The decrease was attributed to dredging, channelizing and clearing that occurred before the turn of the century. Smith (1960, 1971) reported similar results from Illinois. Biomass and number of fish species have been found to be reduced in channelized streams. Golden and Twilley (1976) reported downstream reduction in game and fish species and biomass, especially centrarchids, while greater numbers of nongame fish were evident where channelization removed

riffles and instream cover. Schlosser (1982) noted more stable trophic structure, biomass, and age structure in fish communities of a natural headwater stream when compared with a similar modified stream. He noted that seasonal and annual variations in fish biomass and trophic structure occurred in the modified stream because of shifts in both amounts and types of instream production. Large pools in the natural stream increased habitat volume and stability relative to the modified stream. This resulted in a trophic structure of predominately large insectivore-piscivore and benthic insectivore fish species. Trophic structure, age structure, and recruitment were stable in the natural stream.

Bayless and Smith (1964) evaluated fish populations in 23 channelized streams and 36 proximate natural streams in eastern North Carolina. Comparisons indicated that reductions in the magnitude of 90 percent occurred both in weight of game fish per acre and in number of game fishes over six inches total length per acre, and following channelization no return towards natural stream populations had occurred within a 40 year period.

Spawning of fishes dependent on bottom substrate can be severely altered by channel modification. Bowman (1970) showed that slight differences in bottom grain distribution resulted in marked segregation of spawning distribution of three species of redbreast. Grain size has been considered a spawning stimulus, and lack of suitable grain size or proper spatial grain configuration may result in lack of egg maturation, behavior alterations impeding spawning, and egg resorption (Simpson *et al.*, 1982).

Flow or substrate alteration due to channelization may cause reduced spawns of species utilizing bottom material to deposit their eggs. Darters and sculpins actively use substrate for reproduction. Channel modification may remove suitable spawning sites, thereby forcing substrate spawners to move either up or downstream, use less suitable substrate, or not to spawn at all and to resorb eggs (Simpson *et al.*, 1982).

This investigation tested the hypothesis that stream fishes inhabiting a third order stream in the Boston Mountains Ecoregion of Arkansas are reduced in biomass and diversity by channel alteration; that fish biomass and diversity will change in altered reaches over time; and that altered reach instream habitat will return to prechannelization conditions.



## Danny J. Ebert and Stephen P. Filipek

## STUDY AREA

Haw Creek lies in northwestern Arkansas, draining an area of approximately 200 km<sup>2</sup>. The stream, located in the Boston Mountains Ecoregion, flows in a southeasterly direction for 13 km, attaining third order before entering Big Piney Creek. The majority of the drainage basin is sandstone substratum covered by oak-hickory forest and pasture. Continuous flow in the headwater reaches is dependent on extended rainfall. Intermittent flow is characteristic from July through November.

Stream channels in Haw Creek are fluvially-formed, alluvial, riffle-pool structure from headwaters to third order. Shallow, slow flowing pools alternate with short, shallow swift riffles. Gravel is concentrated in riffle areas and slopes of pools, while pool bottoms are predominately bedrock-rubble.

## MATERIALS AND METHODS

Quantitative fish samples were collected in third order reaches of Haw Creek, Johnson County, Arkansas. Pools and riffles were visually inspected, measured, then partitioned based on depth, flow, and substrate. Small mesh block nets were placed at the ends of each areas to prevent fish movement in and out of the study area. Fishes were captured by electroshocking with a generator coupled to a variable voltage pulsator (Coffelt VVP-2C) and hand held electrodes. A minimum of three electroshocking runs was conducted at each site. Specimens were preserved in 10% formalin in the field. Upon return to the laboratory, fishes were identified to species utilizing taxonomic identification keys of Buchanan (1973), weighed, measured, preserved in 50% isopropanol and catalogued.

Population size for each species was estimated. Areas were compared for fish community distribution and partitioning. All species were grouped by feeding guilds based on Pflieger's (1975) general description of food habits. Structure of the fish community at each site and habitat type was summarized using percentage composition of biomass by species and by feeding guild.

Quantitative habitat analysis were performed using methods developed by Ebert *et al.* (1987b) and Platts *et al.* (1987). Water quality and velocity analyses and channel typing were conducted at each sample site following the methods of Standard Methods (1975), Patton (1987), and Rosgen (1985).

## RESULTS

A total of 1826 individuals comprising six families and fourteen species was represented in electrofishing samples (Table 1). Although channelized reaches had fewer species (6-10/10-15), biomass was greater immediately after channelization compared with that of natural reaches (0.57-0.69/0.47-0.59 g/m<sup>2</sup>). Fish biomass in altered reaches did not show an increase with time, but returned to approximate natural reach levels 2 years after channelization (0.43-0.58/0.44-0.51 g/m<sup>2</sup>) (Table 2). Mean length and weight per individual was also greater in natural reaches. Darters (Percidae), and stonerollers-shiners (Cyprinidae) dominated altered reaches (67-98%) and comprised a substantial percentage, by number, of natural reaches (48-77%). Sunfishes (Centrarchidae) and catfishes (Ictaluridae) were abundant in natural reaches (23%).

Dominant feeding guilds in altered reaches were herbivores and insectivores, while natural areas were dominated by insectivores, insectivores-piscivores, and omnivores (Table 1). *Campostoma anomalum*, a herbivore, was the most numerous species collected at all sites, and was primarily concentrated in natural riffles and altered reaches. *Etheostoma blennioides*, *E. spectabile* and *Noturus exilis*, insectivores, were also abundant in natural riffles. Smaller individual sizes of *E. spectabile* were consistently collected in altered riffles. *Lepomis cyanellus*, *L. megalotis*, and *Micropterus dolomieu*, insectivores-piscivores; *Notropis boops*, insectivore; and *Pimephales notatus*, omnivore; dominated natural areas.

Study areas differed greatly in channel and water width, depth, substrate particle size, and length (Table 3). Channelized reaches were

Table 1. Species list for 3rd order reaches of Haw Creek, Johnson County, Arkansas (1 = herbivore-detrivore; 2 = omnivore; 3 = insectivore; 4 = insectivore-piscivore).

Cyprinidae	Cyprinodontidae
<i>Campostoma anomalum</i> (1)	<i>Fundulus olivaceus</i> (3)
<i>Notropis boops</i> (3)	Centrarchidae
<i>Pimephales notatus</i> (2)	<i>Lepomis cyanellus</i> (4)
Catostomidae	<i>Lepomis megalotis</i> (3)
<i>Hyphantilium nigricans</i> (3)	<i>Micropterus dolomieu</i> (4)
<i>Erimyzon oblongus</i> (3)	Percidae
Ictaluridae	<i>Etheostoma blennioides</i> (3)
<i>Ictalurus natalis</i> (3)	<i>Etheostoma spectabile</i> (3)
<i>Noturus exilis</i> (3)	<i>Etheostoma whipplei</i> (3)

Table 2. Fish biomass (g/m<sup>2</sup>) and numbers for channelized and natural sample reaches of Haw Creek, Johnson County, Arkansas.

	CHANNELIZED		NATURAL	
	Reach 1	Reach 2	Reach 1	Reach 2
Spring 1986	0.57-0.69 132	0.51-0.55 105	0.47-0.59 109	0.39-0.42 137
Summer 1986	0.06-0.11 63	0.10-0.12 49	0.23-0.27 78	0.26-0.34 87
Fall 1986	0.41-0.51 105	0.39-0.46 117	0.48-0.63 113	0.39-0.70 120
Spring 1987	0.46-0.56 98	0.56-0.71 101	0.49-0.56 165	0.37-0.42 219
Summer 1987	0.11-0.19 45	0.16-0.19 67	0.26-0.28 109	0.22-0.27 64
Fall 1987	0.43-0.58 121	0.44-0.67 112	0.44-0.51 134	0.41-0.51 143

\* fish biomass (g/m<sup>2</sup>) (top) and numbers (bottom) determined by area of wetted perimeter (available habitat) per sample.

smaller in area, shallower, swifter, and had a more homogenous substrate than did natural reaches. Channel water width was similar in all areas. Size of substrate was substantially less in altered reaches. Dissolved oxygen and specific conductance values were similar among study sites. Stream bank erosion was moderate, and canopy closure and instream cover were lacking in altered reaches.

## DISCUSSION

Stream fish biomass, species number and species composition have been found to decrease with channelization (Bayless and Smith, 1964; Smith, 1968 and 1971; Trautman and Gartman, 1974; Golden and Twilley, 1976; and Schlosser, 1982). Increase in species number in streams, attributed to addition rather than replacement of species, occurs as a stream progresses from its headwaters to its mouth. Increase in species diversity has been found to be directly related to habitat variability (Horwitz, 1978). When channelization alters a stream, decreases in both number and diversity of fishes are characteristic. In biologically diverse streams, such as Haw Creek, distribution of fish has been found to be correlated with instream habitat (Schlosser, 1982; Ebert *et al.*, 1987) and constrained by environmental tolerances (Smith and Powell, 1971) and habitat and foot preferences (Matthews and Hill, 1979a, 1979b; Orth and Maughan, 1984). In our investigation altered reaches failed to provide the habitat requirements of numerous species, primarily centrarchids and ictalurids. This compares with results documented by Lotrich (1973). Populations of sport fish, such as larger centrarchids, have been directly related to stream reaches with a higher proportion of pools (Wydoski and Helm, 1980). Shallow riffle species, characterized by *C. anomalum* and *E. spectabile*, were more abundant in altered reaches of Haw Creek than in natural channels. Todd and



## Response of Fish Communities to Habitat Alteration in a Small Ozark Stream

Table 3. Physical and chemical parameters for channelized and natural reaches (3rd order) of Haw Creek, Johnson County, Arkansas.

		Channelized		Natural	
		Reach 1	Reach 2	Reach 1	Reach 2
Channel Width (m)	S*	18.2	18.9	23.4	30.1
	S	18.0	18.2	23.1	29.7
	F	19.3	17.9	22.8	29.3
Water Width (m)	S*	16.3	17.0	14.5	16.2
	S	8.3	10.1	13.6	15.2
	F	14.9	16.6	14.7	15.9
Max. Depth (ft)	S*	0.5	0.6	2.9	2.1
	S	0.3	0.3	1.9	1.0
	F	0.4	0.6	2.8	1.9
Substrate		gr/cb	gr/cb	cb/bd	cb/bd
Length (m)		82.5	63.4	72.7	71.1
Dissolved Oxygen (mg/l)	S*	9.9	9.8	9.9	9.9
	S	7.9	8.1	8.1	8.1
	F	10.0	9.6	9.6	9.6
Specific Conductance (u/mhos)	S*	34.0	34.0	34.0	34.0
	S	42.0	42.0	42.0	42.0
	F	29.0	29.0	29.0	29.0
Canopy Closure (%)	S*	0.0	0.0	54.6	62.5
	S	0.5	1.1	72.1	89.0
	F	0.5	1.1	70.9	88.1

\*S=Spring; S=Summer; F=Fall  
 (gr=gravel; cb=cobble; bd=bedrock)

Stewart (1985) found primary food items of *E. spectabile* to be mayflies, chironomids, amphipods and crustaceans, all of which are plentiful in shallow riffle areas. Abundance of *C. anomalum* has been suggested by Brown and Todd (per. comm.) to be influenced by abundance of periphyton on shallow riffle substrate in the Illinois River, Washington County, Arkansas. This species is considered to be herbivorous (Pflieger, 1975; Sewell *et al.*, 1980; Orth and Maughan, 1984). Channelized reaches of Haw Creek had abundant periphyton coverage on all instream substrate due to shallow depth and lack of overhead cover, both of which allow more solar radiation to reach the stream substrate. *C. anomalum* was the most abundant fish collected in channelized reaches, accounting for 56 to 67 percent of total numbers of individuals.

In our investigation, it is apparent that channelization not only reduced fish biomasses and numbers in altered reaches (Table 2), but also reduced species composition and biased altered reach fish populations towards smaller individuals which are capable of withstanding shallow water conditions. Trautman and Gartman (1974), reporting on Gordon Creek in Ohio, and Schlosser (1982), reporting on a natural headwater stream in east central Illinois, noted total population shifts and apparent size reductions of groups resulting from channel modifications. It is important to note that altered reaches of Haw Creek were bounded by natural areas, thus offering refugia to many species, especially centrarchids and ictalurids. Ebert *et al.* (1987a), in their quantification of habitat requirements for eight species of Ozark fishes in streams within the Ozark-St. Francis National Forests, noted that *E. spectabile*, *C. anomalum*, and *N. exilis*, and juvenile life stages of *L. megalotis*, *L. cyanellus* and *M. dolomieu* preferred shallow, fast/slow riffles with a gravel dominated substrate. In their investigation, *N. boops* was primarily a shallow pool species and adult *L. megalotis*, *L. cyanellus*, and *M. dolomieu* preferred deep, moderately flowing pools with bedrock/boulder substrate. Channel alteration in Haw Creek resulted in shallow, slow/moderate flowing gravel dominated reaches which offered preferred habitat to darters and stonerollers. Natural stream reaches with an abundance of debris and boulder dominated pools were preferred by centrarchids and ictalurids.

During low summer flows in 1986 and 1987, altered reaches of Haw Creek were practically dewatered. This occurrence is common in many Ozark streams. Fish biomasses in altered reaches during these periods are greatly reduced (0.12-0.21 g/m<sup>2</sup>) compared to natural reaches (0.22-0.26 g/m<sup>2</sup>). This may be a result of suitable instream cover loss and an overall reduction of wetted area in altered reaches. Ebert *et al.*

(1987a) found a strong correlation between wetted area (m<sup>2</sup>) and total fish weight ( $r^2 = 0.94$ ) and wetted area (m $\pm$ ) and total fish numbers ( $r^2 = 0.61$ ) in 10 streams in the Boston Mountains Ecoregion of Arkansas, sampled from 1985 to 1987. Their investigation indicated that fish numbers and weight would increase with wetted area until an inflection point was reached, based on channel form, where water levels above the point would result in no significant additional usable fish habitat. This is one of the basic tenants of many instream methods used to reserve water for stream fisheries and aquatic ecosystems (Filipek *et al.*, 1987). Two years after channelization altered channels were scouring. Rubble/boulder material that moved into the altered reaches during storm events had diversified the bottom substrate, and fish populations during normal flows were comparable to those of natural channels (Table 2). In two altered reaches scour pools were formed where natural reaches entered the areas. However, this is often offset by silt deposition downstream of the scoured, channelized area (Yearke, 1971). It is apparent that with time the altered reaches will return to a natural state. This is due in part to the altered reaches being bounded by natural areas and to the small overall length of each altered reach (> 1 km). Previous long term studies have indicated an irreversible destruction of stream habitat and fish populations in channelized streams. Trautman and Gartman (1974) reported that after 86 years relative abundance of fish in Gordon Creek, Ohio, was decreased and diversity altered. Bayless and Smith (1964) reported fish populations in 23 channelized streams and 36 proximate natural streams in eastern North Carolina had reductions in the magnitude of 90 percent in number and weight of game fish following channelization, with no return towards natural stream populations over a 40 year period. Also, the physical loss of habitat and loss in ecotone, both aquatic and terrestrial, can occur above and below the channelized section, expanding the area impacted by channelization (Simpson *et al.*, 1982).

This investigation indicated that small Ozark stream fish populations and habitat can recover from channelization if altered reaches are short in overall length and bounded by natural undisturbed areas. There was a direct tendency for darters and stonerollers to seek the shallow, slow/moderate flowing, gravel substrate of altered reaches. The stimulus for the new habitat colonization may be related to preference for that type of habitat or for abundant food organisms. Large size fishes were excluded from altered reaches due to depth and cover limitations. Channelization of natural stream reaches should be avoided in highway construction and improvement if possible because of major impacts, not only to the aquatic system, but also to the terrestrial environment and its associated wildlife (Hedrick, 1975). Further, upstream channelization has caused engineering problems, such as increased bank and bottom erosion, increased frequency of floods, and a higher incidence of downstream bridge repair due to the above factors (Emerson, 1971).

## ACKNOWLEDGEMENTS

We wish to acknowledge review of the manuscript and verification of fish names by Dr. Thomas Buchanan. Dick Patton, Hydrologist, Ozark-St. Francis National Forests, provided instream flow analysis. Arkansas Tech University fisheries classes assisted in data collection from 1985-1988.

## LITERATURE CITED

- BARTON, J. R., E. J. PETERS, D. A. WHITE and P. V. WINGER. 1972. Bibliography on the physical alteration of the aquatic habitat (channelization) and stream improvement. Brigham Young University Publications, Provo, UT. 30 pp.
- BAYLESS, J. and W. B. SMITH. 1964. The effects of channelization upon the fish populations of lotic waters in eastern North Carolina. Proc. S.E. Assoc. Game & Fish Comm. 18:230-238.
- BOWMAN, M. L. 1970. Life history of the black redhorse, *Moxostoma duquesnei* (Lesueur). Trans. Amer. Fish Soc. 99:546-559.

## Danny J. Ebert and Stephen P. Filipek

- BUCHANAN, T. M. 1973. Key to the Fishes of Arkansas. Arkansas Game and Fish Comm., Little Rock, AR. 68 pp.
- EBERT, D. J., A. V. BROWN and C. B. FIELDER. 1987. Distribution of fish within headwater riffles of the Illinois River System, Washington County, Arkansas. Proc. Arkansas Acad. Sci. 41:38-42.
- EBERT, D. J., S. P. FILIPEK and R. D. PATTON. 1987a. Evaluation of instream flow requirements of fishes in the ozark National Forest: A status report. Proc. of a workshop on instream flow for fisheries biologists. Warmwater Streams Committee, Southern Division. Amer. Fish. Soc. Tenn. Tech Univ., Cookeville, TN. (abstract).
- EBERT, D. J., S. P. FILIPEK and R. D. PATTON. 1987b. Guide to the monitoring and analysis of Arkansas streams. USDA Forest Service. Russellville, AR. 197 pp.
- EDWARDS, C. J., B. L. GRISWOLD, R. A. TUBB, E. C. WEBER and L. C. WOODS. 1984. Mitigating effects of artificial riffles and pools on the fauna of a channelized warmwater stream. N. A. J. Fish. Manage. 4:194-203.
- EMERSON, J. W. 1971. Channelization: A case study. Science 173:325-326.
- FILIPEK, S. P., W. E. KEIGH, and J. GIESE. 1987. The status of the instream flow issue in Arkansas, 1987. Proc. Ark. Acad. Sci. 41:43-48.
- GOLDEN, M. F. and C. E. TWILLEY. 1976. Fisheries investigation of a channelized stream. Big Muddy Creek, Watershed, Kentucky. Trans. Ky. Acad. Sci. 37:85-90.
- HEDRICK, R. D. 1975. Impact of channelization and associated land use changes on wildlife habitat. MS thesis. Oklahoma State University, Stillwater, OK. 47 pp.
- HORWITZ, R. J. 1978. Temporal variability patterns and the distribution patterns of stream fishes. Ecol. Monogr. 48:307-321.
- HUBBARD, W. D., D. C. JACKSON, and D. J. EBERT. 1988. Stream impact evaluation guidelines: Channelization. Report to Warmwater Streams Committee, Southern Division, Amer. Fish. Soc. Bethesda, MD. 39 pp.
- LOTRICH, V. A. 1973. Growth, production and community composition of fishes inhabiting a first, second and third order stream of eastern Kentucky. Ecol. Monogr. 43:377-397.
- MATTHEWS, W. J. and L. G. HILL. 1979a. Age specific differences in the distribution of red shiners (*Notropis lutrensis*) over physiochemical ranges. Amer. Midl. Nat. 101:366-372.
- MATTHEWS, W. J. and L. G. HILL. 1979b. Influence of physicochemical factors on habitat selection by red shiners, *Notropis lutrensis*, (Pisces, Cyprinidae). Copeia 1979:70-81.
- MOYLE, P. B. 1976. Some effects of channelization on the fishes and invertebrates of Rush Creek, Modoc County, California. Calif. Fish and Game. 62:179-186.
- ORTH, D. J. and O. E. MAUGHAN. 1984. Community structure and seasonal changes in standing stocks of fish in a warmwater stream. Amer. Midl. Nat. 112(2):369-378.
- PATTON, R. D. 1987. Instream flow methodology. Pp. 123-128, in Guide to the monitoring and analysis of Arkansas streams. USDA Forest Service, Russellville, AR. 197 pp.
- PFLIEGER, W. L. 1975. The fishes of Missouri. Missouri Dept. Conserv., Jefferson City, MO. 343 pp.
- PLATTS, W. S., C. ARMOUR, G. D. BOOTH, M. BRYANT, J. L. BUFFORD, P. CUPLIN, S. JENSEN, G. W. LIENKAEMPER, G. W. MINSHALL, R. L. NELSON, J. R. SEDELL and J. S. TUHY. 1987. Methods for evaluating riparian habitats with applications to management. USDA Forest Service. Gen. Tech. Report Int-221. Intermountain Res. Stat. Ogden, UT. 177 pp.
- ROSGEN, D. L. 1985. A stream classification system. Pp. 1-42, in Riparian ecosystems and their management: Reconciling conflicting issues. US Forest Service Symposium. Tucson, AZ.
- SCHLOSSER, I. J. 1982. Trophic structure, reproductive success and growth rate of fishes in a natural and modified headwater stream. Can. J. Fish. Aquat. Sci. 39:968-978.
- SCHOOF, R. 1980. Environmental impact of channel modification. Water Res. Bull. 16:697-701.
- SCHNEBERGER, E. and J. L. FUNK. EDS. 1971. Stream channelization - a symposium. Special Publ. 2, North Central Division, Amer. Fish. Soc., Bethesda, MD. 136 pp.
- SEWELL, S. A., J. K. BEADLES and V. R. McDANIEL. 1980. The systematic status of the fishes of the genus *Campostoma* (Cyprinidae) inhabiting the major drainages of northern Arkansas. Proc. Arkansas Acad. Sci. 34:97-100.
- SHELFORD, V. E. 1911. Ecological succession I. Stream fishes and the method of physiographic analysis. Biol. Bull. Mar. Biol. Lab., Woods Hole, Mass. 21:383-385.
- SHELFORD, V. E. 1917. An experimental study of the effects of gas waste upon fishes with special reference to stream pollution. Illinois St. Lab Natural Hist. Urbana, IL. 54 pp.
- SIMPSON, P. W., J. R. NEWMAN, M. A. KEIRN, R. M. MATTER and P. A. GUTHRIE. 1982. Manual of stream channelization impacts on fish and wildlife. Envir. Sci. and Eng. Inc., Gainesville, FL. 154 pp.
- SMITH, P. W. 1968. An assessment of changes in the fish fauna of two Illinois rivers and its bearing on their future. Trans. Illinois St. Acad. Sci. 61:31-45.
- SMITH, P. W. 1971. Illinois streams: a classification based on their fishes and an analysis of factors responsible for disappearance of native species. Illinois Nat. Hist. Surv., Biol. Notes. 76:3-14.
- SMITH, C. L. and C. R. POWELL. 1971. The summer fish community of Brier Creek, Marshall County, Oklahoma. Amer. Mus. Novit. 2458:1-30.
- STANDARD METHODS. 1975. For the examination of water and wastewater. 14 ed. APHA-WPCF. Washington, D.C. 1193 pp.
- TODD, C. S. and K. W. STEWART. 1985. Food habits and dietary overlap of nongame insectivorous fishes in Flint Creek, Oklahoma, a western Ozark foothills stream. Great Basin Natr. 45:721-733.
- TRAUTMAN, M. B. and D. K. GARTMAN. 1974. Re-evaluation of the effects of man-made modifications on Gorden Creek between 1887 and 1973 and especially as regards its fish fauna. Ohio J. Sci. 74:162-173.
- WILKINSON, J. M. 1973. Report on channel modifications. Vol. 1. Report prepared for Council on Environmental Quality. Stock No. 4111-00014. 394 pp.

**Response of Fish Communities to Habitat Alteration in a Small Ozark Stream**

---

WOODS, L. C. III, and B. L. GRISWOLD. 1981. Channelization and mitigation: Their effects on macroinvertebrate communities of the Olentangy River, Columbus, Ohio. Pp. 113-118, in L. A. Krumholz ed. The Warmwater Streams Symposium. So. Div. Amer. Fish. Soc. Bethesda, MD.

WYDOSKI, R. S., and W. T. HELM. 1980. Effects of alterations to low gradient reaches of Utah streams. US Fish and Wildlife Serv. Rept. FWS/OBS-80/13. Wash., D.C. 118 pp.

YEARKE, L. W. 1971. River erosion due to channel relocation. Pp. 39-40, in Civil Engineering-ASCE. Madison, WI.

# FORESTRY ON THE ISLAND OF TAIWAN, ROC - THE STATE OF THE ART

JAMES M. GULDIN, TIMOTHY T. KU,  
and R. SCOTT BEASLEY

Department of Forest Resources  
Arkansas Agricultural Experiment Station  
University of Arkansas at Monticello  
Monticello, AR 71655

## ABSTRACT

The forests of Taiwan vary from lush subtropical vegetation to subalpine coniferous associations. Topography is exceedingly rugged, and stands border on the verge of silvicultural inoperability. In the 1950s and 1960s, the wood products industry in the Republic of China was of paramount importance; the production of high-quality sawtimber from old-growth cypress (*Cupressaceae*) stands provided the financial capital that built one of the most prosperous national economies in the modern world. In the 1980s, forestry in Taiwan is a curious blend of old methods and new technologies, as modern silvicultural practices are used to reforest cutover cypress stands, to harvest and reproduce remaining old-growth stands, and to expand the silvicultural importance of other forest types on the island. Many applied research efforts would be promising in application to the forests of Taiwan, such as long-term studies of silvicultural practices on water quality, methodology of natural regeneration applied to cypress and *Taiwania cryptomerioides* (*Taxodiaceae*), uneven-aged regulation applied to bamboo, *Phyllostachys pubescens* (*Bambusaceae*), growth and yield in coniferous plantations, effectiveness of modern herbicides in controlling competition in young plantations, and application of contemporary economic assessments in the evaluation of silvicultural alternatives.

## INTRODUCTION

During the past 20 years, a number of forestry scientists and officials from the U.S. and Taiwan have participated in exchange programs to visit and observe forestry programs within the universities, government agencies and industries of the two nations. Among the U.S. representatives, the Department of Forest Resources at the University of Arkansas at Monticello (UAM) has played a significant role. Dr. T. T. Ku was invited to participate in the Sixth National Reconstruction Conference in Taiwan in 1975, and served as a Visiting Professor at the National Taiwan University in 1983 (Ku, 1983) supported by Taiwan's National Science Council. In the late 1970s, and again in the mid-1980s, a number of forest scientists and high-level forest administration officials from Taiwan came to study the operations of the U.S. Forest Service and forest industries in the U.S., including Arkansas.

This decade of cooperation resulted in an international research accord between the University of Arkansas (UA) and the Council of Agriculture (COA) of Taiwan. The agreement was initiated with an international symposium on Forest Productivity and Site Evaluation held in Taipei in the Fall of 1987 (COA, 1987). Over 20 papers, including eight by the authors of this article, were presented to more than 90 scientists representing 15 governments and private agencies from the two countries. However, the symposium was only the centerpiece of a 2-week adventure that included eight days of field tours to observe forest practices and management operations in the southern central and northern sections of Taiwan. This paper reports on those observations.

## GEOGRAPHY

Taiwan is located along the fringe of the continental shelf of Asia, on the western border of the Pacific Ocean. It is about 395 kilometers long and 145 kilometers at its broadest width near the central portion of the island. The principal mountain system runs north-south with its highest peak, Mount Jade (Yushan), standing at 3,997 meters near the center of Taiwan. The Tropic of Cancer bisects the island and confers upon it a tropical and subtropical climate. Annual rainfall ranges from 1,000-67,000 millimeters and averages 2,600 millimeters; the average annual temperature is 22 °C. An excellent overview of the physiography and climate can be found elsewhere (Liu, 1976, 1987).

Over 52 percent of its land area is in forests at the present time, with biomes ranging from tropical hardwoods in the coastal low elevations

to the humid, montane coniferous forests at the higher elevations. The present population of nearly 20 million people has brought a socio-economic impact to forest policy. The objective in forest resource management over the past years has shifted from timber production in the 1960s to soil and water conservation in the 1970s, and to recreation and environmental preservations in the 1980s.

## ECOLOGICAL ZONES

Liu (1976) identified four major ecological zones on the island of Taiwan based primarily on an elevation gradient; these are the subalpine, cool-temperate, warm-temperate, and tropical zones. The extremely rugged topography, high rainfall accentuated by local orographics, and variability in temperatures result in highly heterogeneous climatic and ecological conditions within each zone. Geologically, soils are quite young with the notable exception of the tropical ultisols and oxisols in the lowlands. Important forest soils on the island include the spodosols at higher elevations (1800 meters and higher), alfisols, inceptisols, and the lithosolic entisols associated with recent landslide activity (Shen, 1987).

Six ecologically-derived forest formations have been recognized (Liu, 1987). These closely correspond with five silvicultural regions, identified by combining the gradients of elevation and temperature with species that are of commercial importance (Kuo, 1987). There are two major distinctions between the ecological and silvicultural classification. First, the division of forestry and agriculture is found at approximately 500 meters (Chen, 1957). Secondly, the lowland littoral ecosystems have little value for commercial timber production.

The subalpine coniferous forest is the uppermost forest of the country, dominated by Taiwan fir (*Abies* spp.) and alpine juniper (*Juniperus chinensis* Linn. var. *kaizuka* Hort. ex. Endl.). It occupies the highest elevations in the country and is characterized by the coldest temperatures. This forest type is not commercially productive, but is extremely important in the stabilization of high slopes.

The cold-montane coniferous forest is a mixed forest dominated by Taiwan hemlock (*Tsuga chinensis* var. *formosana* [Hay.] Li et Keng), Taiwan spruce (*Picea morrisonicola* Hay.), Taiwan red pine (*Pinus taiwanensis* Hay.), and Taiwan armand pine (*Pinus armandii* Fr. var. *mastersiana* (Hay.)). This forest type is found between 2000-3000 meters, and is transitional between the types above and below. It is of minor commercial importance.



## Forestry on the Island of Taiwan, ROC - The State of the Art

The warm-temperate montane coniferous forest and warm-temperate montane rain forest are intermingled through altitudes of 700-2500 meters. Generally, the coniferous type occupies the higher elevations, and the hardwood rain forest the lower elevations. Occurrence varies greatly due to local variations in soils, topography, and incidence of precipitation.

The conifers of the warm-temperate montane forest are the backbone of the timber economy in the Republic of China. The species of paramount commercial value are red cypress (*Chamaecyparis formosensis* Matsum.) and yellow cypress (*Chamaecyparis obtusa* var. *formosana* [Hay.] Rehd.). In addition, other conifers of commercial importance in this region are China fir (*Cryptomeria japonica* D. Don.).

Over 200 species of hardwood characterize the warm-temperate montane rain forest. The most important of these is *Zelkova* (*Zelkova serrata* [Thunb.] Mak.), a member of the Ulmaceae with utility similar to that of oak. In addition, the bamboo resource reaches its zenith in this type. The island has over 60 species of bamboo, of which the most usable is moso bamboo (*Phyllostachys pubescens* Mazel.). Moso bamboo is valuable both as an ubiquitous construction material and a source of food in bamboo shoots.

The tropical rain forest of Taiwan has been largely cutover and converted to agriculture. The high rainfall, low elevation, moderate topography, and warm year-round temperatures promote activities other than forestry. The second-growth species composition includes general (*Ficus*, *Trema Macaranga*, *Mallotus*, and *Bischofia* spp.) common to the second-growth rain forests of Indo-Malaysia (Liu, 1987).

The littoral forest is found at the lowest elevations along the coastline. The mangrove forests of Taiwan are similar in structure and composition to mangroves throughout the tropics. Strand forests are common to seashores in the southern part of the island. In a manner similar to the tropical rain forest, the littoral forest of Taiwan is primarily of ecological significance rather than of value as a raw resource material for manufactured forest products.

## DEVELOPMENT OF FORESTRY IN TAIWAN

Forestry has been practiced in Taiwan for over 100 years, beginning with the Japanese occupation of the island in 1895, carrying through the liberation in 1945 with subsequent establishment of the Chinese government, through the present day (Kuo, 1987). Early forest operations were primarily timber mining, as was the case in the United States. In his classic work, Fernow (1913) wrote that the Japanese established an administrative structure for the practice of forestry in the home islands, but exploited the timber resources on the island that was then known as Formosa, a Portuguese word meaning the Island Beautiful or the Fantasy Island. The most valuable species sought in the region were Japanese fir and yellow cypress, with mention of a species of "*Zelkova*" [sp] (Fernow, 1913).

Modern forestry became prominent after the establishment of the Chinese government in 1945. The major capital assets of the island at that time were its forests, particularly yellow cypress and red cypress. Lumber produced from these species is of exceptional quality and value, and provided much of the financial basis for the government in the 1950s and the early 1960s. With the vigorous growth in the economy due to high-tech industry, and the resulting increase in the standard of living, the demand for non-commodity natural resources has increased to a level that has begun to dictate the current character of resource management. In essence, forestry operations have changed from timber production in the 1950s to the present status of emphasis in research and preservation.

## CONTEMPORARY FORESTRY OPERATIONS

Harvest of timber in Taiwan is usually followed by the establishment of plantations. At low elevations (800-1,000 meters), hardwoods such as *Zelkova* and other endemic species, as well as the exotic *Leucaena leucocephala* (Lam.) deWit, are planted at 2 x 2 meter spacings. This dense spacing is important in reducing both competition of weed species

and branchiness of the desired species. Underplanting of *Zelkova* with other species such as nitrogen-fixing *Acacia* spp. is done both to promote plantation diversity and to enhance the nutrient status of the site.

At higher elevations (1,500-2,500 meters), harvest is followed by establishment of plantations of the native China fir, Taiwanian, the yellow and red cypresses, and the exotic Japanese fir. Seedlings are usually planted at 2 x 2 meter spacing. However the growth and yield that can be expected from these stands are not certain, particularly from recently adopted species.

Planting stock is produced as a two-year-old seedling; after the first year seedlings are transplanted to a polyethylene bag holding about 1,500 cm<sup>3</sup> of soil, and spend a second year in the nursery prior to outplanting. At higher elevations, plantation spacings may vary depending on the topographic severity of the site. On reasonably flat sites (less than 30% slope), spacing within the row and between rows may vary from 2 to 3 meters. On steep slopes, seedlings are planted as a linear clump of three or four trees within a meter; approximately 5 meters separate the clumps within the row, with rows 3 meters apart. This unique practice is easier to implement on steep slopes, promotes desirable form in crop trees, and improves the efficiency of competition control.

Natural regeneration is an increasingly common practice, especially with the more tolerant red and yellow cypress. Two silvicultural systems are frequently employed. Clearcutting is a common practice, with the new stand originating either as advance growth or by means of seed fall from adjacent stands. The uniform seed tree method is also employed, though the sites are frequently inaccessible for seed tree removal. A third alternative that was observed is a classic textbook variation of the seed tree method known as the group seed tree method, where seed trees are left as isolated groups. This practice promotes windfall resistance of the seed trees, and also allows operational harvest of the seed trees associated with early pre-commercial or commercial thinning.

Competition control is a critical aspect of stand establishment in the warm-temperate and subtropical environment. The standard method of weed control is by means of human labor. Woods workers typically use small scythe-like knives to cut swaths amid the competing vegetation within which seedlings can develop. Between 17 and 20 such treatments are applied in the first 10 years of plantation development; three treatments per year are required in the first three growing seasons. Because of such intense labor requirements as well as the logistic support required for these workers at high elevations, the present net value of plantation establishment in the coniferous forest varies from U.S. \$2,500-7,500 per hectare (Jen, 1984). Naturally regenerated stands require less competition control — between 10 to 12 treatments in the first 10 years, followed by a pre-commercial pruning/thinning treatment after the tenth growing season.

Herbicides have been considered as a much less expensive form of competition control, but are judged by the Taiwan Forestry Bureau to be impractical for two reasons. First, water (the medium of application) is scarce at high elevations. Secondly, it is thought, though not confirmed by research, that the watershed values of the forest would be compromised by herbicide application.

No discussion of forestry in Taiwan would be complete without a tribute to the commercial and cultural value of the many species of bamboo. Moso bamboo, the major commercial species, is managed on a five-year cycle under an uneven-aged system of density regulation. At the end of each growing season, the oldest age class is harvested. This age class contains about 20% of the culms in the stand, which are randomly distributed and identifiable by the unique color-age relationship of the genus. Culm growth of root-sprout origin occurs in the following spring, reestablishing the youngest 20% of the stand. Research is underway on the nutrient dynamics of bamboo, and on the artificial regeneration of bamboo using coppice plantation silviculture (Kao, 1987). A productive stand of Moso bamboo may produce an annual income of more than U.S. \$7,400 per hectare (Kao, 1985).

The forest resource plays a major role as both a watershed and water impoundment landscape for low elevation urban centers. Occurrence of precipitation is highly heterogeneous, varying from dry seasons to storms of typhoon intensity. The government of Taiwan is, of course, aware that its forests directly provide the water for the island economy

## James M. Guldin, Timothy T. Ku, and R. Scott Beasley

and its people. A number of large scale reservoirs and dams have been constructed among the 22 watersheds of Taiwan since the 1950s. Many of these were built in extremely rugged terrain with intense labor forces. Baseline watershed monitoring, initiated in the 1960s, occurs on over a dozen large (100 hectare plus) watershed throughout the island. The effects of silvicultural practices, such as clearcutting and selection cutting, on watershed values are currently being investigated.

At the non-commodity level, the national demand for non-commodity forest resources has increased dramatically with the vigorous national economy and the concomitant increase in the per capita standard of living. Because of increased demand on outdoor recreation, several well known parks, recreational areas, and nature areas have been established for urban dwellers. Among these, the Yangmingshan park, Hsitou and Chihpen recreational areas, and the Kenting and Alishan national parks are most prominent, and operate at full capacity during most weekends and holidays. One component of the surge in popularity of noncommodity forest resources is attributable to an increasingly affluent population learning to enjoy and appreciate the beauty of a natural resource setting. A darker component is attributable to the Malthusian paradox whereby an increasingly large population undertakes the utilization of an increasingly scarce resource. If the enjoyment of these non-commodity resources follows the pattern of western Europe and North America, use will continue to grow at a nearly exponential rate in the next few decades.

## CONSTRAINTS ON FORESTRY

Forest practices in Taiwan are constrained by many factors. The high population on a limited land base, about 36,000 square kilometers, dictates an intensive utilization of available acreage. Intensive agriculture (rice, asparagus and other grain and legume crops), orchards of fruit trees (banana, citrus, pear, apple, vineyard, mango and other scrumptious native species and varieties), and cash crops (vegetables, mushrooms and the highly profitable betelnut) prioritize the rich, level coastal plains and the lower elevation tablelands and rolling hills. The successful agricultural technology literally pushed forestry practices into the higher and agriculturally inaccessible terrains.

Silvicultural operations at high elevations are often impractical due to the lack of water. This limits the upkeep of facilities for woods workers, constrains the application of fertilizer and perhaps herbicides, and leads to an uncertainty in supply of the basic fire fighting tool of the foresters. Conversely, the amount and intensity of rainfall associated with severe storms and typhoons can wash away plantations, access roads, and even entire mountainsides. Taiwan has a high rate of landslide activity due to its relatively youthful geological age. Timber production at high elevations is usually conducted by clearcutting using skyline logging systems, followed by planting and competition control; whether this intensive timber management predisposes slopes to mass-wasting is a concern of the Taiwan forestry officials.

The sheer ruggedness of topography limits operational timber management. Mechanization of forest operations within a forest stand is extremely difficult. Log trucks are modified with water cooled brakes for the steep descent from the logging sites to the mills. Topographic limitations accentuate the disadvantageous aspects of commodity production from the island.

Last and perhaps of greatest significant, sociology comes into play as an operational limitation. As a modern industrialized society, Taiwan is currently experiencing the migration of labor from rural to urban areas. Taiwanese foresters are losing the rural labor pool required to conduct labor-intensive forest operations, particularly those of plantation establishment and competition control in both plantations and natural stands. With respect to balance between commodity and non-commodity resources, the public generally supports efforts by the government to reduce its subsidy of timber management in favor of the watershed and recreational values of the forest.

## FORESTRY RESEARCH

Forestry research programs have been conducted in universities and the provincial Taiwan Forestry Research Institute (TFRI) during the

past four decades with funding provided from Taiwan's National Science Council, the COA, and private organizations and industries. Two of the three universities in Taiwan offer doctorate programs in forestry, with the National Taiwan University at the forefront in both seniority and academic services.

On the forefront of applied ecology, research is underway at TFRI and at the universities on nutrient cycling in plantation forests (Hornig, 1987). Production of *Liquidambar formosana* Hance and *Paulownia taiwaniana* Hu and Chang that are resistant to diseases and insects is a major goal of tissue culture research (Yang *et al.*, 1987). Mycorrhizal research focuses on vasicular-arbuscular mycorrhizae in the fast growing hardwood exotic *Leucaena* (Huang, 1987) and on the mycorrhizal symbiosis of high altitude conifers (Hu, 1987).

During the past decades, both native and exotic species trials have been practices in plantations. Today, the use of natural regeneration is becoming more important, especially in remote areas. Research is underway to improve growth and yield forecasting, and to apply modern technology in the field. Thus the evolution from the historical events to the state-of-the-art has occurred in little more than four decades. These trends are noteworthy because modern Taiwan imports over 90% of its timber and fiber needs.

## DISCUSSION AND CONCLUSIONS

The divergence between the operational aspects of timber production and the economic and social limitations upon timber production appear to be increasing in Taiwan. Timber production was fundamental to the establishment of the island economy in the 1950s, but is of decreasing importance. The alternative source of timber for Taiwan is primarily of tropical origin in Indo-Malaysia; all indications are that this source is not immediately renewable. From a global perspective, it is unfortunate that managing temperate forest ecosystems in a constrained manner leads directly to an increased reliance upon tropical ecosystems that are even less able to bear sustainable commodity production.

These divergent demands on the forest ecosystems of Taiwan are by no means resolved. As the population becomes more urban and affluent, the recreational aesthetic and watershed amenities of the forest will become more important. In view of the emphasis placed on sound forestry practices and advanced research, the foundation is in place for farsighted stewardship of the forest ecosystems on the island to meet the growing and diverse demands that characterize the Taiwan forests.

## ACKNOWLEDGEMENTS

The authors gratefully acknowledge the assistance from the Council of Agriculture and the National Science Council of Taiwan, as well as the Taiwan Forestry Bureau, the Taiwan Forestry Research Institute, and the Forestry Development Administration of the Vocational Assistance Commission of Retired Servicemen.

## LITERATURE CITED

- CHEN, C. H. 1957. The classification of climate. Bulletin of the Experimental Forest, National Taiwan University, No. 7. 102 pp.
- COUNCIL OF AGRICULTURE (COA). 1987. Proceedings of the Seminar on Forest Productivity and Site Evaluation. Kiang, T., Yang, J. C., and Kao, Y. P., Editors. Published by Council of Agriculture, Taipei. 225 pp.
- FERNOW, B. 1913. A brief history of forestry in Europe, the United States, and other countries, 3rd edition. University Press, Toronto, and the American Forestry Association, Washington, D.C. 506 pp.

Forestry on the Island of Taiwan, ROC - The State of the Art

- HORNG, F. W. 1987. Nutrient cycling in plantation forests in Taiwan, pp. 79-94. *In*: COA, 1987. Proc. of the seminar on Forest Productivity and Site Evaluation. COA, Taipei. 225 pp.
- HU, H. T. 1987. Mycorrhizae in Taiwan forests, pp. 167-174. *In*: COA, 1987. Proc. of the seminar on Forest Productivity and Site Evaluation. COA, Taipei. 225 pp.
- HUANG, R. S. 1987. Influence of vesicular-arbuscular mycorrhizae on *Leucaena leucocephala* growth, water relations, and nutrient acquisition. pp. 203-225. *In*: COA, 1987. Proc. of the seminar on Forest Productivity and Site Evaluation. COA, Taipei. 225 pp.
- JEN, I. A. 1984. An economic analysis on planting China fir (*Cunninghamia lanceolata* [Lamb.] Hook) in Taiwan. Taiwan Forestry Research Institute Bulletin No. 433.
- KAO, Y. P. 1985. The productivity and biological nutrient cycling of Moso bamboo (*Phyllostachys pubescens*) stands in Taiwan. Ph.D. dissertation, National Taiwan University, Taipei, Taiwan. 191 pp.
- KAO, Y. P. 1987. Aboveground biomass estimation equations for *Cryptomeria*, *Leucaena* and Moso bamboo in Taiwan. pp. 105-116. *In*: COA, 1987. Proc. of the seminar on Forest Productivity and Site Evaluation. COA, Taipei. 225 pp.
- KU, T. T. 1983. A critical look at Taiwan forestry practices — with recommendations. Quarterly Journal of Chinese Forestry 16(4):451-452.
- KUO, P. C. 1987. Classification of silvicultural regions in Taiwan, pp. 29-49. *In*: COA, 1987. Proc. of the seminar on Forest Productivity and Site Evaluation. COA, Taipei. 225 pp.
- LIU, V. T. 1976. Ecological zones of Taiwan. Quarterly Journal of Chinese Forestry 9(3):31-42.
- LIU, V. T. 1987. Taiwan forest ecosystems, pp. 19-27. *In*: COA, 1987. Proc. of the seminar on Forest Productivity and Site Evaluation. COA, Taipei. 225 pp.
- SHEN, K. S. 1987. Classification of forest soils in Taiwan, pp. 57-62. *In*: COA, 1987. Proc. of the seminar on Forest Productivity and Site Evaluation. COA, Taipei. 225 pp.
- YANG, J. C., S. H. CHANG, and C. K. HO. 1987. The effects of growth regulators on differentiation and morphogenesis in cultured tissues of *Paulownia taiwaniana*. Unpublished data on file at TFRI, Taipei, Taiwan.



# COMPARISON OF CYCLIC NUCLEOTIDE PHOSPHODIESTERASE IN *PHYSARUM FLAVICOMUM*

C. KAY HOLTMAN, TAMMY K. EBSEN, JUDITH A. BEAN<sup>1</sup>,  
J. SCOTT BRYLES and THOMAS J. LYNCH

Department of Biology, University of Arkansas at Little Rock  
Little Rock, AR 72204

and

<sup>1</sup>Department of Biology, University of Central Arkansas,  
Conway, AR 72032

## ABSTRACT

We have studied both cyclic AMP phosphodiesterase and cyclic GMP phosphodiesterase in the myxomycete *Physarum flavicomum*. The cyclic AMP phosphodiesterase preparations were isolated from both the diploid plasmodial stage of the life cycle and the haploid myxamoebal stage. The plasmodial enzyme was prepared from spent medium (extracellular) and also from purified nuclei. The myxamoebal enzyme was prepared from purified nuclei. Cyclic GMP phosphodiesterase activity was studied in purified nuclei isolated from the plasmodium. One unusual feature of all the enzymes from the plasmodium is extreme heat stability; they remain catalytically active even after exposure to a boiling water bath for twenty minutes. The myxamoebae enzyme lost all activity after five minutes in a boiling water bath. All four enzyme preparations gave linear product formation with time and all were inhibited by isobutyl-methyl xanthine, a potent competitive inhibitor of cyclic nucleotide phosphodiesterase.

## INTRODUCTION

Cyclic 3'-5' adenosine monophosphate (cyclic AMP) has been shown to be of major importance in regulating cellular events in eukaryotic cells. Cyclic 3'-5' guanosine monophosphate (cyclic GMP), although much less understood, is rapidly gaining attention from many researchers. Both cyclic nucleotides have been studied in many eukaryotic and prokaryotic systems (Pastan *et al.*, 1975).

The regulation of the intracellular (and extracellular) levels of these cyclic nucleotides is coordinated by both synthetic enzymes and degradative enzymes. Cyclic AMP is synthesized by adenylate cyclase and degraded by cyclic AMP phosphodiesterase. Cyclic GMP is synthesized by guanylate cyclase and hydrolyzed by cyclic GMP phosphodiesterase. The work of our laboratory has emphasized the degradative enzymes for both cyclic nucleotides in the myxomycete *Physarum flavicomum*.

Myxomycetes offer a unique model for the study of cellular differentiation and mitotic synchrony (Gray and Alexopoulos, 1968; Aldrich and Daniel, 1982). The life cycle of myxomycetes involves a number of stages that alternate between diploid and haploid structures. The vegetative diploid phase is a macroscopic, single-celled plasmodium. This single cell is multinucleated, with all the nuclei dividing at the same time (mitotic synchrony). Under adverse conditions the plasmodium can differentiate into a dormant sclerotium, which can reform into a plasmodium upon the return of appropriate environmental conditions. A second option available to the plasmodium is the formation of fruiting bodies with the production of haploid spores. These spores can germinate to form the vegetative, single cell haploid phase of the life cycle (myxamoebae and swarm cells). Each of these cells is microscopic and contains one nucleus. These haploid structures can fuse together to form the diploid plasmodium and the life cycle is completed.

Cyclic AMP phosphodiesterase and cyclic GMP phosphodiesterase have been studied in the myxomycete *Physarum flavicomum* in our laboratory (Lynch and Farrell, 1984; Lynch and Farrell, 1985; Lynch and Ross, 1985; and Bean *et al.*, 1986). These studies have been aimed at identifying the location of the intracellular (or extracellular) enzymes and characterizing these proteins. We have shown the existence of cyclic AMP phosphodiesterase in the medium of the plasmodium and in several different intracellular locations, including within the nucleus. A cyclic GMP phosphodiesterase from the medium has also been identified in the plasmodium of *P. flavicomum*. We have recently extended our studies to include cyclic AMP phosphodiesterase from the nucleus of the haploid stage of the life cycle (myxamoebae). This paper will compare data from both cyclic AMP and cyclic GMP phosphodiesterase in *P. flavicomum*. Our work here includes three studies on the plasmodium and one on the myxamoeba. The plasmodial investigations

confirm the presence of both a nuclear cyclic AMP and cyclic GMP phosphodiesterase as well as an extracellular cyclic AMP phosphodiesterase isolated from the spent medium. Within the myxamoeba we have studied a nuclear cyclic AMP phosphodiesterase. We believe that this is the first such report of a nuclear cyclic AMP phosphodiesterase in the haploid stage of any myxomycete.

## MATERIALS AND METHODS

Both plasmodia and myxamoebae of *Physarum flavicomum* were grown in liquid shake culture and harvested as previously described (Lynch and Farrell, 1985). The organisms were inoculated into two liter flasks containing one liter of semi-defined medium. Normally 3-6 liters of each batch of cells were grown at one time. Both sets of cells were harvested at late log phase, usually about 5-7 days, depending on the inoculum. It should be emphasized that in liquid cultures both myxamoebae and swarm cells are present. Myxamoebae are the predominate cell type. To facilitate usage, these haploid cells will be referred to as myxamoebae.

Three different preparations were used for the measurement of either cyclic AMP or cyclic GMP phosphodiesterase. Crude spent medium from plasmodial cultures was used to determine the activity of extracellular cyclic AMP phosphodiesterase. This medium was collected from the late log cultures described above. After centrifugation at 2,500xg the medium was decanted and saved for cyclic AMP analysis. The cells were washed several times and used for nuclear isolation. Nuclei were isolated according to Henney and Yee (1979) and Bean *et al.* (1986). The plasmodial nuclear preparations were used for measurements of both cyclic AMP and cyclic GMP phosphodiesterase activity.

Myxamoebae were also collected by centrifugation at 5000 xg for seven minutes. They were washed several times in 20 mM Tris HCl (pH 8.0). The cells were homogenized and the nuclei purified by the procedure described above for the plasmodial nuclei. Myxamoebae nuclei were used to measure cyclic AMP phosphodiesterase activity.

Both cyclic AMP and cyclic GMP phosphodiesterase activity were measured by a two-stage anion-exchange resin procedure as described previously (Lynch and Cheung, 1975). The extracellular cyclic AMP phosphodiesterase and the myxamoebae enzyme were assayed at pH 8.0 (Tris HCl). The cyclic AMP and cyclic GMP phosphodiesterase from the nuclei of the plasmodium were assayed at pH 5.5, where they both exhibited maximum activity. Included in the reaction mixture was 5 mM MgCl<sub>2</sub>, 0.05 mM CaCl<sub>2</sub>, and 2 mM <sup>3</sup>H-cyclic AMP or <sup>3</sup>H-cyclic GMP. The concentration of <sup>3</sup>H-cyclic AMP in the measurements of the myxamoeba phosphodiesterase was 0.1 mM. Radioactive cyclic AMP and cyclic GMP were purchased from Amersham. Unlabelled cyclic nucleotides were obtained from Sigma Chemical Co.



Comparison of Cyclic Nucleotide Phosphodiesterase in *Physarum flavicomum*

The enzyme reaction was initiated with the addition of sample from one of the preparations described above. Incubation was at 30°C for 10-20 minutes, depending on the sample. The enzyme activity of the heat labile preparation was terminated by placing the tubes in a boiling water bath. The heat stable enzyme was terminated with acid and base as described by Lynch and Farrell (1985). Upon equilibration to 30°C, 0.05 mg of snake venom (*Crotalus atrox*) was added as a source of 5' nucleotidase. This step quantitatively converted all <sup>3</sup>H-nucleotides to <sup>3</sup>H-nucleosides and inorganic phosphate. The snake venom reaction was stopped by the addition of 1.0 ml of a 33% slurry of AG1-X2 anion exchange resin (Bio-Rad). The tubes were centrifuged and aliquots of the supernatant fraction, which contained either <sup>3</sup>H-adenosine or <sup>3</sup>H-guanosine, were analyzed for radioactivity in a Packard 300C Liquid Scintillation Counter. When appropriate, enzyme activity was based on protein concentration as determined by the Lowry method (Lowry *et al.*, 1951). Since extracellular (medium) phosphodiesterase activity cannot accurately be expressed on a protein basis, this activity was expressed as product formed per/ml of medium.

## RESULTS

One of the characteristics of cyclic nucleotide phosphodiesterase from the plasmodium of *P. flavicomum* is heat stability. We have found that the enzyme from some intracellular locations is extremely heat stable. Table 1 compares the heat stability of phosphodiesterase from different locations in the plasmodium and from the nucleus of the myxamoeba. Heat stability was determined by placing the protein samples in a boiling water bath for five minutes. At the end of five minutes the samples were returned to 30°C and enzyme activity was determined in both the heated sample and in the unheated control sample. Although the specific activities varied, all the plasmodial samples were heat stable for the time indicated. The nuclear enzyme from the haploid stage of the life cycle was denatured during the heating process.

The previous data showed the results of enzyme activity after exposure to a boiling water bath for five minutes. The next set of experiments was designed to determine if the enzymes could be denatured with a longer boiling time. As can be seen in Table 2, the fractions that showed heat stability in Table 1 also retained heat stability when exposed to a boiling water bath for up to twenty minutes. As would be expected from the results of Table 1, the myxamoebae enzyme lost all activity after five minutes.

Isobutyl-methyl xanthine (IBMX) is generally considered to be a potent competitive inhibitor of cyclic nucleotide phosphodiesterase. Table 3 shows the results of enzyme activity in the presence of various concentrations of IBMX. The extracellular enzyme activity was determined in the presence of only one concentration of IBMX whereas the other samples were measured in the presence of four different IBMX concentrations. All the samples were inhibited by this compound and when used at different concentrations, enzyme inhibition was concentration dependent. Inhibition by IBMX indicates the presence of a cyclic nucleotide phosphodiesterase enzyme.

Another type of experiment that strongly supports the presence of an enzyme is a continuous assay where the amount of product formed is monitored with increasing time. Such a series of experiments is shown in Figure 1. Enzyme activity was measured at each of the time data points shown on the abscissa. At the time intervals indicated, aliquots were removed and the amount of product formed for that time period was determined as described in the Materials and Methods. All four samples showed a linear increase in product formed per time interval.

## DISCUSSION

The results presented in this paper compare some of the recent data available for both cyclic AMP phosphodiesterase and cyclic GMP phosphodiesterase in *Physarum flavicomum*. These enzymes have been shown to be present in various intracellular locations of several stages in the life cycle of this organism.

One unusual feature of the plasmodial enzyme studied here is their extreme heat stability. The heat stability of the extracellular

Table 1. Activity of heated versus unheated enzyme.

	Myxamoebae Nuclear cAMP	Plasmodia Nuclear cAMP	Plasmodia Nuclear cGMP	Plasmodia Medium cAMP
Unheated	5	21	47	25
Heated	0	21	40	24

Plasmodial nuclear activity is in nMoles/min/mg protein. Myxamoebae activity is reported in nMoles/20min/mg protein. Plasmodial extracellular activity is reported in nMoles/min/ml media. Samples were heated for 5 min in a boiling water bath.

Table 2. Variable heating time assay for phosphodiesterase.

Time (min)	Myxamoebae Nuclear cAMP	Plasmodia Nuclear cAMP	Plasmodia Nuclear cGMP	Plasmodia Medium cAMP
0	5	49	45	25
5	0	57	54	24
10	0	47	64	25
15	0	46	83	28
20	0	44	83	25

Nuclear plasmodial activity is in nMoles/1'/mg protein. Nuclear myxamoebal activity is in nMoles/20'/mg protein. Extracellular activity is in nMoles/1'/ml media. Each was heated in a boiling water bath for the times indicated and assayed for phosphodiesterase activity as described in the materials and methods.

Table 3. Inhibition of phosphodiesterase by IBMX.

IBMX (mM)	Myxamoebae Nuclear cAMP	Plasmodia Nuclear cAMP	Plasmodia Nuclear cGMP	Plasmodia Medium cAMP
0.0	100%	100%	100%	100%
0.2	73	80	65	
0.5	60	51	37	44*
0.8	29	20	24	
1.2	25	10	0	

\*The concentration of IBMX for this data is 0.6mM. Enzyme activity is expressed as a percentage of each control tube i.e. without added IBMX.

phosphodiesterase was first suggested in 1971 when Murray (Murray *et al.*, 1971) commented on the "unusual stability of the excreted enzyme". Extremely stable extracellular enzymes are understandable in that an organism has very little control over its outside environment. The more resistant an enzyme is to the external environment, the greater ability it would have to degrade any compound that might disrupt the organisms normal regulatory mechanisms.

Why a nuclear enzyme would be heat stable is unknown. One obvious suggestion is that the extracellular enzyme and the nuclear enzyme from the plasmodium are identical or similar in structure and that heat stability is an inherent characteristic of the molecule. Reason suggests that the two proteins should be genetically distinct in that any regulatory mechanisms that activate (or inhibit) a nuclear enzyme would presumably be different from those that regulate an enzyme that is released to the outside of the cell.

## C. Kay Holtman, Tammy K. Ebsen, Judith A. Bean, J. Scott Bryles and Thomas J. Lynch

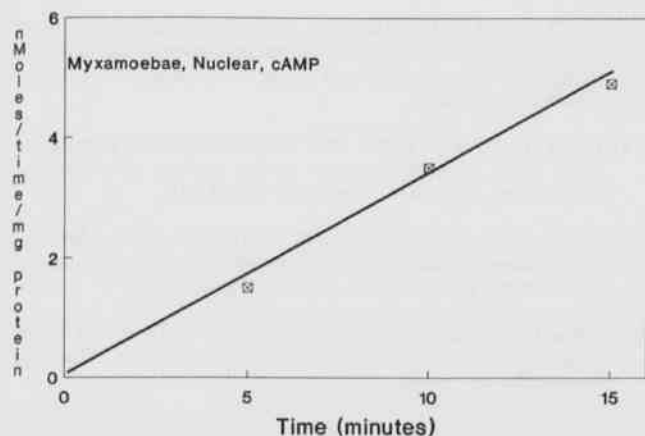


Figure 1. Continuous Assay of Cyclic Nucleotide Phosphodiesterase. Activity of cyclic AMP phosphodiesterase from nuclei of myxamoeba was determined for the times indicated on the abscissa. Enzyme activity is expressed as the amount of product converted for that total time interval.

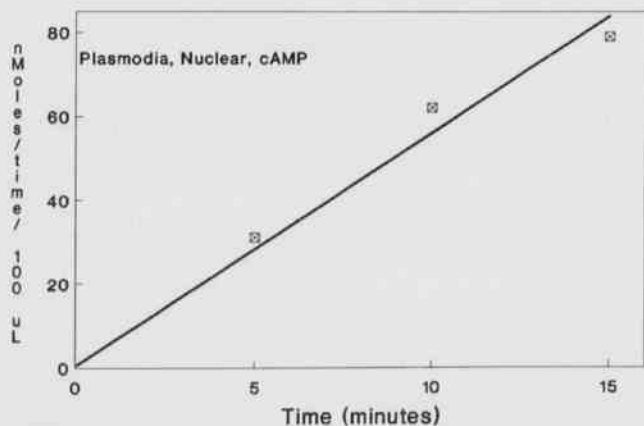


Figure 2. Continuous Assay of Cyclic Nucleotide Phosphodiesterase. Activity of cyclic AMP phosphodiesterase from the nuclei of plasmodia was determined for the times indicated on the abscissa. Enzyme activity is expressed as the amount of product converted for that total time interval.

The regulatory role of the plasmodial cyclic AMP and cyclic GMP phosphodiesterase in the nucleus is unknown at this time. Adenylate cyclase, the enzyme responsible for the synthesis of cyclic AMP, has also been shown to be present in the nucleus of *Physarum* (Atmar *et al.*, 1976). In general it has been noted that in cells growing in culture, factors that decrease cyclic AMP tend to stimulate cell proliferation whereas those that increase cyclic AMP levels tend to inhibit growth rate (Pastan *et al.*, 1975). Knowing the multi-nucleated condition of the plasmodium and the naturally occurring mitotic synchrony, it will be interesting to see if cyclic nucleotides play a role in maintaining this synchronous mitosis.

The nuclear cyclic AMP phosphodiesterase from the myxamoeba does seem to be a separate protein from its counterpart in the plasmodium. This is suggested by the differences in heat stability, with the myxamoeba enzyme being heat labile while that from the plasmodium is heat stable. The myxamoebae are single cells containing one nucleus. Even though there is no mitotic synchrony in these cells, it is still possible that cyclic nucleotides may play a role in cell division in the haploid stage of the life cycle.

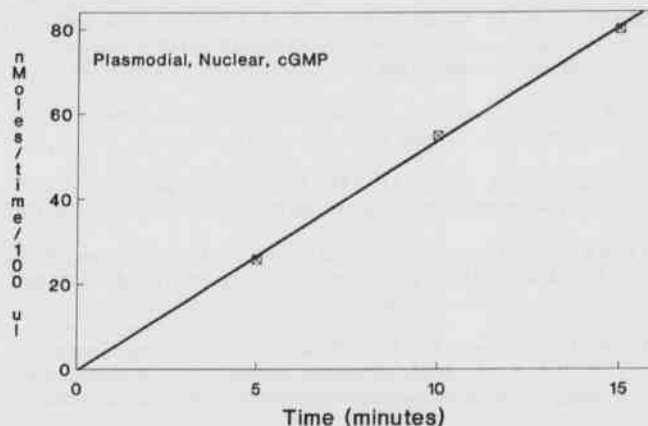


Figure 3. Continuous Assay of Cyclic Nucleotide Phosphodiesterase. Activity of cyclic GMP phosphodiesterase from the nuclei of plasmodia was determined for the times indicated on the abscissa. Enzyme activity is expressed as the amount of product converted for that total time interval.

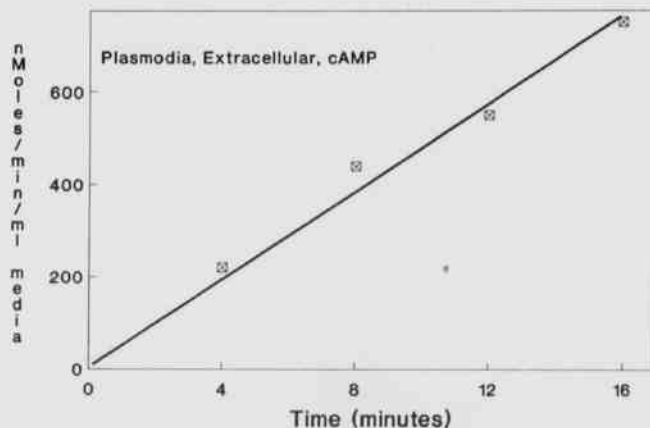


Figure 4. Continuous Assay of Cyclic Nucleotide Phosphodiesterase. Activity of extracellular cyclic AMP phosphodiesterase from the medium of plasmodia was determined for the times indicated on the abscissa. Enzyme activity is expressed as the amount of product converted for that total time interval.

A question that remains to be answered is whether the cyclic AMP and the cyclic GMP phosphodiesterase from the plasmodial nucleus are the same protein or are separate, distinct proteins. Our preliminary data (not shown in this paper) suggest that they may indeed be one and the same protein. This question cannot be answered with certainty however until the enzymes are purified to homogeneity.

## LITERATURE CITED

- ALDRICH, H. C., and J. W. DANIEL. (Eds.). 1982. *Cell Biology of Physarum and Didymium*. 2 Vols. Academic Press, New York, NY.
- ATMAR, V. J., J. A. WESTLAND, G. GARCIA, and G. D. KUEHN. 1976. Adenylate cyclases in *Physarum polycephalum*: Inhibition of a nuclear enzyme by polyamines. *Biochem. and Biophys. Res. Comm.* 68:561-568.

Comparison of Cyclic Nucleotide Phosphodiesterase in *Physarum flavicomum*

- BEAN, J. A., M. G. KLEVE, and T. J. LYNCH. 1986. Isolation of nuclei from *P. flavicomum*: Demonstration of a nuclear cyclic AMP phosphodiesterase. Proc. Ark. Acad. Sci. 40:17-19.
- GRAY, W. D., and C. J. ALEXOPOULOS. 1968. Biology of the Myxomycetes. Ronald press, New York, NY.
- HENNEY, H. H. JR. and M. YEE. 1979. Nuclear actin and histones from the myxomycete *Physarum flavicomum*. Cytobios 24:103-116.
- LOWRY, O. H., N. J. ROSEBROUGH, A. L. FARR, and R. J. RANDALL. 1951. Protein measurements with the folin phenol reagent. J. Biol. Chem. 193:265-275.
- LYNCH, T. J. and W. Y. CHEUNG. 1975. Underestimation of cyclic 3'-5' nucleotide phosphodiesterase by a radioisotopic assay using an anion-exchange resin. Anal. Biochem. 67:130-138.
- LYNCH, T. J. and M. E. FARRELL. 1984. Comparison of cAMP phosphodiesterase from the haploid and diploid phase of the myxomycete *Physarum flavicomum*. Cytobios 39:71-79.
- LYNCH, T. J. and M. E. FARRELL. 1985. Extracellular cyclic AMP phosphodiesterase from plasmodia and myxamoebae of *Physarum flavicomum*: Demonstration of a heat stable plasmodial enzyme. Cytobios 44:251-252.
- LYNCH, T. J. and M. S. ROSS. 1985. Demonstration of a Heat-Stable cyclic GMP phosphodiesterase in the medium of *Physarum flavicomum*. Proc. Ark. Acad. Sci. 39:139-141.
- MURRAY, A., M. SPISZMAN, and D. ATKINSON. 1971. Adenosine 3',5'-monophosphate phosphodiesterase in the growth medium of *Physarum polycephalum*. Science 171:496-498.
- PASTAN, I. H., G. S. JOHNSON, and W. B. ANDERSON, 1975. Role of cyclic nucleotides in growth control. Ann. Rev. Biochem. 44:491-522.

# ANALYSIS OF WILDFIRE OCCURRENCE IN SOUTHEASTERN ARKANSAS, 1984-1987

R. A. KLUENDER, L. C. THOMPSON  
and G. W. CALLAHAN

Department of Forest Resources  
University of Arkansas at Monticello  
Monticello, AR 71655

## ABSTRACT

Wildfire statistics for Arkansas Forestry Commission District I in southeastern Arkansas were analyzed for the period 1984 through 1987. A mean of 313 fires and 1103 hectares burned annually during the study period. Most (87%) of the land burned was forested. The greatest number (90%) of wildfires occurred when fire-danger was moderate to high. Most fires were started (90%) and detected (51%) by local residents. Arson was responsible for the majority of fires (68%) and hectares burned (65%). A disproportionately high number (43%) of the incendiary fires occurred in Ashley County. Mean fire size was smaller in this county. Fire suppression professionals attribute this to increased surveillance and suppression efforts in this county as compared with other counties. Many more fires occurred in 1987 than in other years. On forest-industry land more fires occurred in 1987 than in previous years (65% vs. 42%). Also, for all lands, more fires were of incendiary origin in 1987 than in previous years (78% vs. 60%). The authors provide evidence that the change in fire pattern in 1987 was due in part to a drastic change in administration of hunting privileges by a major forest industry in the area.

## INTRODUCTION

Despite the fear or respect with which most people treat fire, considerable loss of property, and occasionally human life, occurs annually from forest wildfires. In spite of the wildfire awareness crusades championed by Smokey Bear, arson continues to be the largest single cause of wildfires in the South (U.S. Department Agriculture, 1980). Unfortunately, well-meaning individuals continue to set forest and openland fires due to a misunderstanding of fire's ecological effects or an overestimation of their ability to control fire. Many of these fires escape control and culminate in wildfires.

The Arkansas Forestry Commission (AFC) is the principal organization charged with wildfire suppression in the state. For administrative purposes the AFC is organized into districts of about 0.7 million hectares each that typically include four to seven counties.

The 1987 spring fire season (January through June) in southeastern Arkansas was typical. However, the fall fire season was an anomaly, compared to the three previous years. Beginning with the first weekend in September, the number of wildfires increased sharply and continued for several months. These fires were concentrated on forest-industry lands and were of incendiary origin (arson). This research was undertaken to determine the typical pattern of wildfire occurrence in southeastern Arkansas and to investigate causes of the anomaly that occurred in 1987.

## METHODS

A data set for AFC District I was developed from Individual Fire Reports for 1984-1987 (AFC Form 2410.1). For each year, 20% of the Individual Fire Reports were randomly sampled. District I includes Ashley, Chicot, Cleveland, Desha, Drew, Jefferson and Lincoln counties in southeastern Arkansas (Figure 1). Chicot and Desha counties include mostly Delta agricultural land and fire occurrence in these counties is extremely low. The random sample did not include fires in either of these two counties.

Information recorded for each fire included: year, county, type of fire (forest, non-forest or a combination), day of the year, statistical cause (e.g. arson — wildfires willfully set by anyone to burn vegetation or property not owned or controlled by the person, and without consent of the owner or the owner's agent; debris burning — wildfires spreading from clearing land, burning trash, range, stubble, logging debris, or other prescribed burning), who discovered the fire (aerial,



Figure 1. Seven-county study area in southeast Arkansas.

tower, or ground surveillance by AFC, or general public), how the fire was extinguished (suppression, burn out or rain out) and fire-danger class-day. Fire-danger class-day is a measure of the total wildfire danger anticipated for an area. It is calculated based on anticipated fire behavior. Class 1 denotes low fire-danger, while Class 5 denotes extreme fire-danger. Arkansas uses a modified form of the 1972 National Fire-Danger Rating System (Deeming *et al.*, 1972). A second data set was compiled which contained the year, day of the year, month, and class-day for each day of the four-year period. Finally, data on number of fires by statistical cause and hectares burned for Arkansas and each county in District I were obtained from the Annual Fire Reports—Classification and Size Statistics, published by the Arkansas Forestry Commission.

The analysis of fire data was done with a standard statistical package (Morusis, 1988) using a multiple dimension frequency analysis.



**Analysis of Wildfire Occurrence in Southeastern Arkansas, 1984-1987**

**Table 1. Number and size of forest/non-forest wildfires in Arkansas Forestry Commission District I (southeastern Arkansas), 1984-1987.**

	Year				Mean
	1984	1985	1986	1987	
Total Wildfires (N)	123	274	322	533	313
Forest Fires (N)	103 (84%)	225 (82%)	267 (83%)	490 (92%)	271 (86%)
Non-Forest Fires (N)	10 (8%)	15 (5%)	10 (3%)	10 (2%)	11 (4%)
Mixed Forest & Non-Forest Fires (N)	10 (8%)	34 (13%)	45 (14%)	33 (7%)	31 (10%)
Total Area Burned (Ha)	439	804	1448	1720	1103
Forest Area Burned (Ha)	344 (78%)	695 (86%)	1314 (91%)	1434 (87%)	962 (87%)
Non-Forest Area Burned (Ha)	95 (22%)	109 (14%)	134 (9%)	226 (13%)	141 (13%)
Forest Area Burned per Fire (Ha)	2.8	2.5	4.1	2.8	3.1
Non-Forest Area Burned per Fire (Ha)	0.8	0.4	0.4	0.4	0.4
Average Fire Size (Ha)	3.6	2.9	4.5	3.2	3.5

Source: Arkansas Forestry Commission, Annual Fire Reports

**Table 2. Number and percentage of wildfires by the two leading causes and area burned for Arkansas and for Arkansas Forestry Commission District I (southeastern Arkansas), 1984-1987.**

	Year									
	1984		1985		1986		1987		Mean	
	N	Ha	N	Ha	N	Ha	N	Ha	N	Ha
<b>Arkansas</b>										
Totals	1,650	11,111	1,981	7,683	3,170	22,040	4,150	27,146	2,738	16,997
Cause	%									
Arson	39	60	43	53	49	66	54	55	48	59
Debris burning	31	22	30	21	26	17	23	15	26	17
<b>District I</b>										
Totals	123	439	274	804	322	1,448	533	1,720	313	1,103
Cause	%									
Arson	54	65	63	60	61	69	78	64	68	65
Debris burning	33	29	21	21	24	19	11	12	19	18

Source: Arkansas Forestry Commission, Annual Fire Reports

**RESULTS**

The completed data set included 252 fires occurring over the four-year study period. Table 1 shows the number and size of wildfires by type. The number of fires and hectares burned increased each year, with a mean of 313 fires and 1,103 hectares per year over the 4-year period. Of the total hectares burned, 87% were forested. Each fire burned about 3.1 forested hectares and 0.4 non-forested hectare.

Table 2 shows the two major causes of wildfires by year for all of Arkansas and for District I. As expected from historical records (U.S. Department Agriculture, 1980), arson remained the leading cause of wildfires, with fire escapes from debris burning distant second. Notably, the percentage of fires caused by arsonists increased with time, both

state-wide and in southeastern Arkansas. However, there was no trend for percentage of hectares burned by arson-caused fires. Wildfires caused by debris burning tended to decrease with time, both state-wide and in District I for percentage of fires and for percentage of hectares burned. Mean percentage of wildfires caused by arsonists was much higher in southeastern Arkansas than the state-wide average (68% vs. 48%). Although the trend was similar for hectares burned, the difference was not as great (65% vs. 59%). The reverse pattern was true for mean numbers of fires caused by debris burning, with southeastern Arkansas lower than the state-wide mean (19% vs. 26%). Mean percentage of hectares burned by wildfires started by debris burning was similar for Arkansas and District I. For southeastern Arkansas, arson and debris burning combined for 87% of the fires started and 83% of the hectares burned. The remaining fires were started by: equipment 2.8%, children 2.1%, railroads 1.7%, campfires 0.8%, lightning 0.8%, smokers 0.5%, and other miscellaneous causes 4.6%.

The AFC's aerial patrols discovered 28% of the fires, observers in towers discovered 8% and AFC ground patrols 12%, while local residents reported 51%. Almost 70% of the fires on non-industry private land were discovered by local residents. However, fires on forest-industry land were more often (53%) discovered by active patrols. Incendiary fires were more likely (53%) to be discovered by local residents than by active patrols. Active fire suppression extinguished 97% of the fires, while 3% burned out by themselves. Fires were as likely to occur in spring (49%) as in fall (51%).

The owner of the land on which the fire occurred was responsible for starting 14% of the wildfires. Local residents accounted for 59%, non-residents of the area accounted for 9% and "unidentified agents" started 18% of the wildfires. Only three groups were responsible for arson fires: local residents started 82%, non-residents started 12% and unknown persons caused the remaining 6%.

On days when fires occurred, 7% were ignited on Class 1 fire-danger days, 48% on Class 2, 42% on Class 3, 2% on Class 4 and 1% on Class 5 days. These percentages for fire-days by class-day did not differ over the study period.

Ashley County has historically been an area with a high incidence of incendiary fires; this trend continues. Of the total arson fires recorded for District I over the 4-year period, 43% were started by local residents of Ashley County. Arson-starts by local residents for the other counties were: Jefferson 15%, Drew 14%, Cleveland 8%, and Lincoln 2%. Ashley County consistently reports a disproportionately large number of all District I fires (43%) and District arson-caused fires (34%) (Table 3). However, in Ashley County, the percentage of hectares burned by

**Table 3. Comparison of number of arson-caused wildfires and area burned in selected counties to respective totals for Arkansas Forestry Commission District I, 1984-1987.**

	County	Fires	Year									
			1984		1985		1986		1987		Mean	
			N	Ha	N	Ha	N	Ha	N	Ha	N	Ha
<b>District I</b>												
Dist. Total			123	439	274	804	322	1448	533	1720	313	1103
<b>County</b>												
Ashley	All	37	30	43	17	36	20	48	27	43	23	
	Arson	20	19	32	16	26	18	43	20	34	17	
Cleveland	All	13	6	12	17	8	13	10	15	10	14	
	Arson	6	1	8	18	5	8	7	12	7	10	
Drew	All	20	16	20	28	26	31	22	30	22	28	
	Arson	11	8	11	32	12	20	13	11	12	15	
Jefferson	All	19	23	16	18	22	27	16	25	18	24	
	Arson	12	19	7	17	13	17	10	17	10	16	
Lincoln	All	12	25	10	20	8	9	5	4	7	11	
	Arson	4	18	5	17	6	6	4	4	4	6	

Source: Arkansas Forestry Commission, Annual Fire Reports

## R. A. Kluender, L. C. Thompson and G. W. Callahan

incendiary fires has been less than the percentage of incendiary fires by number. In other counties in the District these percentages are usually reversed (Table 3). These statistics may be attributed to the detection and suppression activities of AFC and forest-industry fire fighters, which are concentrated in Ashley County. Emphasis on detection and suppression in areas of high wildfire-incidence tends to keep fire size smaller by reducing total suppression time from detection to control.

For District I, fire-danger was significantly higher statistically in 1987 than in the other three years of the study. For 1984-1986, 41% of the days were Class 1, and 58% were Class 2 or 3 days. However, for 19887, 28% were Class 1 and 70% were Class 2 or 3 days. Fire-danger did not by itself, however, explain the anomalous fall fire-season of 1987. More fires occurred on forest-industry land (65%) during 1987 than in the previous three years (42%). In addition, there were many more incendiary fires in 1987 (78%) than other years (60%). Also, in 1987, 91% of the fires on forest-industry land originated by arson, with local residents responsible for 90%. The majority (65%) of 1987 fires on non-industry private lands were also the product of arsonists, with 92% started by local residents.

## DISCUSSION

The increasing number of fires over time is a cause for concern to fire suppression organizations and to forest landowners. Industrial forestland managers, facing the additional threat of arson, have just cause to be anxious.

Results of a study of national wildfire statistics from 1973 to 1978 (U.S. Department Agriculture, 1980) revealed that 39% of the wildfires and 55% of the hectares burned in the southern region were of incendiary origin, 26% of the fires and 20% of the hectares burned were started by debris burning. Arkansas and southeastern Arkansas are almost 10 and 20 percentage points, respectively, above the 5-year regional mean. Although explanations for these phenomena are many, several dominate. First, southeastern Arkansas has a mostly rural population that traditionally uses fire for land-management purposes, especially burning to manage unwanted vegetation and fuels that accumulate in the vast pine forests of southern Arkansas. Second, southeastern Arkansas has a climate that produces both an abundance of fuels and the seasonal weather patterns that carry wildfires through these cured fuels (Schroeder and Buck, 1970). Third, there is a tendency for local residents to deliberately set fires on the lands of another. The forested areas of southeastern Arkansas, especially in Ashley County, have a lengthy history of incendiary fires. Fortunately, the wildfires in Ashley County are kept "smaller" due to the surveillance and suppression efforts concentrated there.

There are several possible explanations of the anomalous 1987 fall fire season. The higher occurrence of Class 2 and 3 days played a part in the spread of fires once started. The class-day fire-danger classification scheme takes into account weather and fuel-flammability conditions. While there was an increase in fire-danger during 1987, the increase alone did not totally explain the disproportionate rise in incendiary fires, nor the fact that the majority of the increase in fire numbers was on forest industry land.

Concurrent with the beginning of the increase in incendiary fires was the beginning of small-game hunting season on September 12 and deer-archery hunting season on October 1 in southeastern Arkansas. The 1987 hunting season also marked the beginning of a drastically different policy concerning hunting on forest-industry lands in the study area. Prior to 1987, public access to most forest-industry lands in the seven-county area was unrestricted. Access was on a first-come basis, with some local hunting clubs claiming "rights" to certain areas by tradition. However, in 1987, the principal forest-industry landowner in the areas leased all hunting privileges on about 200 thousand hectares to hunting clubs. This precluded unrestricted and free access by the general public and denied access to many individuals who had hunted on these lands all of their lives. Most of these individuals had viewed the forest-industry lands as quasi-public in nature. Thus, we feel that the decision to lease land for hunting was the single most important factor in the high incidence of incendiary fires on forest-industry lands in 1987.

Studies of arsonists have indicated that people starting fires general-

ly come from a rural background, are less well socially integrated and tend to have less formal education than the norm (Bertrand *et al.*, 1970; Bertrand and Baird, 1975; Bradsaw and Huff, 1985). Additionally, results reported by Doolittle and Lightsey (1979) showed that the conduct of starting fires on the lands of another for traditional land-management reasons is at least tolerated if not often approved of in many cases by local populations. However, acts of pure vandalism are seldom condoned. Social protection of fire starters and the general perception that industry or public lands belong to everyone add to the problem of curtailing such behavior.

Doolittle and Lightsey (1979) emphasized that local perception of public and industry lands is strongly shaped by the company or agency's representative with local responsibility. If the local representative is viewed as a policeman from outside, rather than as a community member, there is a high likelihood of multiple land-management problems.

Based on results of a survey of forest industries in the southeastern U.S., Kluender (1978) found that 91% of the responding companies leased land for hunting and/or other privileges. Public response to these leasing programs was highly favorable (95%). Additionally, it was concluded in the same study that promoting a feeling of surrogate ownership and the use of local residents to actively help in protecting industry land was desirable and achievable. Such a high degree of cooperation was generally realized by preferential treatment of locals in hunting-lease assignments, firewood permits and educational endeavors.

## CONCLUSIONS

Organized wildfire detection in high risk areas and during high risk periods coupled with rapid response by trained fire suppression professionals are important factors in reducing the total acreage burned by wildfires. While the anomalous fall fire season of 1987 did incinerate valuable timber and open land, it was not the catastrophe that could have occurred had active surveillance and suppression not been practiced during the fall fire season. Finally, successful local administration of policy changes by large landowners requires a sustained flow of information in addition to well nurtured interpersonal relationships between landowner representatives and local residents.

## ACKNOWLEDGEMENTS

This paper was approved for publication by the Director, Arkansas Agricultural Experiment Station. Doug Grimmert, AFC District Forester, provided the raw data for District I.

## LITERATURE CITED

- BERTRAND, A. L., W. D. HEFFERNAM, G. D. WELCH and J. P. O'CARROLL. 1970. Attitudinal patterns prevalent in a forest area with high incendiary. Louisiana Agricultural Experiment Station, Bulletin No. 648. Baton Rouge. 20 pp.
- BERTRAND, A. L. and A. W. BAIRD. 1975. Incendiary in southern forests: a decade of sociological research. Mississippi Agricultural and Forestry Experiment Station, Bulletin No. 838. Mississippi State. 40 pp.
- BRADSAW, W. G. and T. G. HUFF. 1985. Arsonists in California and New York. U. S. Forest Service, Pacific Southwest Forest and Range Experiment Station, Research Note PSW-372. 5 pp.
- DEEMING, J. E., J. W. LANCASTER, M. A. FOSBERG, R. W. FURMAN, and M. J. SCHROEDER. 1972. The National Fire-Danger Rating System. U.S. Forest Service, Rocky Mountain Forest Range Experiment Station, Research Paper RM-84. 165 pp.

**Analysis of Wildfire Occurrence in Southeastern Arkansas, 1984-1987**

---

DOOLITTLE, M. L. and M. L. LIGHTSEY. 1979. Southern woods burners: a descriptive analysis. U.S. Forest Service, Southern Forest Experiment Station, Research Paper SO-151. 6 pp.

KLUENDER, R. A. 1978. Public use of industry lands in the southeast. American Pulpwood Association. Special Report Series. American Pulpwood Association. Washington, D.C. 18 pp.

MORUSIS, M. J. 1988. SPSS/PC+, statistical package for the social sciences. IBM/PC version. SPSS Inc., Chicago, IL. 1500 pp.

SCHROEDER, M. J. and C. C. BUCK. 1970. Fire weather, U.S. Dep. Agr. Handbook No. 360. 229 pp.

U.S. DEPARTMENT AGRICULTURE. 1980. 1978 Wildfire Statistics. U.S. Forest Service Publication FS-343. Government Printing Office, Washington, DC 78 pp.

# FACTORS AFFECTING ANNUAL DEER HARVEST IN ARKANSAS

R. A. KLUENDER<sup>1</sup>, T. B. WIGLEY<sup>1</sup>,  
and M. E. CARTWRIGHT<sup>2</sup>

<sup>1</sup>Arkansas Agricultural Experiment Station  
University of Arkansas  
Monticello, AR 71655

and  
<sup>2</sup>Arkansas Game and Fish Commission  
Sylamore Experiment Station  
Calico Rock, AR 72519

## ABSTRACT

An understanding of general forces affecting annual harvest is essential to the management of white-tailed deer (*Odocoileus virginianus*). A predictive model based on such factors would be valuable to managers. The relationship between 27 different variables and annual, legal deer harvest in Arkansas was evaluated for 1957-1986. Variables most affecting harvest were soybean acreage, hay acreage, number of days in the deer season, rain during the deer season, and total state timber production, total state pulpwood production, and deer harvest 2 years prior. Because significant autocorrelation and heteroscedasticity were present in the variables, log-linear, first differencing and non-linear quasi-Newton regression methods were used in addition to ordinary least squares. First differencing removed autocorrelation and heteroscedasticity, but fit was not acceptable ( $R^2 = 0.710$ ). Non-linear estimation of first differenced log transformed variables provided an acceptably high  $R^2$  (0.896) with high significance of the individual parameter estimators. Factors associated with habitat quality 2 years prior most affected present-year deer harvest.

## INTRODUCTION

Numerous attempts have been made to identify those factors most closely associated with white-tailed deer (*Odocoileus virginianus*) harvest (Fobes, 1945; Mechler, 1970; Hansen *et al.*, 1986). The ability to project harvest would enable managers to make better decisions regarding season parameters, and harvest and user regulations. Policy developed from incorrectly formulated models, however, can lead to disastrous consequences. Estimating legal deer harvest for policy reasons, thus, requires a proper knowledge and appreciation of the factors that influence annual harvest and the appropriate statistical tools to interpret them.

Many of the factors potentially affecting annual deer harvest, such as annual license sales, are classified as time-series variables. Present levels of time-series variables are at least partially dependent on antecedent levels. When this type of variable is used with ordinary least squares regression (OLS) modeling techniques, the error term may display autocorrelation and/or heteroscedasticity. Autocorrelation exists when the error term in one period is not independent of its value in other periods. Heteroscedasticity exists if there is unequal variance over time. The presence of either of these problems violates the fundamental assumptions of OLS regression (Neter and Wasserman, 1974). In addition, OLS methodology requires that the analyst specify the functional form of the estimated equation. There are, of course, no biological guidelines for specifying the relationships among variables potentially affecting deer harvest.

Two errors commonly derive from improper methodology in developing statistical models. First, variables are often included solely from their ability to reduce the unexplained variance of the dependent variable (Lovell, 1983). A second error is caused when the assumptions of OLS regression are not satisfied. This results in the estimates of the parameters not being best linear unbiased estimates of their true values. Therefore, the models themselves and structural inferences drawn from them may not be valid.

The objectives of this study were to (1) evaluate methods of modeling annual deer harvest using data commonly available to state wildlife agencies, and (2) use the most appropriate modeling technique to determine what factors affect annual deer harvest in Arkansas.

## METHODS

Twenty-seven variables for the period of 1957 through 1983 were examined for inclusion in a reliable structural model of annual, legal deer harvest. Data were obtained from the Arkansas Game and Fish Commission, the Arkansas Cooperative Extension Service's Crop Reporting Service, the National Oceanographic and Atmospheric Administration, and the Arkansas Forestry Commission. For each year, variables examined were annual legal deer harvest, sales of resident hunting licenses and dog licenses, number of days in the modern weapon, archery, crossbow and muzzleloader seasons, number of seasons per year for modern weapons, bag limits, total state production of timber and pulpwood, acreages of corn, soybeans, oats, hay, sorghum, wheat and rice, number of farms, and November rainfall in the Coastal Plain region (where most of the state's deer harvest is taken). Each time-series variable was also lagged 1 and 2 years.

Variables that were used in the modeling effort were chosen by a three step process. First, variables that showed a high correlation ( $r > 0.75$ ) with the dependent variable were noted. Second, for these variables, only if there was a strong visual relationship between the dependent and independent variables, was the variable designated for possible inclusion in the modeling effort. Final selection of variables for inclusion was made with the stepwise regression process. A parameter significance of  $P < 0.1$  was required for final inclusion in the model (Wilkinson, 1986). First-differencing (Neter and Wasserman, 1974) and logarithmic transformations were performed on all variables.

Five separate models were analyzed and the residuals checked for compliance with the underlying assumptions of OLS regression (Steel and Torrie, 1960). The five models were 1) standard OLS regression, 2) OLS regression of first-differenced data, 3) OLS regression of log-linear transformed data, 4) non-linear quasi-Newton regression (Wilkinson, 1986) of untransformed variables and 5) log-linear estimation of first-differenced and log-transformed data using quasi-Newton regression techniques (Wilkinson, 1986). All analyses were performed using SYSTAT (Wilkinson, 1986). Statistical significance was accepted at the  $P < 0.05$  probability level.

Elasticities (Pindyck and Rubinfeld, 1981) were computed for each variable included in the models. Elasticity is a ratio of responsiveness



## Factors Affecting Annual Deer Harvest in Arkansas

and is computed by dividing the percent change in the dependent variable by the associated percentage change in an independent variable. An elasticity value of 2.0 would indicate that for every 1% change in the independent variable a 2% change would occur in the dependent variable. If an elasticity value is less than one, the relationship is said to be inelastic. A value of one is said to be unitary elasticity, and a value greater than one is termed elastic.

## RESULTS AND DISCUSSION

Variables chosen were soybean acreage (current-year and 2 years prior), current-year hay acreage, state total timber production (2 years prior), state pulpwood production (2 years prior), deer harvest (2 years prior), days in modern weapon seasons and rain during the month of November (Table 1).

The error terms associated with three of the models resulted in violations of OLS regression assumptions. OLS regression on untransformed variables produced a model with a high  $R^2$  (0.93) but autocorrelation and heteroscedasticity were present. OLS regression of first-differenced variables produced a model free of autocorrelation and heteroscedasticity but with a relatively low  $R^2$  value (0.71). The log-linear OLS regression ( $R^2 = 0.93$ ) model resulted in heteroscedasticity in the residuals.

The error terms for two models (conformed to the assumptions of OLS regression. The non-linear estimation process using untransformed data, free of the assumptions shackling OLS regression, provided the best fit ( $R^2 = 0.994$ ) and high "t" values of the parameter estimators. Further, non-linear regression provided a multidimensional response surface conceptually compatible with a dynamic process such as wildlife harvest over time. However, untransformed data used in this method was not free of time-related bias. Sequential observations of independent variables had a high multiple correlation coefficient but could have been related to a third unidentified variable proxied by time. Without addressing this problem, increasingly distorted projections would occur.

The  $R^2$  (0.896) for the differenced, log-transformed variable set modeled with the quasi-Newton method was lower than for the non-linear estimation of untransformed variables. However, the transformed data set had several advantages. First, since the variables were stripped

of long-term time trends before modeling, their true relationship to each other was modeled. Second, auto-or serial correlation was removed from the series before modeling. Even though lagged variables were present, their selection for the model was not based on their ability to reduce autocorrelation. Rather, each variable stood alone in explaining variation of the dependent term. Finally, the quasi-Newton method of regression converges on the parameter estimates through an iterative process which can continue to the degree of precision desired. Therefore, parameter estimates generally had a lower standard error associated with them than with other methods. Only one variable was not significant at the 0.05 level, and only two were not significant at the 0.01 level (Table 1).

We hypothesize that the independent variables included in the models may be grouped as 2 sets of factors: those affecting hunt intensity and those influencing deer population density. Variables that could affect population density were timber production, pulpwood production, soybean acreage and deer harvest (all two years prior). Factors possibly related to hunt intensity were those for the current year: soybean acreage, hay acreage, days in modern weapon seasons and rainfall during November.

With the exception of current-year soybean acreage, all factors were found to be inelastic. That is, current-year deer harvest was not very responsive to changes in the independent variables (Table 1). Factors associated with population density two years prior had a stronger (2 to 3 times) influence on deer harvest than factors associated with hunt intensity but were only slightly inelastic with respect to harvest.

There are many possible explanations for how each variable related to population density could affect annual deer harvest. Timber production data used in this study includes clear cutting, which connotes severe stand disturbances and site preparation practices. These activities may disrupt forage production and diminish cover for a period of 1 to 2 years. In contrast, pulpwood production includes operations that often remove mid-story and create canopy openings without site preparation, thereby providing increased browse production. Thus, the difference in signs between pulpwood production and total timber production may reflect differences in animal use of harvested areas or alternatively, the ability of hunters to harvest deer. Soybean production two years prior could have provided forage during late spring and

Table 1. Results of log-linear estimation of annual deer harvest in Arkansas from 1956-1986 using Quasi-Newton non-linear regression with first-differenced and logged data.

Variables	Units	Elast- icity	Coeffi- cients	T-value
Constant			-0.311	-2.549***
<u>Present-year</u>				
Soybean acreage	Hectares x 1000000	-1.21	-1.209	-3.489***
Hay acreage	Hectares x 1000000	+0.31	0.307	1.412*
Seasons length, modern weapons	Days	+0.35	0.354	2.058**
November rainfall	Cm.	+0.15	0.150	3.125***
<u>Lagged 2 years</u>				
Soybean acreage	Hectares x 1000000	+0.74	0.740	3.045***
Timber production	Meters <sup>3</sup> x 1000	-0.85	-0.845	-2.118***
Pulp production	Meters <sup>3</sup> x 1000	+0.99	0.988	2.498***
Deer harvest	Animals	-0.46	-0.462	-3.787***

\*  $P < 0.10$ .

\*\*  $P < 0.05$ .

\*\*\*  $P < 0.01$ .

## R. A. Kluender, T. B. Wigley, and M. E. Cartwright

early summer, and beans prior to winter. Thus, a healthy herd two years previous would provide many of the animals that would be harvested in the current year.

The low elasticities for the variables we feel affected hunt intensity, such as modern weapon season length, suggest that these factors had minimal direct effect on deer harvest. The low responsiveness of deer harvest to season length is important to policy decisions. For example, our analysis shows that increasing the hunting season from 30 to 35 days (a 16.7% increase) would result in only a 5.8% increase in deer harvest. Thus, season length could be increased with the expectation that deer kill would not rise proportionately.

There are also numerous explanations for how variables related to hunt intensity could affect annual deer harvest. Of all the variables, current-year soybean acreage had the strongest statistical relationship to deer harvest. The negative elasticity of soybean acreage could be a result of soybeans typically being produced in large fields unsuitable for hunting. Conversely, hay fields in Arkansas are usually much smaller than soybean fields and often provide forage and cover during hunting season. Thus, hay acreage could positively affect harvest. Rainfall may reduce hunter numbers and deer harvest (Curtis 1972; Mechler 1970), but in this study total rainfall during the hunting season had a slightly positive effect on harvest.

## CONCLUSIONS

Deer harvest can be projected using data commonly available to state wildlife agencies. However, for best results data must be stripped of their time-dependency before the modeling process. Quasi-Newton non-linear regression, using first-differenced, logged data, was the most appropriate modeling procedure. Some variables, particularly those related to habitat or previous harvests, may affect deer harvest in subsequent time periods. Therefore, variables should be examined prior to modeling for significant time lags, and so that autocorrelation can be removed.

Based on results of this study, factors associated with habitat quality two years prior to harvest were the most important for determining present-year deer harvest. Only one hunting season factor, days in modern weapon seasons, was important. Many other variables that could affect annual deer harvest, however, were not examined. For example, off-road vehicle use or sales, and sex-age ratios of earlier deer harvests

could affect harvest, but these data were not available. It may also be important when modeling deer harvest to account for differences in variables among physiographic regions.

Definitive biological cause-and-effect relationships are more difficult to develop than a valid statistical model. While the modeling process we utilized insures statistical validity, adequate explanation of model structure is more difficult. One factor that makes interpreting the model results more difficult is that the data we used was aggregated at the state level. Accordingly, additional research on a regional level is required.

## LITERATURE CITED

- FOBES, C. B. 1945. Weather and the kill of white-tailed deer in Maine. *J. Wildl. Manage.* 9:76-78.
- HANSEN, L. P., C. M. NIXON, and F. LOOMIS. 1986. Factors affecting daily and annual harvest of white-tailed deer in Illinois. *Wildl. Soc. Bull.* 14:368-376.
- LOVELL, M. C. 1983. Data mining. *Review Econ. and Stat.* 65:1-12.
- MECHLER, J. L. 1970. Factors influencing the white-tailed deer harvest in Virginia, 1947-1967. M.S. Thesis, Virginia Polytech. Inst. and State Univ., Blacksburg. 106 pp.
- NETER, J., and W. WASSERMAN. 1974. Applied linear statistical models. Richard D. Irwin, Inc. Homewood, Ill. 842 pp.
- PINDYCK, R. S., and D. L. RUBINFELD. 1981. Econometric models and economic forecasts. McGraw-Hill Book Co., Inc. New York, NY. 630 pp.
- STEEL, R. G. D., and J. H. TORRIE. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc. New York, NY. 481 pp.
- WILKINSON, L. 1986. SYSTAT: the system for statistics. Systat, Inc. Evanston, Ill. 522 pp.

# ARKANSAS' TIMBER RESOURCE: YESTERDAY, TODAY AND TOMORROW

R. A. KLUENDER<sup>1</sup> and R. L. WILLETT<sup>2</sup>

<sup>1</sup>Arkansas Agricultural Experiment Station  
Monticello, AR

and

<sup>2</sup>Arkansas Cooperative Extension Service  
Monticello, AR 71655

## ABSTRACT

Demand for forest products continues to rise. Arkansas provides about 4% of the U.S. total forest production and about 12% of the south central region production. Questions exist about the ability of current forest resources to completely meet anticipated future demand. In 1985, the U.S. Forest Service and the Arkansas Timber Study Committee began to analyze the existing forest base to determine whether future demand could be met from the current forest, or if not, what management changes were needed to help meet future demand. In 1985, Arkansas forests covered approximately 48% of the total land area of the state. However, the forest land base has changed drastically over the last 20 years. Projections show that changes in forest acreage, ownership, and management types will continue for the next 40 years. Greatest changes in land ownership will occur in the nonindustrial private forest (NIPF) landowner sector. Forest industry lands will show the greatest changes in timber type. Public forest ownerships will continue to be a significant part of the state's total resource base, but will not undergo the significant changes of other sectors. This paper discusses these trends and the reasons for changes that are occurring.

## INTRODUCTION

Total U.S. aggregate demand for forest products is a function of population and the health of the economy. Long-term U.S. forest products consumption correlates highly with the traditional economic growth estimators. These general economic trends form the basis of forecasting long-term demand. Short-term market place fluctuations are generally not considered in long-term projections.

Long-term economic indicators suggest that demand for forest products will continue to rise steadily for the next half century according to the U.S. Department of Agriculture, Forest Service (U.S.D.A., 1987). In 1985, the Forest Service, began an in-depth evaluation of the ability of the nation's forests to meet forest products demand in the near and long term future. Because of the South's large forest acreage and fast timber growth rates the southern region was the focal point of the study. The head of the state forestry agency in each of the southern states was asked to appoint and chair a broad-based committee to provide information for the U.S. Forest Service's southwide study and to simultaneously assess the forests of the individual states. This paper is a report of the Arkansas Timber Study Committee's analysis of the past and present forests of Arkansas and its projections concerning the future forest.

## METHODS

The Arkansas Timber Study Committee consisted of representatives of forest industry, private non-industrial forest landowners, forestry consultants, the Arkansas Forestry Commission and forest research specialists. Committee members were appointed by and served under the leadership of the State Forester. Because of previous forest resource assessment experience, researchers from the Department of Forest Resources, University of Arkansas at Monticello, were selected to act as principal investigators in the study.

The study was divided into several phases. The initial phase was an assessment of the trends in forest acreage and management intentions by ownership class in the state. The first step was to compile resource data from the last U.S. Forest Survey of Arkansas (Quick and Hedlund, 1979a,b,c,d; van Hees, 1980), the Midcycle Survey (Beltz *et al.*, 1987), a U.S. Forest Service special report (U.S.D.A., 1987), and other information from the Arkansas Forestry Commission (unpublished data,

Arkansas Forestry Commission, 1986). Additionally, to validate the analysis, 50 forest managers in the state were surveyed regarding their personal and/or company's plans for changes in the future. The summary provided both qualitative and quantitative information regarding current trends in forest production, anticipated future production changes, and the effect of differing management strategies on their lands. General management implications for Arkansas' total forest base were developed based on the committee's assessment and the survey results. The survey and initial assessment were completed by late 1986.

In the second phase projections of forest acres by management type and ownership class were formulated. These projections were made based on long-term and more recent trends and upon the survey responses.

Third, the projections of future acreage and management practices which were developed in the first two phases of the study were used to estimate future timber production for the state. This projection was compared with that developed by the U.S. Forest Service (U.S.D.A., 1987).

Differences in projections made by the Forest Service and by the Arkansas Timber Study Committee were noted and reconciled where possible. In some cases, the Arkansas Timber Study Committee's projections were accepted as being the most likely future scenario because they were based on more specific data and better knowledge of unique conditions.

Where the Arkansas Timber Study Committee projections and the U.S. Forest Service projections were in close accord the U.S. Forest Service is cited as the original source. Where substantial differences were apparent, the projections of the Arkansas Timber Study Committee were accepted. Findings of other studies are also reported here to complete the present and future picture of the forest resource of the state.

## STUDY RESULTS

### THE FOREST BASE AND PRODUCTION

In 1985, Arkansas forests covered approximately 48% of the total land area of the state (U.S.D.A., 1987). Of the total land base, 50% was in commercial forest and 29% was in row crops. Other land uses, such as urban areas, rights of way, water, and open land accounted for about 19% of the surface area. Arkansas forests were predominantly hardwood (54.2%). Natural or planted pines and mixed pine-hardwoods

## R. A. Kluender and R. L. Willett

accounted for 27.4% and 18.3% respectively (U.S.D.A., 1987).

Production from Arkansas' forests has increased over time. Total production in 1965 was slightly less than 500,000 MCF (thousand cubic feet) and in 1985 was 542,208 MCF, an 8% increase. Production dips occurred in 1974-1976 (over 20%) and 1982-1984 (about 10%) and reflected dips in total U.S. lumber demand (Kluender *et al.*, 1988). Traditionally, Arkansas has provided slightly over 4% of the total U.S. production and over 12% of the south-central region's production (Kluender *et al.*, 1988).

Roundwood products had a combined stumpage value of about \$237.0 million in 1985. Production from private forest industry lands accounted for \$119.4 million or 50% of the total. Another 40% (\$95.0 million) came from stumpage payments to private non-industrial forest landowners and 10% (\$22.6 million) was for timber harvested from public ownerships (Kluender *et al.*, 1987.).

Table 1. Total Arkansas by management type, 1952 to 2030, in 1000's of acres.

Year	Pine		Mixed Pine-Hardwood	Hardwood		TOTAL
	Plantations	Natural		Upland	Bottomland	
1952	55	4481	2181	8500	4410	19627
1962	161	4690	2667	8351	4102	19971
1970	256	4180	2870	7779	2947	18032
1977	415	3882	2956	6691	2849	16793
1985	990	3377	2926	5970	2687	15950
1990	1486	3026	2743	5511	2775	15541
2000	2558	2296	2399	5076	2663	14992
2010	3027	2197	2132	4855	2537	14748
2020	3237	2158	2004	4697	2412	14508
2030	3348	2109	2001	4645	2346	14449

Source: Arkansas Timber Study Committee, 1988; U.S.D.A., 1987.

### THE CHANGING FOREST LAND BASE

Arkansas' total forest land-base decreased from 19.9 million acres in 1962 to about 16 million acres in 1985 (U.S.D.A., 1987) (Table 1). Future reductions will probably lower the forest base to about 14.4 million acres by 2030. Reductions in the past were attributable to three principal causes. First, there was large scale agricultural clearing in the Delta (1960-1975). Most of this clearing removed bottomland hardwood stands. Second, many upland hardwood stands were cleared for grazing, especially in the Ozark Region (1970s). And, finally, many other stands were cleared for urban development. Future removals from the forest base will most likely be for increased urbanization and industrialization.

Forest acreage reductions were primarily in the private nonindustrial landowner sector (Table 2). Acreages owned by the private forest industry (Table 3) and the public sectors (Table 4) have remained nearly stable, so they now comprise a larger percent of the total state forest area. In the late 1950's, private non-industrial forest landowners held almost 70% of Arkansas' total timberland. By 1985, however, private nonindustrial forest landowner's holdings had decreased to 54% (Table 5). In 1985, private forest industry held 27% and public ownerships 18%. We project that by 2030 Arkansas will have 14.4 million forested acres of which 47% will be owned by private non-industrial landowners, 31% in private industry and 22% by the public (previously unpublished projections developed by the Arkansas Timber Study Committee, 1988; U.S.D.A., 1987.).

### CHANGING MANAGEMENT TYPES

With the shift in control of forest lands has come a change in the nature of Arkansas' forest. The management styles of private forest industry and private nonindustrial forest land owners differ. Consequently, the distribution of forested acres by management type has also changed.

Acreage changes have occurred in all management types (Table 1). Decreases have occurred in the upland hardwood management group

Table 2. Private nonindustrial forest area by management type, 1952 to 2030, in 1000's of acres.

Year	Pine		Mixed Pine-Hardwood	Hardwood		TOTAL
	Plantations	Natural		Upland	Bottomland	
1952	24	1946	1136	6059	3368	12533
1962	75	2180	1549	6229	3060	13093
1970	134	1784	1423	5929	1838	11108
1977	207	1482	1549	4745	1730	9713
1985	276	1225	1478	4106	1569	8654
1990	320	1112	1405	3661	1694	8192
2000	400	947	1216	3295	1671	7529
2010	500	900	1015	3167	1589	7171
2020	550	850	880	3073	1503	6856
2030	560	800	855	3052	1457	6724

Source: Arkansas Timber Study Committee, 1988; U.S.D.A., 1987.

Table 3. Forest industry by management type, 1952 to 2030 in 1000's of acres.

Year	Pine		Mixed Pine-Hardwood	Hardwood		TOTAL
	Plantations	Natural		Upland	Bottomland	
1952	21	1693	617	1114	733	4178
1962	57	1631	650	951	733	4022
1970	110	1554	912	609	800	3985
1977	186	1613	912	667	784	4162
1985	681	1392	909	603	780	4365
1990	1121	1174	710	626	732	4363
2000	2088	648	433	587	623	4379
2010	2447	533	352	510	550	4392
2020	2602	513	336	457	499	4407
2030	2693	509	330	427	465	4424

Source: Arkansas Timber Study Committee, 1988; U.S.D.A., 1987.

Table 4. Publically owned forest area management type, 1952 to 2030, in 1000's of acres.

Year	Pine		Mixed Pine-Hardwood	Hardwood		TOTAL
	Plantations	Natural		Upland	Bottomland	
1952	10	842	428	1327	309	2916
1962	29	879	468	1171	309	2856
1970	12	842	535	1241	309	2939
1977	22	787	495	1279	335	2918
1985	33	760	539	1261	338	2931
1990	45	740	628	1224	349	2986
2000	70	701	750	1194	369	3084
2010	80	764	765	1178	398	3185
2020	85	795	788	1167	410	3245
2030	95	800	816	1166	424	3301

Source: Arkansas Timber Study Committee, 1988; U.S.D.A., 1987.

(- 2.5 million acres), the bottomland hardwood group (- 1.7 million acres) and the natural pine group (- 1.1 million acres). Net gains in the mixed pine-hardwood (+ 745,000 acres) and pine plantation groups (+ 935,000 acres) have mostly been captured from the natural pine and upland hardwood groups (U.S.D.A., 1987).

Since 1952, private forest industry holdings have increased (+ 287,000 acres) and the acreages in various management types have changed. The greatest change in the character of private forest industry land is the increase in pine plantations from less than 1% (1962) to 16% (1985) (Table 2). Plantation acres are projected to increase to 61% by 2030. At the same time, natural pine stands have decreased from 41% to 32% (1962 to 1985). They will probably decrease to only 12% by 2030. The mixed pine-hardwood group will decrease from 21% (1985) to about



## Arkansas' Timber Resource: Yesterday, Today and Tomorrow

Table 5. Distribution of growing stock, supply, and 1985 Growth:Drain ratios across landowners in Arkansas.

	Landowner Group		
	Private Forest Industry	Private Nonindustrial	Public
Acres Owned (%)	27	54	18
Supply Category			
Softwood			
Inventory (%)	39	40	21
Supply (%)	51	39	9
Growth:Drain Ratio <sup>1</sup>	1.16	1.52	1.29
Hardwood			
Inventory (%)	23	56	21
Supply (%)	29	62	9
Growth:Drain Ratio <sup>1</sup>	1.98	2.26	4.36
Total			
Inventory (%)	30	49	21
Supply (%)	44	47	9
Growth:Drain Ratio <sup>1</sup>	1.34	1.84	2.63

Source: U.S.D.A., 1987.

<sup>1</sup> Growth: Drain is the proportion of yearly forest growth removed in harvesting and other removals from the forest.

7% (2030). The acreage of both upland and bottomland hardwoods has been relatively stable since 1970 and now amount to 14% and 18% respectively on private forest industry lands. However, it is estimated that in 2030 upland and bottomland hardwoods will decrease to 10% and 11% respectively (U.S.D.A., 1987; previously unpublished projections developed by the Arkansas Timber Study Committee, 1988).

In 1983, 3% of private nonindustrial forest lands were in plantations (U.S.D.A., 1987) (Table 3). That may increase to nearly 8% by 2030 (previously unpublished projections developed by the Arkansas Timber Study Committee, 1988). During the same period natural pine stands will probably decrease from 14% to about 12%. Mixed pine-hardwood and upland hardwood stands will remain at about 13% and 45%, respectively, in 2030.

Management types on public lands should not change significantly over the period of the analysis (Table 4). Of total public acreage, plantations will account for roughly 3%, natural pine about 24%, mixed-pine-hardwood about 24%, upland hardwood about 35% and bottomland hardwoods about 13% (previously unpublished projections developed by the Arkansas Timber Study Committee, 1988).

## INVENTORY AND NET ANNUAL GROWTH

### Softwood

Softwood inventories in the state should continue to increase until about 1990, and then begin a slow decline. This will happen due to volume increases in older plantations coming to harvest age followed by harvesting in these same plantations. Increasing harvest and other removals will exceed declining softwood net annual growth by 1990 if Forest Service projections are correct.

Private forest industry will increase its harvest while converting natural pine stands to pine plantations with higher stocking. The trend of softwood timber growth dropping below timber drain could continue until about 2020. For some time softwood net annual growth rates have been declining on both industrial and nonindustrial private lands. In the next few years, removals will exceed net annual growth for the private sector. However, projections indicate that softwood growth:drain ratios (net annual forest growth divided by harvest removals) will once again approach 1:1 by about 2020 (U.S.D.A., 1987).

### Hardwood

Hardwood inventories in the state decreased in the 1970s and then began to increase. Projections indicate that hardwood inventory will peak around 2000 and then decline (U.S.D.A., 1987). Hardwood removals peaked in the early 1970s, coinciding with large scale agricultural clearings. The largest inventory declines were in the private

nonindustrial forest landowner sector. Hardwood net annual growth will fall below harvest beginning about the year 2000 if present cutting practices continue. Private forest industry removals of hardwood often coincides with the conversion of upland hardwood and mixed pine-hardwood stands to pine. Continued removal of hardwood at the present rate will reduce industry hardwood growing stock to the point that harvest will begin to exceed net annual growth by the year 2005 (U.S.D.A., 1987).

Hardwood inventory levels on private nonindustrial forest lands reflect a continued removal of less than growth until 1990. This may be followed by harvest exceeding net annual growth in the late 1990s. Harvests and other removals could continue to exceed growth until the end of the analysis period.

Public lands will continue to provide a major portion of hardwood supplies. In particular, the large Ozark and Ouachita National Forest hardwood resource will continue to provide at a high rate (previously unpublished projections developed by the Arkansas Timber Study Committee, 1988).

## STOCKING LEVELS AND STOCKING PROBLEMS

Over half of Arkansas' forest acres are at least 85% stocked with trees that are not rough or rotten (van Hees, 1980). Over three-fourth carry 70% or better stocking. However, less than a third of the total forest acres carry 25% or better stocking of silviculturally desirable trees (i.e., the type that foresters would favor). In addition, only 50% of the state's forest acres are better than 70% stocked with trees that are acceptable (they meet the requirements of growing stock trees, but not of being desirable) (van Hees, 1980). In short, Arkansas forest lands carry relatively high total stocking levels, but little of the forest land may be characterized as having commercially desirable or acceptable trees growing on it (van Hees, 1980; Birdsey *et al.*, 1981).

In general, the most serious problems with low quality growing stock are on private nonindustrial ownerships. Many of these owners have repeatedly harvested the better pine and hardwood trees while leaving the undesirable trees. On pine lands, low quality understory hardwoods are often allowed to dominate the site after pines are harvested. Private forest industry lands, on the other hand, are generally in good condition in regard to the quality of growing stock. As a rule, the companies eliminate cull and undesirable trees in both their hardwoods and pine stands. On pine lands they control undesirable hardwoods to insure that pines continue to dominate the site. Regardless of species and class, most Arkansas sites are of sufficiently high quality to support greater inventory, growth and harvest levels. This is especially true in the pine and mixed pine-hardwood areas of the state.

## METHODS OF INCREASING THE FUTURE TIMBER SUPPLY

Arkansas' timber production could be increased by manipulating site quality, stocking level, and the quality of growing stock on the site. Each of these factors is controllable to some degree. Control, however, will require investments of time and money. Just under 40% of the total forest acres in Arkansas are in need of some cultural treatment to improve productivity. The majority (60%) of these 6.6 million acres are private forest industry lands (22%), and public holdings (18%). The 6.6 million acres that could benefit from cultural treatment fall into two categories. First, there are about 2.0 million acres that have never been actively managed, but have a high potential for increased production of timber. These acres could yield a return of at least 10 percent (real, net of inflation) on the required investment (U.S.D.A., 1987). The total cost of treating these 2.0 million acres would be about \$184 million, or an average cost of \$92 an acre (U.S.D.A., 1987). The increased timber yield on these acres would amount to an additional 105 million cubic feet of net annual growth. This would amount of over 52 cubic feet per acre per year. The majority of the acres in this category are on private nonindustrial forest lands.

Second, there are approximately 2.75 million additional acres which could yield a real return of at least 4 percent but less than 10 percent on the cost of applying cultural treatments to correct stand deficiencies (U.S.D.A., 1987). The total cost of treating these 2.75 million acres would be \$350 million, or an average \$127 per acre. The estimated net annual growth increase would total 108 million cubic feet, or an addi-

## R. A. Kluender and R. L. Willett

tional 39 cubic feet per acre per year. In addition to increased growth and yield, additional forest cultural work would create jobs for Arkansas. However, most positions would be seasonal labor requiring little skill.



Figure 1. Past ■, USFS projected, ▲, and Arkansas Timber Study Committee projected, ●, production for Arkansas forests. Source: Kluender *et al.*, 1988; USDA, 1987; Arkansas Timber Study Committee, 1988.

## FUTURE PRODUCTION FROM ARKANSAS' FORESTS

The Arkansas Timber Study Committee estimates that production will rise to 620 million cubic feet by 1990 (up 14% from 1985), and to 725 million cubic feet by 2030 (up 34% from 1985) (Figure 1). It is probable that an increasing number of unmanaged private nonindustrial lands will come under management for the first time in the next five to ten few years. Many landowners will use natural regeneration or low cost-low intensity methods of artificial regeneration. Many will elect uneven-aged management schemes. Several facts have lead us to these projections. The most important of these facts are as follows. First, there is an increasing tendency of landowners to manage for products that have a higher marketplace value (e.g. sawlogs rather than pulpwood). Second, both natural regeneration and uneven-aged management have lower initial cost than artificial regeneration. Third, there continues to be an intense interest by private nonindustrial forest landowners in non-timber forest values. These values are perceived to be at variance with some plantation management techniques. Fourth, uneven-aged management allows for frequent income flows from the forest investment. Fifth, many of the under-managed or non-managed sites in Arkansas are not well suited to intensive forest management practices due to site conditions or small tract size. Sixth, there are an increasing number of Arkansas landowners who are willing to perform forest management work on their land themselves.

After intensive study, the Arkansas Timber Study Committee makes the following suggestions in four areas for increasing long term supply from the state's forest lands. First, Improve and control stocking on all forest land in the state. This can be done by gradually replacing undesirable and unmerchantable stems with high quality growing stock. Desirable crops trees should also be released to grow free of competition. Second, increase the quality of forest investment opportunities. Low initial cost investment alternatives should be used on both industrial and private lands when ever possible. Qualifying landowners should utilize incentive programs such as FIP, CRP, etc. that can offer significant cost reductions and provide for higher internal rates of return on investments. Landowners should use the planning and management assistance that is available from public and private sectors of the forestry community to aid in decision making. Also the taxation climate for timber investment at the state and federal level needs to be improved

if forest investment is to be competitive. Third, improve markets for forest products. Research should be continued to develop forest products compatible with the long term timber resource of the state. In addition, export markets for Arkansas forest products should be pursued to provide additional outlets for Arkansas' products. Fourth, overcome factors restricting the development of Arkansas resources. Arkansas forest landowners need to be provided with continuing educational services to enable them to make good decisions. The major problems to be dealt with in bringing about major changes to the states' forests are not technical questions but rather turning individual landowners into active forest managers. Better road systems need to be provided into undeveloped but heavily timbered areas of the state. Better access will improve markets and the forest resource to management as it is in other places in the state.

## LITERATURE CITED

- BELTZ, R. C., R. LEISTER and W. R. SMITH. 1987. Midcycle survey of Arkansas' forest resources. U.S. Department of Agriculture, Forest Service. Resource Bulletin SO-123. Southern Forest Experiment Station, New Orleans, 21 pp.
- BIRDSEY, R. A., W. S. VAN HEES, and R. C. BELTZ. 1981. Pine regeneration in southwest Arkansas. U.S. Forest Service. Southern Forest Experiment Station. Research Paper SO-165. New Orleans, LA. 12 pp.
- KLUENDER, R. A., J. L. GREENE, and B. G. BLACKMON. 1987. The effect of the tax reform act of 1986 on forest income and forest lands values in Arkansas. *Arkansas Economic and Business Review*. 20(2):27-35.
- KLUENDER, R. A., E. W. McCOY, and J. K. EASTERLING. 1988. Arkansas forest products industry. Bulletin 908. Arkansas Agricultural Experiment Station. University of Arkansas, Fayetteville, AR. 42 pp.
- QUICK, R. and M. HEDLUND. 1979a. Forest statistics for Southwest Arkansas counties. U.S. Department of Agriculture, Forest Service. Resource Bulletin SO-70. Southern Forest Experiment Station. New Orleans. 22 pp.
- QUICK, R. and M. HEDLUND. 1979b. Forest statistics for Arkansas Delta counties. U.S. Department of Agriculture, Forest Service. Resource Bulletin SO-71. Southern Forest Experiment Station. New Orleans. 22 pp.
- QUICK, R. and M. HEDLUND. 1979c. Forest statistics for Arkansas Ouachita counties. U.S. Department of Agriculture, Forest Service. Resource Bulletin SO-72. Southern Forest Experiment Station. New Orleans. 22 pp.
- QUICK, R. and M. HEDLUND. 1979d. Forest statistics for Arkansas Ozark counties. U.S. Department of Agriculture, Forest Service. Resource Bulletin SO-73. Southern Forest Experiment Station. New Orleans. 22 pp.
- U.S. DEPARTMENT OF AGRICULTURE. 1987. The south's fourth forest: Alternatives for the future. (Review draft) from U.S. Forest Service. Government Printing Office. Washington, D.C. 540 pp.
- van HEES, W. 1980. Arkansas forests: Trends and prospects. U.S. Forest Service, Southern Forest Experiment Station, Resource Bulletin SO-77. New Orleans, Louisiana. 32 pp.

# ASSOCIATION OF MESOCOTYL AND COLEOPTILE ELONGATION WITH SEEDLING VIGOR IN RICE

M. A. MGONJA  
Tanzania Agri. Res. Inst.  
Tanzania, Africa

R. H. DILDAY and S. L. SKINNER  
USDA-ARS-SPA  
P.O. Box 287  
Stuttgart, AR 72160

F. C. COLLINS  
CR Seed  
P.O. Box 729  
Bay, AR 72411

## ABSTRACT

Three experiments were conducted to evaluate the relationship of mesocotyl and coleoptile elongation to seedling vigor and plant height in rice (*Oryza sativa*). A laboratory experiment was conducted to evaluate the potential lengths of the mesocotyl and coleoptile of semidwarf and standard rice genotypes. Four genotypes exhibited inherent differences in their ability for mesocotyl and coleoptile elongation. The semidwarf genotypes ('M-101' and RU 7703008) showed reduced mesocotyls, coleoptiles, and total lengths (mesocotyl + coleoptile); whereas, the tall plant type ('L-201' and 'Labelle') had comparatively longer mesocotyls, coleoptiles, and total lengths. It is assumed that mesocotyl elongation is the most important of the three parameters evaluated in seedling vigor, but total length is the least variable. Significant differences were detected among seeding depths and genotypes in the greenhouse experiment for emergence percentage, emergence index, coleoptile, and mesocotyl lengths. The field experiment verified that the low seedling vigor was due to the shorter mesocotyls and coleoptiles of the semidwarf genotypes in this test and was primarily responsible for poor stand establishment.

## INTRODUCTION

Dwarf genotypes of wheat (*Triticum aestivum* L. em. Thell.) that were developed in Mexico by N.E. Borloug in the 1970's have doubled wheat yields in many countries and contributed to the "Green Revolution". Similar advances have been made in rice (*Oryza sativa* L.) with the release of dwarf and semidwarf genotypes. Short-statured genotypes are desirable for their increased lodging resistance and high nitrogen responsiveness which usually increase grain yield (Hargrove *et al.*, 1980, Mikkelsen and Dedatta, 1980).

Plant population is a major yield component and is often directly dependent upon seedling vigor and stand establishment. However, difficulties in establishing a stand of short-statured rice have been associated primarily with the germplasm that has been used in breeding programs to develop semidwarf genotypes (Dalrymple, 1980). Also, seedling emergence problems have been associated with the short-statured phenotype in winter wheat after deep seeding. The coleoptile ruptures below the soil surface and does not allow the leaves to push through the soil (Sunderman, 1964). Research on semidwarf rice genotypes have indicated that reduced mesocotyl elongation seems to hinder seedling emergence and, consequently, leads to poor stand establishment (Turner *et al.*, 1982). Therefore, the mesocotyl and coleoptile have a major role in stand establishment of most monocotyledonous plants.

The mesocotyl is the internode between the coleoptile node and the point of union of the root and the culm. The mesocotyl (internode) only elongates in the dark; therefore, its length can be measured only when the seedlings have been grown in a dark environment (e.g., growth chamber or underground). The elongation of the mesocotyl elevates the coleoptile, which is the protective sheath enclosing the young leaves, above ground. Nagai (1958) used mesocotyl and coleoptile lengths to differentiate genotypes and indicated that the two traits could serve as indices of seedling vigor.

Knowledge of the relationship between the mesocotyl, coleoptile, and plant height is essential as breeders incorporate semidwarf genes into new and adapted rice genotypes. The objectives of the present study were to: a) determine the length of the mesocotyl and coleoptile of two semidwarf and two standard rice genotypes; b) compare the mesocotyl/coleoptile elongation phenomenon in laboratory, greenhouse, and field conditions; c) determine the effect of seeding depth of the genotypes on mesocotyl and coleoptile elongation; d) and examine the relationship between mesocotyl/coleoptile elongation, percentage emergence, and plant height.

## MATERIALS AND METHODS

In this study three rice genotypes and one experimental line, all of diverse origin, were evaluated. The semidwarf genotypes were 'M-101' (an early maturing California genotype) and RU 7703008 (a sister line of a USDA-Texas Agricultural Experiment Station midseason genotype 'Bellemont'). The other two genotypes of comparatively taller stature were 'Labelle', a genotype developed by USDA and the Texas Agriculture Experiment Station, and 'L-201' (an early maturing genotype developed by the California Cooperative Rice Research Foundation). Three experiments were conducted at the Rice Research and Extension Center near Stuttgart, Arkansas.

## LABORATORY, GREENHOUSE, AND FIELD EXPERIMENTS

A laboratory test was designed to determine the potential length of the mesocotyl and coleoptile of the four genotypes and to test the visibility of the seed. In this test, a modification of the slantboard technique described by Jones and Peterson (1976) was used. Moistened blotters (15 x 20 cm) were placed on acrylic plates of the same size and twenty seeds were placed on the blotters approximately one cm apart, germ-end down along a horizontal line 4.5 cm from the bottom edge of the blotter.

The seeds were held in position by a single thickness tissue that was moistened with distilled water. Plates, blotters, and adhering seed were placed in slotted racks that were made of acrylic plastic. Each rack held 15 plates. The entire assembly was placed in aluminum trays that contained enough distilled water to keep the lower edge of the blotters continuously wet. The trays were wrapped in black polyethylene bags to maintain high humidity, eliminate evaporative cooling, and to provide a dark environment because of the effect of light on mesocotyl/coleoptile elongation. The trays were placed in a temperature-controlled germinator for 10 days (at 25°C ± 1.0), after which the mesocotyl and coleoptile lengths were measured. Abnormal or diseased seedling data were also recorded for percent germination, but their mesocotyl and coleoptile lengths were not measured because of abnormal growth and development of those seedlings.

The greenhouse test was designed to determine the effect of seeding depth and genotype on mesocotyl/coleoptile length and their subsequent influence on seedling emergence. A split-plot design with four replications was used. Seven seeding depths ranging from 1.3 to 8.9 cm (increments of 1.25 cm) were handled as main plots, and the four genotypes were sub-plots. Aluminum trays were lined with single thickness paper. Soil was added to the trays and uniformly spread to provide a thin layer on which the seeds could be planted. Each tray represented a particular



## M. A. Mgonja, R. H. Dilday, S. L. Skinner, and F. C. Collins

seeding depth. Four rows were marked in each tray and the genotypes were randomly assigned. Thirty seeds per row were planted and a marked garden label was placed vertically to attain the required seeding depth for each tray. Water was added at regular intervals to maintain adequate soil moisture for seed germination. Seedling emergence started on the fourth day after seeding and seedling counts were taken daily for eight days. The total number of seedlings for a particular day minus the previous total equaled the seedling emergence for an individual day. This information was used to determine the emergence percentage and emergence index (EI). The formula used to determine EI was the one used by Jones and Peterson (1976) and McKenzie *et al.*, (1980). The EI provides a weighted score for both early emergence and high emergence percentage.

A field experiment designed to complement the laboratory and greenhouse experiments was conducted. The four genotypes were seeded on a Cowboy silt loam soil, a fine montmorillonitic thermic Typic Albaqualf. The seeding depths were randomly assigned to the main plots and each main plot was replicated six times. The land was prepared and rolled so the soil was uniformly compact and essentially level. This allowed for uniform planting depth. Thirty mature seeds were planted in each row with a cone planter. To minimize variability of the main plots between replications due to planter effect, the planter plates were adjusted for each planting depth for each main plot. The seeding depths of 1.3, 2.5, 3.8, 5.1, 6.4 and 7.6 cm were tested.

Rows were 18 cm apart and 1.5 m long. Propanil was applied two weeks after seeding at the rate of 9.3 kg/ha for weed control. Urea fertilizer was applied at the rate of 133 kg N/ha in three split applications. The first fertilizer application was made three weeks after seeding and a 5 to 8 cm flood was applied and maintained until maturity. The number of emerged seedlings 20 days after seeding was recorded.

Statistical analysis of greenhouse and field data was accomplished by using SAS procedures of the General Linear Model and Analysis of Variance. Multivariate statistics were necessary because the model statements included more than one dependent variable (Helwig, 1979). Mean separations were by Duncan's Multiple Range Test (1955).

Table 1. Mean separation for coleoptile, mesocotyl and total length laboratory experiment.

Variety	Mesocotyl	Coleoptile
- - - Lengths in mm - - -		
M-101	2.1	26.7
RU 7703008	1.6	13.4
L-201	16.9	31.6
Labelle	15.9	20.7
LSD 0.05	2.9	7.6

## RESULTS AND DISCUSSION

The four genotypes differed significantly in mesocotyl, coleoptile and total length (Table 1). The mesocotyl and total lengths of M-101 and RU 7703008 were significantly shorter than those of L-201 and Labelle. This supported the assumption by Turner *et al.* (1982) that dwarf genotypes have shorter mesocotyl and total lengths as compared to standard genotypes. These data also showed that genotypes exhibit different potential for mesocotyl and coleoptile lengths and that differences in mesocotyl and coleoptile lengths can be selected by breeders in subsequent development of semidwarf genotypes for drill-seeded rice.

**Emergence Percentage:** A significant effect on seedling emergence was observed between seeding depths and genotypes (Table 2 and 3). The genotype differences could be attributed to their inherent mesocotyl and coleoptile length differences. Genotypes with the greatest total length (mesocotyl and coleoptile) in the laboratory test had correspondingly

Table 2. Percentage emergence of the four genotypes at seven different seeding depths greenhouse experiment.

Seeding depth cm	- - - - - Genotype - - - - -			
	M-101	7703008	L-201	Labelle
- - - - - Emergence (%) - - - - -				
1.3	91.7	92.5	90.0	94.2
2.5	90.8	89.2	85.8	90.8
3.8	85.8	82.5	81.1	87.5
5.1	82.5	55.0	82.5	89.2
6.4	60.8	44.2	78.3	83.3
7.6	34.2	5.0	63.3	78.3
8.9	0.0	0.8	15.0	19.2
Cultivar Mean	63.7	52.7	71.0	77.5

LSD for genotype differences = 3.6.  
0.05

LSD for seeding depth differences = 10.3.  
0.05

Table 3. Emergence Index of four genotypes at seven different seeding depths greenhouse experiment.

Seeding depth cm	- - - - - Genotype - - - - -			
	M-101	7703008	L-201	Labelle
- - - - - Emergence (%) - - - - -				
1.3	83.5	76.0	81.8	84.9
2.5	78.1	62.7	76.2	77.6
3.8	49.4	41.2	51.9	54.9
5.1	43.1	24.3	65.4	62.3
6.4	31.5	18.8	52.0	49.5
7.6	15.0	0.8	32.7	41.7
8.9	0.0	0.0	5.0	5.0
Cultivar Mean	42.9	32.0	52.1	53.7

LSD for seeding depth differences = 20.3.  
0.05

LSD for genotype differences = 4.1.  
0.05

higher emergence percentage at deep seeding in the greenhouse experiment. However, there was a consistent decrease in the emergence percentage as seeding depth increased.

Each genotype had a threshold seeding depth and many shallower depth gave an adequate stand establishment. Most seedling mortality occurred before emergence, therefore, emergence percentage was one indicator of seedling vigor. This verified the assumption that the short-statured genotypes used in this test were less vigorous based on emergence and subsequent growth and development as compared to the standard genotypes, especially at deeper seeding.

**Mesocotyl, Coleoptile, and Total Length.** Significant differences among mesocotyl, coleoptile, and total length due to seeding depths and genotypes were detected (Table 4 to 6). The mesocotyl and coleoptile of L-201 and Labelle showed greater elongation potential than did M-101 and RU 7703008. These data agree with those of Mers' (1979) who found that in oats the reduction in mesocotyl growth was accompanied by a transient promotion of coleoptile growth that was apparently due to a reduction in auxin.



Association of Mesocotyl and Coleoptile Elongation With Seedling Vigor in Rice

Table 4. Mesocotyl lengths of four genotypes at seven different seeding depths greenhouse experiment.

Seeding depth cm	Genotype			
	M-101	7703008	L-201	Labelle
	Mesocotyl/Length (mm)			
1.3	2.1	2.2	4.9	6.8
2.5	2.4	1.9	15.2	14.8
3.8	3.2	1.7	14.3	20.7
5.1	5.7	2.9	20.4	32.1
6.4	3.3	2.2	17.7	21.1
7.6	7.2	1.5	24.3	35.2
8.9	0.0	0.0	30.8	34.8
Cultivar Mean	3.4	1.8	18.2	23.6
LSD for seeding depth differences = 8.4 0.05				
LSD for genotype differences = 2.1. 0.05				

Table 5. Coleoptile lengths of four genotypes at seven different seeding depths greenhouse experiment.

Seeding depths cm	Genotype			
	M-101	7703008	L-201	Labelle
	Coleoptile/Length (mm)			
1.3	11.6	12.2	7.4	7.1
2.5	20.1	20.1	11.8	10.6
3.8	26.6	19.5	22.0	14.3
5.1	37.4	38.2	22.1	17.5
6.4	26.6	27.2	25.0	26.7
7.6	40.2	16.0	36.0	31.1
8.9	0.0	0.0	41.6	29.9
Cultivar Mean	23.2	19.0	23.1	19.6
LSD for seeding depth differences = 12.5. 0.05				
LSD for genotype differences = 2.8. 0.05				

Table 6. Arcsin emergence percent of the four genotypes planted at six seeding depths field experiment.

Seeding depth cm	Genotype				Seeding depth average
	M-101	7703008	L-201	Labelle	
	Arcsin %				
1.3	44.1	88.2	100.0	97.2	81.1 a
2.5	36.5	78.2	100.0	94.8	77.4 b
3.8	32.4	58.3	92.0	87.6	67.6 c
5.1	23.0	40.1	93.4	84.5	60.3 d
6.4	24.8	28.1	89.0	83.3	56.3 e
7.6	18.9	28.2	84.0	74.4	51.4 f
Cultivar average	30.0 d	53.5 c	93.1 a	87.0 b	

Means followed by same letter are not statistically different at the 0.05 level of probability.

Total length (mesocotyl + coleoptile) is an important factor in seedling vigor. Emergence occurs only when the coleoptile tip brings the primary leaf to the surface of the soil which is a combined effect of the mesocotyl and coleoptile. Data from this study and Turner *et al.* (1982) agree that total length is a more valuable parameter in seedling vigor studies than mesocotyl or coleoptile length alone. This assumption is based primarily on lower variability of the total length versus the variability of the mesocotyl or coleoptile lengths measured separately. For example, the coefficient of variability (CV) of the mesocotyl, coleoptile, and total length of both the laboratory and greenhouse tests were 38.2, 16.5 and 9.6 versus 32.8, 24.6, and 19.7%, respectively. The short-statured genotypes, M-101 and RU 7703008, showed a decrease in total length at deeper seedings, which indicates that emergence is impaired at deep seeding. Cultivars, L-201 and Labelle, which showed greater potential for mesocotyl elongation also exhibited higher emergence percentage. These data show that the mesocotyl, though highly variable, contributes more than the coleoptile to seedling vigor at deeper seeding depths.

This experiment was conducted to determine the relationship between the mesocotyl and coleoptile elongation in the laboratory and greenhouse experiments versus seedling emergence and plant height at maturity in field conditions. Analysis of variance detected significant differences among genotypes for seedling emergence and plant height. Significant differences are also detected among seeding depths for seedling emergence percent.

The genotypes M-101 and RU 7703008 showed poorer seedling emergence in the field experiment than in the greenhouse. This was probably due to soil compaction of the Crowley silt loam soil in the field after heavy rains (Table 6). A bar diagram showed significant differences between plant height and mesocotyl lengths by genotype (Fig. 1). Figure 1 shows that the short-statured genotypes M-101 and RU 7703008 exhibit reduced mesocotyl lengths and plant heights; whereas, L-201 and Labelle (tall plant types) had comparatively longer mesocotyls. This trend is a major concern among breeders because of the possibility of a pleiotropic effect of mesocotyl/coleoptile elongation and plant height. Furthermore, the assumption of many rice breeders that short-statured plants have a short mesocotyl and low total length which accounts for their low emergence percentage at deeper seeding is supported by these data. The opposite appears to be true for the tall phenotypes.

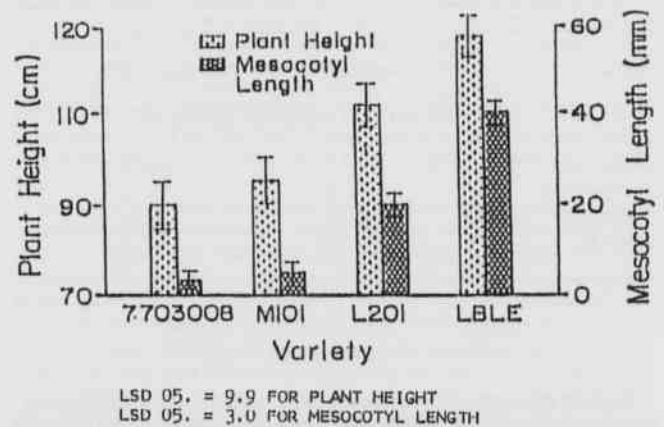


Figure 1. Plant height and mesocotyl lengths of four cultivars (data from 1981 and 1982).

LITERATURE CITED

DALRYMPLE, D. G. 1980. Development and spread of semidwarf varieties of wheat and rice in the United States. Agri. Econ. Reports No. 455, USAD, 101CD in cooperation with USAID, Washington, D.C.

**M. A. Mgonja, R. H. Dilday, S. L. Skinner, and F. C. Collins**

---

- DUNCAN, D. B. 1955. Multiple range test and multiple F tests. *Biometrics* 11:1-42.
- HARGROVE, J. R., W. R. COFFMAN and V. L. CABANILLA. 1980. Ancestry of improved genotypes of Asian rice. *Crop Sci.* 20:721-727.
- HELWIG, J. T. and K. A. COUNCIL (eds.). *The SAS Users Guide*, 1979 ed.
- JONES, D. and M. L. PETERSON. 1976. Rice seedling vigor at suboptimal temperature. *Crop Sci.* 16:102-105.
- MACKENZIE, K. S., J. N. RUTGER, and M. L. PETERSON. 1980. Relation of seedling vigor to semidwarfism early maturity and pubescence in closely related rice lines. *Crop Sci.* 20:169-172.
- MER, C. L. 1959. A study of the growth and the photoperceptivity of etiolated oat seedling. *J. Exp. Bot.* 10:220.
- MIKKELSEN, D. S. and S. K. DEDATTA. 1980. Rice Culture. Pp. 147-234, *in* Bor S. Luh (ed.). Rice production and utilization. AVI Publishing Co., Westport, CT.
- NAGAI, I. 1958. Japonica rice. Its breeding and culture. Yokendo, Tokyo. 843 pp.
- SUNDERMAN, D. W. 1964. Seedling emergence of winter wheats and its association with depth of sowing, coleoptile length under various conditions, and plant height. *Agron J.* 56:23-25.
- TURNER, F. T., C. C. CHEN, and C. N. BOLLICH. 1982. Coleoptile and mesocotyl lengths in semidwarf rice seedlings. *Crop Sci.* 22:43-46.

# AUTUMN FOODS OF WHITE-TAILED DEER IN ARKANSAS

THOMAS A. NELSON<sup>1</sup>, LUKE EGGERING<sup>1</sup>,  
and DANNY ADAMS<sup>2</sup>

<sup>1</sup>Fish and Wildlife Biology Program  
Arkansas Tech University  
Russellville, AR 72801  
and

<sup>2</sup>International Paper Company  
Arkadelphia, AR

## ABSTRACT

Rumen contents from 65 hunter-harvested deer were collected and analyzed during 1985-86 to estimate the principal autumn foods consumed by white-tailed deer inhabiting the Ozark Mountains, Arkansas River Valley, and Gulf Coastal Plain regions of Arkansas. Deer in the Ozarks and Coastal Plain fed heavily on woody browse species, which comprised 99% of rumina identified from these 2 regions. Acorns were the primary food of deer in these heavily forested areas. Acorns and other woody browse were less important to deer inhabiting the Arkansas River Valley. In this region of interspersed agricultural fields and bottomland forests, soybeans and corn comprised 75% of the diet, and acorns accounted for only 2%.

## INTRODUCTION

The principal food consumed by white-tailed deer (*Odocoileus virginianus*) have been well documented in many southern states (Korschgen, 1962; Lay, 1965; Harlow *et al.*, 1975). However, little information is available on the food habits of deer in Arkansas, and no studies have been conducted to compare the diets of deer inhabiting varying ecoregions of the state. A prior study reported important fall foods of deer inhabiting the Ouachita Mountains (Fenwood *et al.*, 1985); however, no published data are available describing deer food habits in three other ecoregions: the Ozark Mountains, Arkansas River Valley, and Gulf Coastal Plain. Such information is useful for habitat improvement and for the assessment of range quality. The purpose of this report is to compare and contrast the autumn diets of deer inhabiting these three ecoregions.

## MATERIALS AND METHODS

During November of 1985 and 1986, rumen samples were collected from 65 hunter-harvested deer at locations representative of each ecoregion. Rumina was collected from 21 deer harvested in Carlk Co., located in the mixed pine-hardwood forests of the Gulf Coastal Plain. Assessment of the diet of deer in the Arkansas River Valley was based on samples from 32 deer collected on Holla Bend National Wildlife Refuge in Pope Co. Holla Bend supports both bottomland hardwoods and extensive agricultural fields, a mixed habitat that is characteristic of much of the Valley. Twelve deer were collected on the Sylamore Wildlife Management Area in Stone and Baxter Counties; an area of the Ozark Mountains dominated by oak-hickory forests.

Approximately 3 L of rumina were collected from each deer; samples were labelled and stored frozen for subsequent analyses. Each sample was washed through a standard 9.51-mm mesh sieve to remove materials too small for analysis. Prior research demonstrated that this size screen provides a reasonable estimate of most food items present in the rumen (Harlow and Hooper, 1971). Suspended food items were separated by species or genus; the portion of each plant consumed (leaves, stems, or fruits) and its volume (measured by water displacement) were recorded. The importance of each food item to deer was based on its relative volume and frequency of occurrence in these rumens.

## RESULTS AND DISCUSSION

All of the deer collected in the Ozarks fed heavily on acorns, which comprised over 90% of the fall diet (Table 1). Fruits and vegetative

parts of woody species made-up 98% of the foods identified from these individuals. Woody vines, such as greenbriers (*Smilax* spp.) and grapes (*Vitis* spp.) occurred frequently in these deer, but seldom constituted more than 5% of the total volume in any rumen. Small volumes of sumac (*Rhus glabra*, *R. copallina*) were also common. Although eastern redcedar (*Juniperus virginiana*) is considered to be a preferred fall food of deer in Missouri (Murphy and Crawford, 1970), and occurs in scattered glades throughout the Ozarks, the species was not found in our samples.

Deer inhabiting the mixed pine-hardwood forests of the Coastal Plain had an autumn diet similar to that of deer in the Ozarks. Acorns predominated in the rumina of these individuals (Table 1); 28 of 31 individuals sampled had fed primarily (87.1%) on acorns. Other woody plants that were commonly eaten in this region included Japanese honeysuckle (*Lonicera japonica*), greenbriers, and sumac.

Deer harvested in the Arkansas River Valley fed on a very different diet than deer inhabiting other regions (Table 1). Agricultural plants, particularly soybeans and corn, comprised the major component of the diet of these deer. Although the fruits of these species appeared to be the most preferred plant part, leaves and stems of both species were commonly consumed. Primary woody plants consumed included: honeysuckle, hackberry (*Celtis occidentalis*), sumac, greenbriers, and grapes. Although some oaks do occur on Holla Bend, they are not common. Consequently, acorns were not an important component of the diet of these deer. While woody plants comprised approximately 98% of the volume of food consumed by deer in the Ozarks and Gulf Coastal Plain areas, only 21% of the diet among Arkansas River Valley deer was from woody species.

Acorn production in Arkansas forests was high during the two years of this study. We speculate that in years of poor production, deer would rely more heavily on woody species such as greenbriers, grapes, and sumac that were present at low levels in our samples. Fenwood *et al.*, (1985) reported that acorns averaged 65% (by volume) of the food consumed by deer in the Ouachita Mountains in a good mast year, but were absent in a year of mast failure.

Our results suggest that deer managers interested in assessing deer densities relative to available food supplies could use greenbriers, sumacs, and grapes as "indicator species" for browse utilization surveys. All three of these foods were consumed in each ecoregion studied, and were used even when acorns, soybeans, or corn were abundant. It is important to note however, that the extent that deer use these "indicator species" will vary among regions and among years, depending on the availability of acorns, crops, and other preferred foods. Management practices which encourage a diversity of understory browse species should help to buffer food supplies during years of poor mast production.

## Thomas A. Nelson, Luke Eggering, and Danny Adams

Table 1. Volume (and frequency) of principal foods found in rumens of white-tailed deer harvested in the Ozark Mountain, Gulf Coastal Plain, and Arkansas River Valley regions of Arkansas, November 1985 and 1986.

Food Items and Parts Eaten	Region		
	Ozarks	Gulf Coastal Plain	Arkansas River Valley
Oak ( <i>Quercus</i> spp.) acorns	91.0 (100)	87.3 (90)	2.1 (3)
Soybeans ( <i>Glycine max</i> ) fruits, leaves, stems	-	-	61.3 (81)
Corn ( <i>Zea mays</i> ) fruit, leaves, stems	-	-	13.8 (44)
Honeysuckle ( <i>Lonicera japonica</i> ) leaves, stems	0.2 (17)	3.9 (43)	9.6 (38)
Hackberry ( <i>Celtis occidentalis</i> ) fruits	-	-	5.0 (3)
Sumac ( <i>Rhus</i> spp.) leaves, stems	0.9 (50)	2.2 (19)	1.3 (6)
Greenbriers ( <i>Smilax</i> spp.) leaves, stems	1.1 (50)	0.6 (76)	0.6 (9)
Unidentified leaves and stems	3.5 (50)	1.0 (57)	0.9 (16)
Partridge pea ( <i>Cassia fasciculata</i> ) fruits, stems	-	-	2.7 (3)
Black cherry ( <i>Prunus serotina</i> ) leaves	-	1.4 (5)	-
Fungi	0.4 (8)	1.0 (71)	-
Grapes ( <i>Vitis</i> spp.) fruits, leaves, stems	0.9 (17)	0.2 (10)	0.5 (6)
Winged elm ( <i>Ulmus alata</i> ) leaves	0.8 (8)	0.2 (6)	0.3 (14)
Grass and/or grass-like leaves	0.4 (83)	0.3 (43)	0.3 (9)
Goldenrods ( <i>Solidago</i> spp.) leaves	0.8 (8)	-	-
Rattanvine ( <i>Berchemia scandens</i> ) fruits	-	0.4 (3)	0.1 (5)
Flowering dogwood ( <i>Cornus florida</i> ) leaves	<0.1 (17)	0.3 (10)	-
Cross-vine ( <i>Bignonia capreolata</i> ) leaves, stems	-	0.3 (14)	-
Gum bumelia ( <i>Bumelia lanuginosa</i> ) fruits	-	-	0.3 (6)
Elderberry ( <i>Sambucus canadensis</i> ) fruits	-	-	0.3 (3)
Blueberries ( <i>Vaccinium</i> spp.) leaves, stems	<0.1 (8)	0.2 (14)	-
Poison ivy ( <i>Toxicodendron radicans</i> ) leaves	-	0.2 (10)	<0.1 (6)
Osage orange ( <i>Maclura pomifera</i> ) fruits	-	-	0.2 (3)
Ground cherry ( <i>Physalis heterophylla</i> ) fruits	-	-	0.2 (3)
Soapberry ( <i>Sapindus drummondii</i> ) fruits	-	-	0.2 (3)
Possum haw ( <i>Ilex decidua</i> ) fruits	-	0.2 (10)	-
Buckbrush ( <i>Symphoricarpos orbiculatus</i> )	<0.1 (33)	-	-
Morning glory ( <i>Convolvulus</i> spp.) leaves, stems	-	-	0.1 (9)
American elm ( <i>Ulmus americanum</i> ) leaves	-	0.1 (5)	-
Box elder ( <i>Acer negundo</i> ) leaves	-	0.1 (5)	-
Devil's walkingstick ( <i>Aralia spinosa</i> ) leaves	-	0.1 (5)	-
Red mulberry ( <i>Morus rubra</i> ) leaves	-	<0.1 (5)	-
Sugarberry ( <i>Celtis laevigata</i> ) leaves	-	<0.1 (5)	-
Wild plum ( <i>Prunus texana</i> ) leaves	<0.1 (17)	-	-
Ironwood ( <i>Ostrya virginiana</i> ) leaves	<0.1 (8)	-	-
Blackhaw ( <i>Viburnum</i> spp.) leaves	-	<0.1 (5)	-
Black willow ( <i>Salix nigra</i> ) leaves	-	<0.1 (5)	-
American holly ( <i>Ilex ambigua</i> ) leaves	-	<0.1 (5)	-
Pine ( <i>Pinus</i> spp.) leaves	-	<0.1 (5)	-
Carolina moonseed ( <i>Cocculus carolinus</i> ) leaves	-	<0.1 (5)	-
Partridgeberry ( <i>Mitchella repens</i> ) leaves	-	<0.1 (5)	-
Beggarweeds ( <i>Desmodium</i> spp.) leaves	-	<0.1 (5)	-
Cancerweed ( <i>Salvia lyrata</i> ) leaves	-	<0.1 (5)	-

## ACKNOWLEDGEMENTS

Funding for this study was provided by the National Park Service, the Ross Foundation, and Arkansas Tech University. The authors wish to thank Mike Cartwright and Donny Harris, Arkansas Game and Fish Commission; Martin Perry, U.S. Fish and Wildlife Service; and Dr. Gary Tucker, Rex Garner, and Brett Perrett, Arkansas Tech University, for technical assistance.

## LITERATURE CITED

FENWOOD, J. D., D. A. SAUGEY, and C. A. RACCHINI. 1985. Fall deer food selection in the Ouachita National Forest. Proc. Ark. Acad. Sci. 39:123-124.

HARLOW, R. F. and R. G. HOOPER. 1971. Forages eaten by deer in the southeast. Proc. Ann. Conf. S. E. Game and Fish Commissioners 25:18-46.

HARLOW, R. F., J. B. WHALEN, H. S. CRAWFORD, and J. E. SKEEN. 1975. Deer foods eaten during years of oak mast abundance and scarcity. J. Wildl. Manage. 39:330-336.

KORSCHGEN, L. J. 1962. Foods of Missouri deer, with some management implications. J. Wildl. Manage. 26:164-172.

LAY, D. W. 1965. Fruit utilization by deer in southern forests. J. Wildl. Manage. 29:370-375.

MURPHY, D. A. and H.S. CRAWFORD. 1970. Wildlife foods and understory vegetation in Missouri's National Forests. Missouri Dept. of Conserv. Tech. Bull. no. 4. 47 pp.



# A BIBLIOGRAPHIC SUMMARY OF ARKANSAS FIELD BOTANY

JAMES H. PECK and CAROL J. PECK  
Dept. Biology and Office Testing Services  
University of Arkansas at Little Rock  
Little Rock, AR 72204

## ABSTRACT

Over 750 references, compiled over the past five years, are presented on floristics, taxonomy, autecology, synecology, species biology, habitat analysis, impact analysis, paleoenvironment, phytogeography, and history of field botany in Arkansas. This bibliography is reported to facilitate efforts to document and interpret the flora, the vegetation, and the natural heritage of Arkansas and to encourage others to participate in that collective effort.

## INTRODUCTION

Arkansas has a flora and vegetation that is characterized by richness and diversity, reflecting its location in the Mid-South, its varied and rugged topography, and the uninterrupted occupation of habitats during the Pleistocene and Holocene. Efforts to describe, inventory, and interpret the flora and vegetation have resulted in the compilation of an impressive body of literature. Access to plant literature was made difficult by the lack of a recent and relatively comprehensive bibliographic compilation. The last bibliography was prepared by Dale (1963) who added 102 references of vegetation studies to an earlier list of 63 taxonomic papers reported by Buchholz and Palmer (1926). According to our list, approximately 60% of the literature documenting or interpreting field botany in Arkansas was reported after 1963. Much of this recent literature is in the form of status reports, government documents, agency reports, and contract reports. In contrast to references in standard journals, this newer body of knowledge is deposited rather than disseminated, abstracted, and widely circulated, and thus, it is less well known and is cited infrequently.

The problem of access to an ever increasing body of literature on field botany is not a problem restricted to Arkansas. Increased efforts to organize natural heritage information resulted in the preparation of bibliographies on plant studies at the national, regional, and state level. On the national level, Gunn (1956) provided access to the major works on each state flora. On the regional level, Duncan (1953), Egler (1961) and Wood (1983) provided access to the regional literature of the southeastern United States. Summaries of literature for other states in the Mid-south and Northcentral United States have also been prepared and reported: Illinois (Risser, 1984), Iowa (Eilers, 1975; Peck and Roosa, 1983; Peck and Smart, 1985; Roosa and Peck, 1986), Kentucky (Browne, 1965; Davies, 1953; Fuller, 1979), Louisiana (Ewan, 1967; MacRoberts, 1984; Sundell, 1983), Missouri (Dwyer, 1970; Weher and Raveill, 1986), and Tennessee (Andre, 1971; Bates, 1985; Corgan, 1977). Workers in these states found that when access to the literature of their state and that of adjacent states is conveniently summarized, interpretations of flora and vegetation problems common to their region are much easier to compare and to assess properly.

Consequently, we prepared this bibliographic summary of 766 references to Arkansas field botanical literature for four reasons: to compile a comprehensive bibliography, to facilitate access to those literature resources, to communicate within and outside Arkansas, and to enhance or stimulate future studies on field botany projects in Arkansas. We welcome notification of references we overlooked and information of new reports, in that we intend to keep the list current, and report update lists as needed.

## METHODS

The bibliography includes references cited by Buchholz and Palmer (1926) and Dale (1963) to provide a complete listing. However, as the scope of our search was broader than those two earlier compilations, we also added references reported before 1963. We included any reference on the flora of vegetation of Arkansas, including pertinent information of plant taxonomy, plant ecology (autecology and

synecology), floristics, phytogeography, palynology, dendrochronology, vegetation management, status reports on rare species, environmental impact statements of significant tracts of natural heritage value, and literature essential to the proper interpretation of Arkansas' botanical natural heritage, such as general works on soil, climate, and geography or on the history of the exploration and study of the natural resources of Arkansas by early naturalists. Some studies conducted outside Arkansas are included if they are of particular importance to the proper interpretation of Arkansas' natural heritage, particularly if these works were excluded included in recent discussions.

References that primarily discuss phytoplankton, agronomic crops, weed control, pest management, or tree plantations were excluded. Rather than cite each soil survey for the 75 counties, a general reference to their existence was noted to direct the reader to the government documents section of the library. Similarly, over 100 reports on the generic flora of the southeastern United States were recently indexed (Wood, 1983), and only a few of these were included. Monographic works on wide ranging taxa were generally not included unless Arkansas material was particularly rare and of national importance. General monographs that include Arkansas taxa are well enough summarized by Smith (1968).

Eventually, any list becomes a matter of personal choice; we included any paper which we deemed to contain sufficient merit that its exclusion might be criticized. Early drafts of the list was submitted for comment to Drs. Ed Dale and Ed Smith, University of Arkansas; Dr. Leon Richards, Arkansas State University; Dr. Gary Tucker, Arkansas Tech University; Dr. Eric Sundell, University of Arkansas at Monticello; Drs. Donald Culwell and Robert Wright, University of Central Arkansas; Dr. Henry Robison, Southern Arkansas University, and to Thomas Foti, Steve Orzell, William Shepherd, and Kenneth Smith, Arkansas Natural Heritage Commission. Their contributions added measurably to our list. Several students helped to clerically update the list, including Mark Schweder, Deborah Prince, and Katie Golden.

## BIBLIOGRAPHIC SUMMARY

- Agnew, D. L. 1941. The government land surveyor as a pioneer. *Mississippi Valley Hist. Rev.* 28:369-382.
- Allen, R. T. 1985. Arkansas' natural areas: Ashley County. *Ark. Nat.* 3(7):1-4.
- Allred, B. W., and H. C. Mitchell. 1955. Major plant types of Arkansas, Louisiana, Oklahoma and Texas and their relation to climate and soils. *Texas J. Sci.* 7:7-19.
- Anon. 1982. Delzie Demaree. *Sida Contributions to Botany.* Sida 9(4):269-286.
- Arend, J. L. 1947. An early eastern red cedar plantation in Arkansas. *J. For.* 45:358-360.
- Arend, J. L. 1950. Influence of fire and soil on distribution of eastern red cedar in the Ozarks. *J. For.* 48:129-130.
- Arend, J. L., and R. F. Collins. 1949. A site classification for eastern red cedar in the Ozarks. *Proc. Soil Sci. Soc. Amer.* 13:510-511.
- Arend, J. L., and O. Julander. 1948. Oak sites in the Arkansas Ozarks. *Univ. Ark. Agric. Exper. Sta. Bull.* 484.

## James H. Peck and Carol J. Peck

- Arkansas Dept. Planning. 1973. Atlas of Arkansas. ADP, Little Rock, AR. 91 pp.
- Arkansas Dept. Planning. 1974. Arkansas natural areas plan. ADP, Little Rock, AR. 248 pp.
- Arkansas Energy Office. 1981. Arkansas Climate Atlas. AEO, Little Rock, AR.
- Arkansas Forestry Comm. 1972. Forestry: its economic and environmental importance to Arkansas. AFC, Little Rock, AR.
- Arkansas Game and Fish Comm. 1948. Wildlife and cover map of Arkansas, 1:461,000 in color. Produced in cooperation with U. S. Wildl. Serv. by AGFC, Little Rock, AR.
- Arkansas Land Office. U. S. Government Land Office Records. [Original state survey records of Arkansas; Archives, Univ. Ark. - Little Rock, Little Rock, AR.]
- Armstrong, R. 1941. A study of the flora of Massard prairie with some ecological notes. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Armstrong, R., and D. M. Moore. 1957. Botanical aspects of Massard prairie with some ecological notes. Proc. Ark. Acad. Sci. 10:44-57.
- Arnold, J. J. 1960. Prairie mounds and their climatic implications. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Ashe, W. W. 1924a. Further notes on the trees and shrubs of southeastern United States. Bull. Torr. Bot. Club. 50:359-368.
- Ashe, W. W. 1924b. Notes on woody plants. J. Elisha Mitchell Soc. 50:43-48.
- Ashe, W. W. 1925. Further notes on woody plants. Torreya 25:10-11.
- Ashmore, H. S. 1978. Arkansas: A history. Norton, NY.
- Babb, D. 1973. Vascular flora of Cleburne County, Arkansas. M. S. thesis, Ark. St. Univ., State University, AR. 57 pp.
- Babcock, R. E., E. E. Dale, S. Hurley, and M. Rolingston. 1975. A contribution to an environmental assessment study for the proposed Bekaert Steel Wire Corporation Van Buren plant site. Dept. Botany, Univ. of Ark., Fayetteville, AR.
- Bailey, S. W. 1976. Vegetation of selected sites of the Buffalo National River area, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Baldwin, F. L., and E. B. Smith. 1982. Weeds of Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Barber, M. G. 1978. Status and distribution of *Monarda stipitoglandulosa* Waterfall. Unpublished report to Ark. Nat. Heritage Comm., Little Rock, AR.
- Barber, M. G. 1979. A floristic study of Franklin County, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Barkley, H. G. 1954. Some observations of fluctuating water levels and seasonal changes in an Arkansas cypress swamp. Proc. Okla. Acad. Sci. 35:1-2.
- Barnett, S. M. 1969. A study of the herbaceous vascular plants from selected sites in Faulkner County, Arkansas. Proc. Ark. Acad. Sci. 23:157-163.
- Baskin, J. M., and C. C. Baskin. 1986. Distribution and geographical/evolutionary relationships of cedar glade endemics in southeastern United States. Assoc. Southeast. Biol. Bull. 33:138-154.
- Beasley, R. S. 1986. Atmospheric deposition: research needs and priorities in the Mid-South. Pp. 57-62, in B. G. Blackmon and R. S. Beasley. Proceedings of Mid-South Symposium on Acid Deposition. Univ. Ark. - Monticello, Monticello, AR.
- Bedinger, M. S. 1971. Forest species as indicators of flooding in the lower White River valley, Arkansas. U. S. Geol. Sur. Prof. Paper 750-C:248-253.
- Bedinger, M. S. 1978. Relation between forest species and flooding. Pp. 427-435, in P. E. Greason, J. R. Clark, and J. E. Clark. Wetland functions and values: the state of our understanding. Proceedings national symposium on wetlands. Amer. Water Resour. Assoc., Minneapolis, MN. 674 pp.
- Bedinger, M. S. 1979. Forests and flooding with special reference to the White River and Ouachita River basins, Arkansas. Open-file report 79-68. Water Resources Investigations, U. S. Geol. Surv., Little Rock, AR.
- Beilman, A. P., and L. G. Brenner. 1951a. The recent intrusion of forests in the Ozarks. Ann. Mo. Bot. Gard. 38:261-282.
- Beilman, A. P., and L. G. Brenner. 1951b. The changing forest flora of the Ozarks. Ann. Mo. Bot. Gard. 38:283-291.
- Bertelson, D. F. 1971. Growth components of Arkansas forests. U. S. For. Serv. Res. Note 114:1-3.
- Bertelson, D. F. 1980. Arkansas Forest Industries, 1977. U. S. Dept. Agri. For. Serv. Resour. Bull. SO-75. South. For. Exp. Stn. New Orleans, LA. 18 pp.
- Bogle, A. L., T. Swain, R. D. Thomas, and E. D. Thomas. 1971. *Geocarpon*: Aizoaceae or Caryophyllaceae. Taxon 20:473-477.
- Bossu, J. B. 1771. Travels through that part of North America formerly called Louisiana. London, printed for T. Davies.
- Bourne, G. E. 1922. Narratives of the career of Hernando de Soto. 2 vol. [Reprinted Allerton Book Co., NY.]
- Bowers, F., and P. L. Redfearn, Jr. 1967. *Lycopodium lucidulum* in the Boston Mountains of Arkansas. Amer. Fern J. 57:91-92.
- Bowers, L. J. 1973. Tree-ring dating of the bald cypress (*Taxodium distichum* L.) in the lower Mississippi valley. M. S. thesis, Ark. St. Univ., College Station, AR. 52 pp.
- Bradbury, J. 1817. Travels in the interior of North America in the years 1809, 1810, 1811, including a description of Upper Louisiana, together with the state of Ohio, Kentucky, Indiana, Tennessee, and Illinois, and western territories, and containing remarks and observations useful to those persons emigrating to those countries Sherwood, Neely, & Jones, London. 364 pp.
- Bradbury, J. L., and D. L. Marsh. 1977. Comparative studies of the witch hazels *Hamamelis virginiana* and *H. vernalis*. Proc. Ark. Acad. Sci. 31:29-31.
- Branner, J. C. 1891. Distribution of timber and its relation to the underlying rock formations. Ann. Rept. Geol. Surv. Arkansas 2:167-170.
- Branner, G. C. 1927. An outline of the physical features of Arkansas. In: Outlines of Arkansas Mineral Resources. Ark. Geol. Surv., Little Rock, AR.
- Branner, J. C. (No Date). Flora of Arkansas with additions by W. S. Blatchley, 1889, and index; also notes of others added at various times. Manuscript in University Library, Univ. Ark., Fayetteville, AR.
- Branner, J. C., and F. V. Coville. 1891. A list of the plants of Arkansas. Annual Report for 1888. Ark. Geol. Surv. 4:155-242.
- Braun, E. L. 1950. The deciduous forests of eastern North America. Chapter 15. Blakiston Company, Philadelphia, PA. 597 pp. [1964 reprint Hafner Pub. Co., NY.]
- Braun, E. L. 1955. The phytogeography of unglaciated eastern United States and its interpretation. Bot. Rev. 21:297-375.
- Breckenridge, H. W. 1814. Views of Louisiana, together with a journal of a voyage up the Mississippi River, in 1811. Quadrangle Books, Chicago, IL. 302 pp.
- Bretz, J. H. 1965. Geomorphic history of the Ozarks of Missouri. Missouri Geol. Surv. Water Resour. Div. 41:1-147.
- Brown, A. V., P. Kittle, E. E. Dale, Jr., and R. T. Huffman. 1974. Rare and endangered species, unique ecosystems and wetlands. Botany Dept., Univ. Ark., Fayetteville, AR. (mimeo. ms.)
- Brown, A. V., and J. P. Ricker. 1982. Macroinvertebrate utilization of leaf detritus in a riffle of the Illinois River, Arkansas. Proc. Ark. Acad. Sci. 36:10-13.
- Brown, A. V., and M. D. Schram. 1982. Leaf detritus processing in an Ozark cave stream. Proc. Ark. Acad. Sci. 36:14-16.
- Browne, E. T. 1974. A preliminary report on the vascular flora of the Sylamore Ranger District Ozark National Forest, Stone Co., Arkansas. Castanea 39:170-188.
- Bryant, V. M. 1969. Late full-glacial and post-glacial pollen analysis of Texas sediments. Ph. D. thesis, Univ. Texas, Austin, TX. 168 pp.
- Buchholz, J. T. 1924. Notes on Arkansas pteridophytes. Amer. Fern J. 14:33-38.
- Buchholz, J. T. 1930. The Ozark white cedar. Bot. Gaz. 90:326-332.
- Buchholz, J. T., and W. R. Mattoon. 1924. Common forest trees of Arkansas. Bull. No. 180. Agri. Ext. Div., Univ. Ark., Little Rock, AR.
- Buchholz, J. T., and E. J. Palmer. 1926. Supplement to the catalogue of Arkansas plants. Trans. Acad. Sci. St. Louis 25:1-164.
- Buck, W. R. 1977. A new species of *Selaginella* in the *S. apoda* complex. Can. J. Bot. 55:366-371.

## A Bibliographic Summary of Arkansas Field Botany

- Bullington, E. H. 1962. The vegetation of Devil's Den State Park, Washington County, Arkansas. M. S. thesis, Univ., Ark., Fayetteville, AR.
- Bush, B. F. 1897. Botany of some southern swamps. Garden and Forest 10:514-16.
- Butler, G. D. 1887. Additions to the flora of Arkansas. Bot. Gaz. 2:104.
- Cain, R. H. 1974. Pimple mounds; A new viewpoint. Ecology 55:178-182.
- Call, R. E. 1887-1889. Notes on the forest trees of eastern Arkansas. Proc. Ia. Acad. Sci. 1:76-85.
- Call, R. E. 1889. Notes on the forest trees of the Crowley's Ridge region. Annual Report for 1889. Ark. Geol. Surv. 2:183-202.
- Carlson, T. M., and W. H. Wagner. 1982. The North American distribution of the genus *Dryopteris*. Contr. Univ. Mich. Herb. 15:141-162.
- Carr, L. 1952. New additions to the flora of Arkansas. Abstract. Proc. Ark. Acad. Sci. 5:11.
- Carrothers, W. N. 1962. An ecological analysis of woody vegetation on selected sites near the White River, northwest Arkansas. National Science Foundation Undergraduate Research Participation Program. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Carter, M. F., F. E. Lane, and J. B. Grace. 1985. Effects of litter on aquatic macrophyte germination and growth. Proc. Ark. Acad. Sci. 39:29-33.
- Census of Agriculture. 1982. Vol. 1. Geographic area series. Part 4. Arkansas: State and county data. 394 pp.
- Chandler, A. 1941. *Pteris multifida* in Arkansas. Amer. Fern. J. 31:112.
- Channell, R. B. and C. E. Wood. 1962. The Leitneraceae in the southeastern United States. J. Arnold Arbor. 43:435-438.
- Chapman, H. H. 1942. Management of loblolly pine in the pine-hardwood region in Arkansas and in Louisiana west of the Mississippi River. Yale Univ. For. Bull. No. 29.
- Clark, G. T. 1971. The ecological life history of *Tephrosia virginiana* (L.) Pers. Ph. D. diss., Univ. Ark., Fayetteville, AR.
- Clark, G. T. 1974. A preliminary ecological study of Crowley's Ridge. Pp. 213-241, in Arkansas Dept. Planning. Arkansas natural area plan. Ark. Dept. of Planning, Little Rock, AR.
- Clark, G. T. 1977. Forest communities of Crowley's Ridge. Proc. Ark. Acad. Sci. 31:34-37.
- Clark, G. T. 1981. Winter twigs of Arkansas. Rose Pub. Co., Little Rock, AR. 93 pp.
- Clark, J. R., and J. Benforado. 1981. Wetlands of bottomland hardwood forests, Proceedings of a workshop on bottomland hardwood forest wetlands of the southeastern United States. Elsevier Pub. Co., New York.
- Clark, M. B. 1962. *Trichomanes boschianum* in Madison County, Arkansas. Amer. Fern J. 52:85-86.
- Clark, M. B. 1977. Remnant prairie plots of Benton County, Arkansas. Proc. Ark. Acad. Sci. 31:112-114.
- Coiles, T. S. 1936. The effect of rainfall and temperature on the annual radial growth of pine in the southern United States. Ecol. Monogr. 6:534-562.
- Cole, H. S. 1933. Drought in Arkansas. Weath. Bur. Monthly Rev. Vol. 61 (May).
- Correll, D. S., and M. C. Johnston. 1979. Manual of the vascular plants of Texas. Univ. Texas Press, Dallas, TX. 1881 pp.
- Correll, D. S., and H. B. Correll. 1972. Aquatic and wetland plants of the southwestern United States. Publ. 16030 DNL 01/72, U. S. Envir. Protect. Agenc., Washington, DC. 1777 pp.
- Coulter, J. M. 1880. Southwestern plants. Bot. Gaz. 5:84.
- Coulter, S. M. 1904. An ecological comparison of some typical swamp areas. Ann. Rept. Mo. Bot. Gard. 15:39-71.
- Covington, S. A. 1969. Studies on the ecology of *Perilla frutescens* (L.) Britt. in northwest Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Coville, F. V. 1888. Notes on the botany of Arkansas. Annual Report for 1888. Ark. Geol. Surv. 4:243-250.
- Cowardian, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. FWS/OBS-79/31, U. S. Fish Wildl. Serv., Office Biological Services, Washington, D.C.
- Cox, E. T. 1860. Search report of a geological reconnaissance of a part of the state of Arkansas made during the years of 1859-1860. 433 pp.
- Cox, I. J. 1922. The journeys of Rene-Robert Sieur de La Salle. [Reprinted by Allerton Book Co., NY.]
- Cozzens, A. B. 1940. Physical profiles of the Ozark province. Amer. Midl. Nat. 24:477-489.
- Cronquist, A. 1955. A new variety of *Solidago ulmifolia*. Rhodora 57:36.
- Culwell, D. E. 1980. Remnant prairie in Faulkner County, Arkansas? Proc. Ark. Acad. Sci. 34:107.
- Culwell, D. E. 1987a. Additions to the atlas and annotated list of the vascular plants of Arkansas. Arkansas Native Plant Society Occasional Paper No. 7. 25 pp.
- Culwell, D. E. 1987b. New records of Arkansas vascular flora from the University of Central Arkansas Herbarium. Proc. Ark. Acad. Sci. 41:102.
- Culwell, D., and W. Welch. 1987. Selected species of native plants for use on highway right of way. Rept. to Ark. Highway and Transpt. Dept., Little Rock, AR.
- Culwell, D. E., and R. D. Wright. 1983. Prairie phenology and seed germination. Proc. Ark. Acad. Sci. 37:80-81.
- Dale, E. E. 1961. Blueberries. *Vaccinium* spp. Pp. 70-73, in Deer browse plants of southern forests. U. S. For. Ser., South. For. Exp. Stn., New Orleans, LA.
- Dale, E. E. 1963. Literature on the vegetation of Arkansas. Proc. Ark. Acad. Sci. 17:40-49.
- Dale, E. E. 1967. The outdoor laboratory as an aid to teaching biology in the secondary schools. Proc. Ark. Acad. Sci. 21:100-102.
- Dale, E. E. 1972. The effects of anhydrous ammonia on native vegetation, hay meadows, and pastures near Floral, Independence County, Arkansas. Gulf Central Pipeline Co. and the Univ. Ark., Fayetteville, AR.
- Dale, E. E. 1973. Vegetation and site characteristics. Pp. 85-98, in R. E. Babcock. Preliminary reconnaissance water quality survey of the Buffalo National River. Water Resources Research Center Publication No. 19. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Dale, E. E. 1977. Report for 1977 on re-establishment of prairie at Pea Ridge National Military Park. Southw. Region Natl. Park Serv., Dallas, TX. 5 pp.
- Dale, E. E. 1978a. Human carrying capacity study on camping areas, vegetation map, and natural areas survey. Pp. 61-82, in R. E. Babcock. Final Report. Buffalo National River Ecosystems Part IV. An interdisciplinary study. Ark. Water Resour. Research Cent. Publ. No. 58. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Dale, E. E. 1978b. Terrestrial resources (plant communities and effects of changes). In: R. E. Babcock. Final report: Environmental effects of the completed McClelland-Kerr Arkansas River navigation system in the Little Rock district, Corps of Engineers. U. S. Army Engineers, Little Rock Distr., Little Rock, AR.
- Dale, E. E. 1979. Vegetation Mapping. Pp. 6-11, in Final report: appraisal of the avifauna, mammalian fauna, and plant communities at developmental sites proposed for the Buffalo National River. Southw. Reg. Natl. Park Serv., Dallas, TX and Dept. Botany, Univ. Ark., [Tables, Vegetation Map of Buffalo River, Lists of Plant Species at Development Sites (Appendix B)].
- Dale, E. E. 1980a. Final report: re-establishment of prairie at Pea Ridge National Military Park, Benton County, Arkansas. Southw. Reg. Natl. Park Serv., Dallas, TX. 22 pp.
- Dale, E. E. 1980b. Search for potential sites of pipewort (*Eriocaulon kornickianum* Van Henick and Muell.-Arg.) and other rare or uncommon species on prairies of Benton County, Arkansas. Final Report to Heritage Program, The Nature Conservancy, Arlington, VA.
- Dale, E. E. 1981. A search for rare or endangered species of vascular plants of the tufa area in Hot Springs National Park, Garland County, Arkansas. Hot Springs Natl. Park, Hot Springs, AR. 10 pp.



## James H. Peck and Carol J. Peck

- Dale, E. E. 1983a. The effects of mowing and burning on a restored prairie at Pea Ridge National Military Park, Benton County, Arkansas. Pp. 134-138, in P. Brewer. Proc. Eighth North American Prairie Conference, Western Mich. Univ., Kalamazoo, MI.
- Dale, E. E. 1983b. Final Report: Plant communities and rare or endangered plant species of Pea Ridge National Military Park, Benton County, Arkansas. 55 pp. Pea Ridge National Military Park, Natl. Park Serv., U.S. Dept. Inter. Dept. Botany, Univ. Ark., Fayetteville, AR. 55 pp.
- Dale, E. E. 1984. Wetlands forest communities as indicators of flooding potential in backwater areas of river bottomlands. Ark. Water Resour. Res. Cent. Publ. No. 106. 85 pp.
- Dale, E. E. 1986. The vegetation of Arkansas. [including an inserted vegetation map]. Ark. Nat. 4(5):7-27.
- Dale, E. E., S. Bailey, and J. Gibbons. 1975. Re-establishment of native prairie at Pea Ridge National Military Park, Pea Ridge, Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR. 13 pp.
- Dale, E. E., A. V. Brown, R. T. Huffman, and P. Kittle. 1975. Unique ecosystem, rare and endangered species and wetlands of Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Dale, E. E., R. H. Davis, and A. Berry. 1977. Final report on survey of natural features of Sweden Creek area, Madison County, Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR. Report prepared for Ark. Nat. Heritage Comm., Little Rock, AR.
- Dale, E. E., and T. L. Foti. 1969. Relation of forage weight to vegetation cover of forage species in deer enclosures. Ark. Game Fish Comm. and Dept. Botany, Univ. Ark., Fayetteville, AR.
- Dale, E. E., and T. M. Fullerton. 1964. Ecological investigations of existing vegetation in the preimpoundment and watershed areas of Beaver Lake. Bur. Sports Fisheries Wildlife, U. S. Fish Wildl. Serv. and Dept. Botany, Univ. Ark., Fayetteville, AR.
- Dale, E. E., and J. W. Gibbons. 1979. Re-establishment of prairie vegetation at Pea Ridge National Military Park, Benton County, Arkansas. Pp. 183-187, in Proc. First Conf. on Scientific Research in the National Parks. Trans. Proc. Ser. No. 5. U. S. Dept. Inter., Natl. Park Serv., Washington, D.C.
- Dale, E. E., and R. T. Huffman. 1974a. Evaluation of Beech Hurricane Ravine as a potential national landmark. U. S. Dept. Inter. Natl. Park Serv., and Dept. Botany, Univ. Ark., Fayetteville, AR. 7 pp.
- Dale, E. E., and R. T. Huffman. 1974b. Evaluation of Grassy Lake as a potential national natural landmark. U. S. Dept. Inter., Natl. Park Serv., and Dept. Botany, Univ. Ark., Fayetteville, AR. 14 pp.
- Dale, E. E., and R. T. Huffman. 1974c. Evaluation of Lake Winona Scenic Area as a potential national natural landmark. U. S. Dept. Inter., Natl. Park Serv. and Dept. Botany, Univ. Ark., Fayetteville, AR. 9 pp.
- Dale, E. E. and R. T. Huffman. 1974d. Evaluation of the Lower Cache River area as a potential national natural landmark. U. S. Dept. Inter., Natl. Park Serv. and Dept. Botany, Univ. Ark., Fayetteville, AR. 9 pp.
- Dale, E. E., and R. T. Huffman. 1974e. Evaluation of Roaring Branch Natural Area as a potential national natural landmark. U. S. Dept. Inter., Natl. Park Serv. and Dept. Botany, Univ. Ark., Fayetteville, AR. 11 pp.
- Dale, E. E., and R. T. Huffman. 1974f. Evaluation of White River Sugarberry Natural Area in the White River National Wildlife Refuge as a potential national natural landmark. U. S. Dept. Inter., Natl. Park Serv. Dept. Botany, Univ. Ark., Fayetteville, AR. 9 pp.
- Dale, E. E., G. T. Johnson, and P. M. Kuroda. 1981. Major wetland forest communities of the U. S. Army Engineer District, Vicksburg: A phytosociological assessment. Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, MI. 94 pp. Technical Report EL-41-81.
- Dale, E. E., and B. D. Keeland. 1977. Human carrying capacity study of campgrounds, Buffalo National River. In: R. E. Babcock, Final Report: Buffalo National River Ecosystems. Part III. Ark. Water Resour. Res. Center Publ. No. 49.
- Dale, E. E., and P. M. Kuroda. 1978. Vegetation map and natural areas survey. Pp. 77-82, in R. E. Babcock. Final Report: Buffalo National River Ecosystems. Part IV. Ark. Water Resour. Res. Center Publ. No. 58.
- Dale, E. E., R. L. Meyer, T. M. Buchanan, and R. T. Huffman. 1975. Environmental evaluation report on various completed channel improvement projects in eastern Arkansas. U. S. Army Corps Engineers and Dept. Botany, Univ. Ark., Fayetteville, AR. Ark. Water Resour. Res. Center Publ. No. 30. 42 pp.
- Dale, E. E., A. F. Posey, P. L. Raines, D. L. Zachry, and J. W. House. 1974. Environmental evaluation report on the Big Mulberry Creek Basin in Franklin, Madison, Newton, Johnson, and Crawford counties, Arkansas. U. S. Army Corps Engineers and Dept. Botany, Univ. Ark., Fayetteville, AR. Ark. Water Resour. Res. Center Publ. No. 21. 31 pp.
- Dale, E. E., E. B. Smith, S. Bailey, and J. Gibbons. 1975. Vascular plants and vegetation types near Bella Vista, Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR and Arkansas Highway Department, Little Rock, AR.
- Dale, E. E., E. B. Smith, J. Gibbons, and S. Bailey. 1976. Vegetation on selected sites. In: R. E. Babcock. Buffalo National River Ecosystems. Part II. Ark. Water Resour. Res. Center, Publ. No. 38. Dept. Botany, Univ. Ark., Fayetteville, AR. 72 pp.
- Dale, E. E., and T. C. Smith. 1979. Re-establishment of prairie at Pea Ridge National Military Park, Benton County, Arkansas. Final Report for 1978. Prepared for Southwest Region, Natl. Park Serv. by Dept. Botany, Univ. Ark., Fayetteville, AR.
- Dale, E. E., and T. C. Smith. 1983. Changes in vegetation of a restored prairie at Pea Ridge National Military Park, Arkansas. Pp. 237-241, in C. L. Kucera. Proc. Seventh North American Prairie Conference, Springfield, MO.
- Dale, E. E., and T. C. Smith. 1985. The effects of different seeding densities on establishment of grasses in a restored prairie at Pea Ridge National Military Park, Arkansas. Pp. 195-196, in C. K. Clamby and R. H. Pemble. Proc. Ninth American Prairie Conference, Tri-College University Center for Environmental Studies, Fargo, ND/Moorhead, MN.
- Dale, E. E., and J. R. Sullivan. 1978. Final report on the composition and abundance of vegetation inhabiting the water fluctuation zones of Beaver and Bull Shoals lakes. Report to Fish and Wildl. Serv. by Water Resour. Res. Center and Dept. Botany, Univ. Ark., Fayetteville, AR.
- Dale, E. E., J. P. Sullins, and T. L. Foti. 1968. Understory vegetation and soils in deer enclosures. Project No. 54-R-9. Ark. Game Fish Comm. and Dept. Botany, Univ. Ark., Fayetteville, AR.
- Dale, E. E., and M. R. Watts. 1980. Vegetation of Hot Springs National Park, Arkansas. Final report to Southwest Region, Natl. Park Serv., Dallas, TX. Dept. Botany, Univ. Ark., Fayetteville, AR. 84 pp.
- Dale, E. E., and D. L. Zachry. 1979. Potential national natural landmarks of the Interior Highlands Natural Region, Central United States. Natl. Park Serv. and Dept. Botany, Univ. Ark., Fayetteville, AR. 272 pp.
- D'Arcy, W. G. 1969. The Ozark flora - Some collections of note. Ann. Mo. Bot. Gard. 56:465-467.
- Davis, A. M. 1959. Brush control and range development study. Agri. Expt. Stat., Univ. Ark., Fayetteville, AR. Arkansas Farm Research 8:2.
- Davis, J. R. 1974. Vascular plants of Lee County, Arkansas. M. S. thesis, Ark. St. Univ., College Station, AR. 49 pp.
- Davis, M. B. 1968. Studies on the ecology of Bangle Grass *Chasmanthium latifolium* (Michx.) Yates, in northwest Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Davis, M. B. 1976. Pleistocene biogeography of temperate deciduous forests. Geosci. Man. 13:13-26.
- Davis, M. B. 1981. Quaternary history and the stability of forest communities. Pp. 132-153, in D. C. West, H. H. Shugart, and D. B. Botkin. Forest succession: concepts and application. Springer-Verlag, New York.
- Davis, M. B. 1983. Holocene vegetational history of the eastern United States. Vol. II, pp. 164-181, in H. E. Wright. Late-



## A Bibliographic Summary of Arkansas Field Botany

- Quaternary environments of the United States. 2 vol. Univ. Minnesota Press, Minneapolis, MN.
- Davis, R. H. 1978. Criteria for selection of relict natural areas in the Interior Highlands Physiographic Region, Central United States. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Davis, R. 1981. Additional records and updates on the Arkansas flora. Proc. Ark. Acad. Sci. 35:84.
- Day, J. W. 1975. The autecology of *Leitneria floridana*. Ph. D. diss., Miss. St. Univ., Mississippi State, MS. 114 pp.
- Deevey, E. S. 1949. Biogeography of the Pleistocene. Geol. Soc. Amer. Bull. 60:1315-1416.
- Delcourt, H. R. 1975. Reconstructing forest primeval, West Feliciana Parish. Melanges No. 10, Louisiana St. Univ., Baton Rouge, LA. 13 pp.
- Delcourt, H. R. 1976. Pre-settlement vegetation of the North of the Red River Land District, Louisiana. Castanea 41:122-139.
- Delcourt, H. R. 1978. Roland McMillan Harper, recorder of early twentieth-century landscapes in the south. Pioneer America 10(2):36-50.
- Delcourt, H. R. 1979. Late Quaternary vegetation history of the eastern Highland Rim and adjacent Cumberland Plateau of Tennessee. Ecolog. Monogr. 49:255-280.
- Delcourt, H. R., and P. A. Delcourt. 1977. Pre-settlement Magnolia-beech climax of the Gulf Coastal Plain: quantitative evidence from the Appalachicola River Bluffs, north-central Florida. Ecology 58:1085-1093.
- Delcourt, H. R., and P. A. Delcourt. 1975. The Blufflands: Pleistocene pathway into the Tunica Hills. Amer. Midl. Nat. 94:385-400.
- Delcourt, H. R., and P. A. Delcourt. 1984. Ice age haven for hardwoods. Nat. Hist. 93(9):22-28.
- Delcourt, P. A., and H. R. Delcourt. 1977. The Tunica Hills, Louisiana-Mississippi: late-glacial locality for spruce and deciduous forest species. Quat. Res. 7:218-237.
- Delcourt, P. A., and H. R. Delcourt. 1981. Vegetation maps for eastern North America: 40,000 years B. P. to the present. Pp. 123-165, in R. C. Romans. Geobotany II. Plenum, New York.
- Delcourt, P. A., and H. R. Delcourt. 1983. Late-Quaternary vegetational dynamics and community stability reconsidered. Quat. Res. 19:265-271.
- Delcourt, P. A., H. R. Delcourt, R. C. Brister, and L. E. Lackey. 1980. Quaternary vegetation history of the Mississippi Embayment. Quat. Res. 13:111-132.
- Demaree, D. 1932a. A catalogue of the ligneous plants of Arkansas. Hendrix-Galloway Bull. 19:1-18.
- Demaree, D. 1932b. Submerging experiments with *Taxodium*. Ecology 13:258-262.
- Demaree, D. 1941. Noteworthy Arkansas plants. Proc. Ark. Acad. Sci. 1:17-19.
- Demaree, D. 1943a. A catalogue of the vascular plants of Arkansas. Taxodium 1:1-88.
- Demaree, D. 1943b. Arkansas fern notes. Amer. Fern J. 30:75.
- Deneke, C. F. 1981. The vascular flora of St. Francis County, Arkansas. M. S. thesis, Memphis St. Univ., Memphis, TN. 100 pp.
- Deneke, C. F. and E. T. Browne. 1987. The vascular flora of St. Francis County, Arkansas. Sida, Bot. Misc. 2:1-13.
- DeSarcos, D. 1979. The ecological life history of Purple Top, *Tridens flavus* (L.) Hitchc. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Desmarais, R. H., and R. Irving. 1983. The Grand Prairie. Ark. Co. Agri. Museum, Stuttgart, AR. 36 pp.
- Dickson, J. F., and J. L. Yeiser. 1987. Woody plants of southern Arkansas: computer aided instruction in dendrology. Proc. Ark. Acad. Sci. 41:102-103.
- Dorris, P. R., K. H. Oliver, J. D. Bragg, D. L. Marsh, D. W. McMasters, and W. W. Fitzgerrall. 1979. Biological inventory of the Red River waterways from Index, Arkansas, to Shreveport, Louisiana. Report by Biology Dept., Henderson St. Univ., Arkadelphia, AR, to U. S. Army Engineers, New Orleans, District, New Orleans, LA.
- Duncan, W. H. 1953. Taxonomic collections of vascular plants in the southeastern states — their abundance and relation to production of floras. Rhodora 55:353-358.
- Duncan, W. H. 1967. Woody vines of the southeastern United States. Sida 3:1-76.
- Duncan, W. H. 1975. Woody vines of the southeastern United States. Univ. Georgia Press, Athens, GA. 76 pp.
- Duncan, W. H., and L. E. Foote. 1975. Wildflowers of the southeastern United States. Univ. Georgia Press, Athens, GA.
- Environmental Laboratory. 1978. Preliminary guide to wetlands of the Gulf Coastal Plain: Major association and communities identified. Tech. Rep. Y-78-5. U. S. Army Engineers, Waterways Expt. Stat., Vicksburg, MS.
- Estes, E. T. 1970. The dendrochronology of black oak (*Quercus velutina* Lam.), white oak (*Q. alba* L.), and shortleaf pine (*Pinus echinata* Mill.), in the central Mississippi Valley. Ecol. Monogr. 40:295-316.
- Evans, D. K. 1975. Characteristics of flora and succession in the middle Mississippi River floodplain. W. Virg. Acad. Sci. 47:7-13.
- Evans, D. K. 1978. Floristics of the Mississippi River sand and mud flats. Castanea 44:8-24.
- Ewan, J. 1965. French naturalists in the Mississippi Valley. Pp. 159-174, in J. F. McDermott. The French in the Mississippi Valley. Univ. Illinois Press, Urbana, IL.
- Eyre, F. H. 1980. Forest cover types of the United States and Canada. Soc. Amer. Foresters. Washington, DC. 148 pp.
- Eyster-Smith, N. M. 1983. The prairie-forest ecotone of the western Interior Highlands: an introduction to the tallgrass prairies. Pp. 73-80, in R. Brewer, Proc. Eighth North American Prairie Conf., Western Mich. Univ., Kalamazoo, MI.
- Eyster-Smith, N. M. 1984. Tallgrass prairies: an ecological analysis of 77 remnants. Ph. D. diss., Univ. Ark., Fayetteville, AR.
- Farrar, D. R., and P. L. Redfearn. 1968. *Trichomanes petersii* in the Boston Mountains of Arkansas. Amer. Fern J. 58:85-86.
- Fassett, N. C. 1951. *Callitriche* in the New World. Rhodora 53:137-155, 161-182, 185-194, 209-222.
- Featherstonehaugh, G. W. 1835. Geological report of an examination made in 1834 of the elevated country between the Missouri and Red rivers. Public Doc. 274, House Exec. Doc. No. 151:1-97, 23 Congress, 2nd session. Vol. IV. Washington, D.C.
- Featherstonehaugh, G. W. 1844. Excursion through the slave states, from Washington on the Potomac to the frontier of Mexico. Harper, NY. 168 pp.
- Federal Committee on Ecological Reserves. 1977. A directory of research natural areas on federal lands of the United States of America. U. S. Forest Serv., Washington, D.C.
- Fenneman, N. M. 1938. Physiography of eastern United States. McGraw-Hill, NY.
- Ferguson, E. R. 1968. Roaring Branch Research Natural Area: establishment report. Ouachita National Forest, U. S. Forest Service, Hot Springs, AR.
- Ferguson, M. 1985. Plant a bit of wilderness. Ark. Nat. 3(5):1-8.
- Fernald, M. L. 1950. Gray's manual of botany. 8th ed., American Book Co., New York. 1632 pp.
- Figler, R. B. 1981. A last stand in Arkansas. Magnolia [J. Amer. Magnolia Soc.] 17(1):17-20.
- Fisk, H. N. 1944. Geological investigations of the alluvial valley of the lower Mississippi River. U. S. Army Engineers, Washington, D.C.
- Flint, T. 1826. Recollections of the last ten years passed in occasional residences and journeyings in the valley of the Mississippi, from Pittsburg and the Missouri to the Gulf of Mexico, and from Florida to the Spanish Frontier, in a series of letters to the Rev. James Flint, of Salem, Massachusetts. Cummings, Hilliard, & Co., Boston. 395 pp.
- Flint, T. 1832. The history and geography of the Mississippi Valley to which is appended a condensed physical geology of the whole American continent. Vol. 1. E. H. Flint & L. R. Lincoln, Cincinnati, OH. 464 pp.
- Fogle, N., and C. L. Fogle. 1959. The ecological relationship between the occurrence of squirrel leaf-nests in different types of oak forest habitats. Proc. Ark. Acad. Sci. 13:75-82.

## James H. Peck and Carol J. Peck

- Fogleman, J. B. 1981. Ordination of bottomland forests at Black Swamp, Cache River. M. S. thesis, Ark. St. Univ., State University, AR. 45 pp.
- Foster, J. W. 1869. The Mississippi Valley: its physical geography, including sketches of all topography, botany, climate, geology, and mineral resources. S. G. Griggs, Chicago, IL. 443 pp.
- Foti, T. L. 1971a. The Grand Prairie. Ozark Soc. Bull. 5(4):6-11.
- Foti, T. L. 1971b. The relationship between woody vegetation and soil factors on selected upland forest sites of the Sylamore District, Ozark National Forest, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Foti, T. L. 1974. Natural Divisions of Arkansas. Pp. 11-37, in Arkansas Dept. of Planning. Arkansas Natural Area Plan. Ark. Dept. of Planning, Little Rock, AR.
- Foti, T. L. 1976. Arkansas: its land and people. Arkansas Dept. Education, Little Rock, AR. 54 pp. + appendix, figures, bibliography.
- Fountain, M. S. 1986. Vegetation associated with natural populations of ginseng (*Panax quinquefolia*) in Arkansas. Castanea 51:42-48.
- Fountain, M. S., and J. M. Sweeney. 1985. Ecological assessment of the Roaring Branch Research Natural Area. USDA Forest Service, So. Forest Expt. Sta., New Orleans. Res. Pap. SO-213.
- Frye, J. C. 1973. Pleistocene succession of the Central Interior United States. Quat. Res. 3:275-283.
- Fullerton, T. M. 1964. The forest vegetation of the Beaver Reservoir impoundment area, northwest Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Geiser, S. W. 1948. Naturalists of the Frontier. 2nd. ed. Southern Methodist Univ. Press, Dallas, TX.
- Geiser, S. W. 1956. Thomas Nuttall's botanical trip to the Red River, 1819. Field and Lab. 24:43-60.
- Gerstaecker, F. 1864a. Western lands and western waters. S. O. Beeton, London. 388 pp. [Translated from German.]
- Gerstaecker, F. 1864b. Wild sports in the far west. Crosby & Sons, Boston. 396 pp. [Translation from 1859 edition in German.]
- Gibbons, J. 1977. Re-establishment of prairie vegetation at Pea Ridge National Military Park, Benton County, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Giles, W. L. 1935. The phanerogamic flora of Washington County, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Gilmore, M. R. 1930. Vegetal remains of the Ozark bluff-dweller culture. Mich. Acad. Sci., Arts, Lett. 14:83-102.
- Gleason, H. A. 1952. The new Britton and Brown illustrated flora of the northeastern United States and adjacent Canada. Hafner, New York, 3 vols.
- Gleason, H. A., and A. Cronquist. 1963. Manual of vascular plants of northeastern United States and Canada. Van Nostrand, Princeton, NJ.
- Godfrey, R. K., and J. W. Wooten. 1979. Aquatic and wetland plants of the southeastern United States. Vol. I and II. Univ. Georgia Press, Athens, GA.
- Goodwin, R. H., and W. A. Niering. 1975. Inland wetlands of the United States evaluated as potential registered natural landmarks. Natl. Park Serv. Nat. Hist. Theme Stud. No. 2. Natl. Park Serv., Washington, D.C.
- Gottlieb, L. D., and G. Pilz. 1976. Genetic similarity between *Gaura longifolia* and its obligatory outcrossing derivative (*G. demareei*). Syst. Bot. 1:181-187.
- Gould, C. 1974. The ecological life history of Heather Aster (*Aster pilosus* Willd.). M. S. thesis, Univ. Ark., Fayetteville, AR.
- Graham, W. L. 1969. *Trillium flexipes* (Liliaceae) in the Arkansas Ozarks. Sida 3:345.
- Grano, C. X. 1955. Behavior of south Arkansas oaks girdled in different seasons. J. For. 53:886-893.
- Greene, W. F., and H. L. Blomquist. 1953. Flowers of the south, native and exotic. Univ. N. Carolina Press, Chapel Hill, NC. 208 pp.
- Gregson, L. S. 1932. The Gramineae of Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Guttenberg, S. 1954. Growth and mortality in an old field southern pine stand. J. For. 52:166-168.
- Haefner, R. 1982. A classification of ecological features in the Interior Highlands of the United States. Draft report. National Park Service, Washington, D.C.
- Hale, H. 1948. University of Arkansas 1871-1948. Univ. Ark. Alumni Assoc., Fayetteville, AR. 289 pp.
- Hale, J. E. 1957. Corticolous lichen flora of the Ozark Mountains. Trans. Kansas Acad. Sci. 60:155-160.
- Hall, M. T. 1955. Comparison of juniper populations on an Ozark glade and old field. Ann. Mo. Bot. Gard. 42:171-194.
- Hall, R. D. 1960. An ecological analysis of woody vegetation near Lake Wedington, Washington County, Arkansas. National Science Foundation Undergraduate Research Participation Program. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Hall, W. L. 1945. Is pine coming or going in south Arkansas? J. For. 43:634-637.
- Harper, M. D., and E. M. Rutledge. 1959. The influence of exposure on woody vegetation on the Allen soils of the Boston Mountain region of northwest Arkansas. Proc. Ark. Acad. Sci. 13:15-21.
- Harper, R. M. 1912. Botanical evidence of the age of certain oxbow lakes. Science 36:760-761.
- Harper, R. M. 1914. Phytogeographical notes on the Coastal Plain of Arkansas. Plant World 17:36-48.
- Harper, R. M. 1917. Some undescribed prairies in northwestern Arkansas. Plant World 20:58-61.
- Harshberger, J. W. 1958. Phytogeographic survey of North America. Hafner, NY. 790 pp.
- Harvey, F. L. 1880a. *Asplenium bradleyi*. Bot. Gaz. 5:15.
- Harvey, F. L. 1880b. Some Arkansas ferns. Bot. Gaz. 5:39.
- Harvey, F. L. 1880c. Early plants. Bot. Gaz. 5:56.
- Harvey, F. L. 1880d. Notes from Arkansas. Bot. Gaz. 5:91-93.
- Harvey, F. L. 1880e. Distribution of Nymphaeaceae in Arkansas. Bot. Gaz. 5:139-140.
- Harvey, F. L. 1880f. Ferns of Arkansas. Bot. Gaz. 6:189-190.
- Harvey, F. L. 1880g. Ferns of Arkansas. Bot. Gaz. 6:213-215.
- Harvey, F. L. 1880h. Some Arkansas trees. Bot. Gaz. 6:215.
- Harvey, F. L. 1880i. *Leavenworthia* in S. W. Missouri and N. W. Arkansas. Bot. Gaz. 6:230.
- Harvey, F. L. 1881a. The flora of Arkansas. Amer. Nat. 15:388-389.
- Harvey, F. L. 1881b. Forest notes. Bot. Gaz. 6:273.
- Harvey, F. L. 1882a. A second Spring in Arkansas. Bot. Gaz. 7:12.
- Harvey, F. L. 1882b. *Selenia aurea*. Bot. Gaz. 7:57.
- Harvey, F. L. 1883a. Forestry notes. Bot. Gaz. 8:355-356.
- Harvey, F. L. 1883b. Arboreal flora of Arkansas. Amer. J. For. 1:413-424, 451-458.
- Harvey, F. L. 1884a. *Carya myristicaeformis*. Bot. Gaz. 9:195.
- Harvey, F. L. 1884b. *Dioclea boykinii*. Bot. Gaz. 9:196.
- Harvey, F. L. 1885a. Notes on forest trees. Bot. Gaz. 10:279-280.
- Harvey, F. L. 1885b. Some abnormal rudeckias. Bot. Gaz. 10:296.
- Harvey, F. L. 1892. Varieties of *Ranunculus abortivus* L. Bull. Torrey Bot. Club. 19:93-94.
- Hawkins, D. L. 1976. Vascular plants of Randolph County, Arkansas. M. S. thesis, Ark. St. Univ., State University, AR. 51 pp.
- Hawks, G. G. 1980. The effects of climatic and non-climatic influences on growth rates and distribution of American beech, white oak, and eastern red cedar along the Buffalo River in northcentral Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR. 95 pp.
- Hedlund, A. 1971. Arkansas Delta forest: A vanishing resource. For. Farm. 30:13-14, 17.
- Hedlund, A., and J. M. Earles. 1970. Forest statistics for Arkansas counties. U. S. D. A., Forest Serv. Resour. Bull. SO-22. S. Forest Exp. St., New Orleans, LA. 52 pp.
- Heineke, T. E. 1984. *Carya pallida* (Ashe) Engl. & Graedn. (Juglandaceae): a new Arkansas record. Sida 10:255-256.
- Heineke, T. E. 1987. The flora and plant communities of the middle Mississippi River valley. Ph. D. diss., S. Ill. Univ., Carbondale, IL. 653 pp.
- Henbest, O. J. 1941. A preliminary report on the legumes of the Arkansas uplands. Proc. Ark. Acad. Sci. 1:21-23.
- Henbest, O. J. 1950a. The lespedezas of northwest Arkansas. Proc. Ark. Acad. Sci. 3:23-30.

## A Bibliographic Summary of Arkansas Field Botany

- Henbest, O. J. 1950b. Some observations on mismanagement of grasslands and woodland. *Proc. Ark. Acad. Sci.* 4:57-60.
- Hermann, F. J. 1972. A new variety of *Carex bicknelli* from Arkansas. *Sida* 5:49.
- Herndon, D. T. 1922. Centennial history of Arkansas. 3 vols. S. J. Clarke Pub. Co., Chicago, IL.
- Herre, A. W. C. T. 1945. Some Arkansas lichens. *Bryologist* 48:85-90.
- Herron, E. D. 1953. The Eocene flora of northern Crowley's Ridge, Arkansas. *Proc. Ark. Acad. Sci.* 6:65-66.
- Hill, J. M., and D. L. Evans. 1981. Remote sensing of Little River, Cossatot River, and Pond Creek Bottoms in Sevier County, Arkansas. Report to U. S. Army Engineers, Tulsa District, Tulsa, OK.
- Hite, J. M. R. 1960. The vegetation of Lowe Hollow, Washington County, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Hoff, V. J., and E. S. Nixon. 1977. Extension of *Gaura demareei* into east Texas. *Southw. Nat.* 22:135.
- Holder, T. H. 1970. Disappearing wetlands in eastern Arkansas. *Ark. Planning Comm., Little Rock, AR.* 72 pp.
- Hooks, S. L. 1986. A preliminary survey of the vascular flora of Ashley County, Arkansas. M. S. thesis, Northeast Louisiana St. Univ., Monroe, LA.
- Hornkohl, L. W., and R. A. Reed. 1948. Forest grazing in the Ozarks. Pp. 270-277, in *Proc. Soc. Amer. Foresters* 1947.
- Howell, A. H. 1911. Birds of Arkansas. *Bull. No. 38, Biol. Surv., U.S. Dept. Agr., Washington, D.C.*
- Howell, J. W. 1964. A study of the major plant communities occurring on Goose Island. M. S. thesis, Memphis St. Univ., Memphis, TN.
- Huey, E. L. 1977. Ozark wild flowers. Woods Brothers Agency, Little Rock, AR.
- Huey, E. L. 1978. Ozark wild flowers II. Woods Brothers Agency, Little Rock, AR.
- Huey, E. L. 1984. Ozark wild flowers III. Woods Brothers Agency, Little Rock, AR.
- Huffman, R. T. 1974a. The origin of Grassy Lake. *Proc. Ark. Acad. Sci.* 28:32-33.
- Huffman, R. T. 1974b. The vegetation of Grassy Lake, Hempstead County, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Huffman, R. T. 1976a. The relation of flood duration patterns to dominant forest species associations occurring on selected bottom sites of the Ouachita River Drainage Basin in southern Arkansas. Ph. D. diss., Univ. Ark., Fayetteville, AR.
- Huffman, R. T. 1976b. Vegetation analysis of the Bayou Meto game management area. *Ark. Dept. Local Services, Little Rock, AR.*
- Huffman, R. T., and E. E. Dale. 1975. Vegetation communities of Bayou Meto Game Management Area. Report to Ark. Game Fish Comm. by Dept. Botany, Univ. Ark., Fayetteville, AR, and Ark. Dept. Local Serv., Little Rock, AR.
- Huffman, R. T., and R. I. Leonard. 1983. Successional patterns on floating vegetation mats in a southern bald cypress swamp. *Castanea* 48:73-78.
- Hunter, C. G. 1984. Wildflowers of Arkansas. Ozark Society Foundation, Little Rock, AR. 296 pp.
- Irving, R. S. 1980. Composition, production, and management of eastern Arkansas prairies. Pp. 281-286, in C. L. Kucera. *Proc. 7th North American Prairie Conf., Springfield, MO.*
- Irving, R. S., and S. Brenholts. 1977a. The forest communities and flora of Arkansas Post National Memorial. Report prepared for National Park Service, Washington, D.C.
- Irving, R. S., and S. Brenholts. 1977b. An ecological reconnaissance of the Roth and Konechy prairies. Report prepared for Arkansas Natural Heritage Commission, Little Rock, AR.
- Irving, R. S., S. Brenholts, and T. Foti. 1980. Composition and net primary production of native prairies in eastern Arkansas. *Amer. Midl. Nat.* 103:298-309.
- Isley, D. 1939. Ecological considerations of certain Arkansas legumes. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Jacobs, D. L. 1951. Ricciaceae of Arkansas. *Bryologist* 54:274-278.
- James, D., E. E. Dale, M. J. Lockerd, D. Schick, and C. R. Preston. 1979. Appraisal of the avifauna, mammalian fauna, and plant communities at developmental sites proposed for the Buffalo National River. Final Report to National Park Service, SW Region, Dallas, TX by Dept. Zoology, Univ. Ark., Fayetteville, AR. 80 pp.
- James, D. A., and J. C. Neal. 1986. Chapter 3: Arkansas birds and the environment. Pp. 17-48, in D. A. James and J. C. Neal. *Arkansas birds, their distribution and abundance.* Univ. Ark. Press, Fayetteville, AR. 402 pp.
- James E. 1823. Account of an expedition from Pittsburg to the Rocky Mountains. Reprinted by University Microfilms, Ann Arbor, MI.
- Jeffries, D. L. 1983. The vegetation and soils of sandstone glades of northern Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Jeffries, D. L. 1985. Analysis of the vegetation and soils of glades on Calico Rock sandstone in northern Arkansas. *Bull. Torrey Bot. Club* 112:70-73.
- Jeffries, D. L. 1987. Vegetation analysis of sandstone glades in Devil's Den State Park, Arkansas. *Castanea* 52:9-15.
- Johnson, D. M., and A. A. Johnson. 1978. Biotic survey of the Big Creek Natural Area. Prepared for Arkansas Natural Heritage Commission, Little Rock, AR.
- Johnson, F. L., and G. D. Schnell. 1985a. Wildland fire history and the effects of fire on vegetative communities at Buffalo National River, Arkansas. Final report to Natl. Park Serv., Southw. Region, Santa Fe, NM.
- Johnson, F. L., and G. D. Schnell. 1985b. Wildland fire history and the effects of fire on vegetative communities at Hot Springs National Park, Arkansas. Final report to Natl. Park Serv., Southw. Region, Santa Fe, NM.
- Johnson, G. T. 1979. Three species of *Trypethelium* new to Arkansas. *Proc. Ark. Acad. Sci.* 33:82-83.
- Johnson, M. I. 1969. A survey of the vascular flora of Poinsett County, Arkansas. M. S. thesis, Memphis St. Univ., Memphis, TN.
- Johnson, M. I. 1971. A survey of the vascular flora of Poinsett County, Arkansas. *Proc. Ark. Acad. Sci.* 25:42-52.
- Justice, J. 1984. Arkansas' mushroom. *Ark. Nat.* 2(5):1-3.
- Justice, J., E. Nelson and J. E. Moore. 1983. Checklist of the mushrooms of Arkansas. *Ark. Acad. Sci., Ark. Biota Survey Checklist* No. 37. 9 pp.
- Kartesz, J. T. and R. Kartesz. 1980. A synonymized checklist of the vascular flora of the United States, Canada, and Greenland. Vol. II. *The Biota of America.* Univ. N. Carolina Press, Chapel Hill, NC. 498 pp. [1985. 2 ed. draft].
- Keeland, B. D. 1978. Vegetation and soils in calcareous glades of northwest Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR. 46 pp.
- Key, J. S. 1975. Pteridophytes of the Interior Highlands of North America. M. S. thesis, Southwest Missouri St. Univ., Springfield, MO.
- King, J. E. 1973. Late Pleistocene palynology and biogeography of the western Missouri Ozarks. *Ecolog. Monogr.* 43:539-565.
- King, J. E. 1973. Late Pleistocene palynology and biogeography of the western Missouri Ozarks. *Ecolog. Monogr.* 43:539-565.
- King, J. E. 1978. New evidence on the history of the St. Francis Sunk Lands, northwest Arkansas. *Geol. Soc. Am. Bull.* 89:1719-1722.
- King, J. E., and W. H. Allen. 1977. A Holocene vegetation record from the Mississippi River valley, southeastern Missouri. *Quat. Res.* 8:307-323.
- Kirkwood, R. T., J. E. Moore, and W. Owen. 1977. A biological survey of the Arkansas Natural Heritage Commission's Cove Creek site. *Biology Dept., Univ. Central Ark., Conway, AR.* Report to Arkansas Natural Heritage Commission, Little Rock, AR.
- Klimas, C. V., C. D. Martin, and J. W. Teaford. 1981. Impacts of flooding regime modification on wildlife habitats of bottomland hardwood forests in the lower Mississippi Valley. *Tech. Rept. EL-81-13.* Environmental Laboratory, U. S. Army Engineer Waterways Expt. Stat., Vicksburg, MS.
- Klomps, V. L. 1980. The status of *Lindera melissifolium* (Walt.) Blume, Pondberry, in Missouri. *Trans. Mo. Acad. Sci.* 14:61-66.



## James H. Peck and Carol J. Peck

- Klomps, V. 1982. Natural Areas Nomination Form - Sand Ponds Natural Area. Report to Arkansas Natural Heritage Commission, Little Rock, AR. 5 pp.
- Knox, B. R. 1967. Pleistocene and recent geology of the southwestern Ozark Plateaus. M. S. thesis, Univ. Iowa, Iowa City, IA.
- Korstain, C. F. 1944. Forestry on private lands in the United States. Duke University School of Forestry, Bull. 8.
- Kral, R. 1980a. *Delphinium newtonianum* D. M. Moore. Status report. Report to U. S. Fish Wildl. Serv., Washington, DC. Biology Dept., Vanderbilt, Univ., Nashville, TN.
- Kral, R. 1980b. *Schoenolirion wrightii* Sherman. Status report to U.S. Fish Wildl. Serv., Washington, DC. Biology Dept. Vanderbilt Univ., Nashville, TN.
- Kral, R. 1983. A report on some rare, threatened, or endangered forest-related vascular plants of the South. U. S. Dept. Agri., Forest Serv., Tech. Publ. R8-TP2. 1305 pp.
- Kral, R., J. Manhart, and C. T. Bryson. 1987. A new *Carex* sect. *Oligocarpae* (Cyperaceae) from western Arkansas and eastern Oklahoma. Ann. Mo. Bot. Gard. 74:440-442.
- Kuchler, A. W. 1964. Potential natural vegetation of the coterminous United States. Amer. Geogr. Soc., Spec. Pub. No. 36. 116 pp.
- Kuroda, P. M. 1979. The relation of principle bottomland hardwood forest types to flooding in the Central Mississippi Delta. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Lang, F. H., and R. D. Stevens. 1942. Pp. 198-245, Chapter V in R. W. Roberts, G. C. Branner, and Mr. R. Owens. Arkansas' natural resources - Their conservation and use. Democrat Print. and Litho., Little Rock, AR.
- Lang, J. M. 1964. The Labiatae of Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Lang, J. M. 1966. Labiatae of Arkansas. Proc. Ark. Acad. Sci. 20:75-84.
- Lang, J. M. 1977. Checklist of the Labiatae (Mints) of Arkansas. Ark. Acad. Sci., Ark. Biota Survey Checklist No. 6. 1 p.
- Lawson, M., and H. C. Ray. 1953. Site characteristics and land use in the forest-prairie margin of Arkansas. U. S. Soil Conser. Serv., Little Rock, AR.
- Leake, H., and D. Leake. 1981. Wildflowers of the Ozarks. Ozark Society Foundation, Little Rock, AR.
- Leroy, J. F. 1957. Les Botanistes francais en Amerique du Nord avant 1850. Centre National de la Recherche Scientifique, Paris.
- Leslie, S. 1986. A preliminary survey of the vascular flora of Bradley County, Arkansas. M. S. thesis, Northeast. Louisiana St. Univ., Monroe, LA.
- Lesquereux, L. 1860. Botanical and palaeontological report of the geological state survey of Arkansas. Pp. 295-400, in D. D. Owen. Second report of a geological reconnaissance of the middle and southern counties of Arkansas made during the years 1859 and 1860. C. Sherman & Sons, Printers, Philadelphia, PA.
- Lewis, A. 1932. La Harpe's expedition on the Arkansas. Pp. 61-85, in Lewis, A. Along the Arkansas. Southwest Press, Dallas, TX.
- Lewis, H. 1854. Das illustrierte Mississippithal. Arnz, Dusseldorf. [Trans. by A. H. Poatguter, ed. by B. L. Heilbron, and printed in 1967 by Minnesota Hist. Soc., St. Paul, MN.]
- Lindsay, H. L., S. J. Bellovich, E. E. Dale, and E. B. Smith. 1974. An environmental inventory and assessment of the Poteau River Basin. Univ. Tulsa, Tulsa, OK. Prepared for U. S. Army Engineers, Tulsa District, Tulsa, OK.
- Linnartz, N. E. 1968. The ecology of southern forests. Louisiana St. Univ. Press, Baton Rouge, LA. 201 pp.
- Linnartz, N. E. 1969. Ecology of southern forests. Louisiana St. Univ. Proc. Ann. Forestry Symp. No. 17. 203 pp.
- Lipscomb, B. L. 1976. A survey of the aquatic and wetland vascular plants of north central Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Lipscomb, B. L. 1978. *Cyperus surinamensis* (Cyperaceae): new to Arkansas, Kansas, and Oklahoma. Sida 7:307.
- Lipscomb, B. L. 1980a. Additions to the Cyperaceae of Arkansas. Castanea 45:70.
- Lipscomb, B. L. 1980b. *Echinodorus tenellus* var. *parvulus* (Alismataceae) in the Ozarks of Arkansas. Castanea 45:254.
- Lipscomb, B. L., and E. B. Smith. 1977. Morphological intergradation of varieties of *Bidens aristosa* (Compositae) in northern Arkansas. Rhodora 79:203-213.
- Little, E. L. 1971. Atlas of United States trees. Vol. 1. Conifers and important hardwoods. U. S. Dept. Agri. Misc. Publ. No. 1146.
- Little, E. L. 1979. Atlas of United States trees. Vol. 4. Minor eastern hardwoods. U. S. Dept. Agri. Misc. Publ. No. 1342.
- Logan, L. A. 1960. The ligneous flora on contrasting sites at Longpool, Pope County, Arkansas. Proc. Ark. Acad. Sci. 15:20-28.
- Long, A. A. 1983. *Neviusia alabamensis*: A phytogeographic analysis. Proc. Ark. Acad. Sci. 37:94-96.
- Long, A. A. 1986. An ecological site analysis of *Neviusia alabamensis*. M. S. thesis, Univ. Central Ark., Conway, AR.
- Lonon, J. H. 1977. The Tremellales of northwest Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Lonon, J. H. 1978. Checklist of northwest Arkansas Tremellales. Ark. Acad. Sci., Ark. Biota Survey Checklist No. 17. 1 p.
- Lookingbill, S. M., M. K. Cleaveland, and M. J. Guccione. 1987. Botanical evidence for Holocene movement of rock streams in Arkansas. Proc. Ark. Acad. Sci. 41:63-68.
- Lorenz, A. 1918. Notes on *Radula obconica* Sull. Bryologist 21:56-59.
- Lowe, R. 1919. Collecting in Arkansas. Bryologist 22:14-15.
- McDonald, P. O., W. E. Frayer, and J. K. Clauser. 1979. Documentation, chronology, and future projections of bottomland hardwood habitat loss in the lower Mississippi alluvial plain, 2 Vol. Report prepared by HRB-Singer, Inc., State College, Pennsylvania, for Division of Ecological Services, Fish and Wildlife Service, U. S. Department of Interior, Washington, D.C.
- Manger, W. L. 1983. The geological provinces of Arkansas. Ark. Nat. 1(7):1-6.
- Manger, W. L. 1983. Landsat imagery of Arkansas. Ark. Nat. 1(10):5-8, 13.
- Mapes, R. B. 1972. The Arkansas waterway, people, places, events in the valley, 1817-1971. University Press, Little Rock, AR. 168 pp.
- Marquette, J., and L. Joliet. 1673. An account of the discovery of some new countries and nations in North America in 1673, in B. F. French. Historical Collections of Louisiana. Part 2.
- Marsh, D. L. 1977a. The distribution of cane: *Arundinaria gigantea* (Poaceae:Bambusoideae). Proc. Ark. Acad. Sci. 31:72-74.
- Marsh, D. L. 1977b. The taxonomy and ecology of cane *Arundinaria gigantea* (Walter) Muhlenberg. Ph. D. diss., Univ. Ark., Fayetteville, AR.
- Marsh, D. L., and A. J. Atkins. 1979. Guide to accompany the map: Vegetation of the Red River from Index, Arkansas to Shreveport, Louisiana. Report prepared for the U.S. Army Corps of Engineers, New Orleans, LA.
- Marsh, M. A. 1977. Natural resource preservation in Arkansas. Proc. Ark. Acad. Sci. 31:116-117.
- Marsh, M. A. 1978. Baker Prairie. Critical habitat for grasshopper sparrow and orate box turtle. Ozark Soc. Bull. 12:10-11.
- Martin, P. S. 1958. Pleistocene ecology and biogeography of North America. Pp. 375-420, in Amer. Assoc. Adv. Sci. Zoogeography. Washington, DC.
- Mathis, W. D. 1974. Studies on the ecology of *Cypridium calceolus* L. var. *parviflorum* (Salisb.) Fern. in northwest Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Mayden, R. L. 1985. Biogeography of Ouachita Highland fishes. Southw. Nat. 39:195-211.
- Maxfield, O. O. 1951. The elements delimiting the Boston Mountain of Arkansas as a geographic region. Proc. Ark. Acad. Sci. 4:149-154.
- McGregor, R. L. 1960. A new species of *Riccia* from the Ozarks. Bryologist 63:30-31.
- McKelvy, S. D. 1956. Botanical explorations of the Trans-Mississippi West, 1790-1850. Arnold Arboretum, Jamaica Plain, MA.
- McNulty, R. 1970. Vascular plants of Lawrence County, Arkansas. M. S. thesis, Ark. St. Univ., State University, AR. 46 pp.



## A Bibliographic Summary of Arkansas Field Botany

- McSwain, E. W. 1946. Compositae of Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- McWilliams, A. L. 1966. Observations on occurrence and range of the three species of *Dentaria* (Cruciferae) in the Ouachita Mountains. Proc. Ark. Acad. Sci. 20:22-24.
- McWilliams, A. L. 1967. The taxonomic status of *Penstemon wherryi* Pennell. Proc. Ark. Acad. Sci. 21:33-35.
- McWilliams, A. L. 1968. The enigma of *Penstemon tenuis* Small (Scrophulariaceae). Proc. Ark. Acad. Sci. 22:57-61.
- Meade, F. M. 1951. Forest plantations in Arkansas. Agricultural Experiment Station Bull. 512. Univ. Ark., Fayetteville, AR.
- Meanely, B. 1972. Swamps, river bottoms, and cane-breaks. Barre Publishers, Barre, MA.
- Mehringer, P. J., C. E. Schweger, W. R. Wood, and R. B. McMillan. 1968. Lake Pleistocene boreal forest in the western Ozark highlands? Ecology 49:568-569.
- Meisel, M. 1924-1929. Bibliography of American natural history. The Pioneer Century, 1769-1865. 3 vols. Publ. by author, N. Y. [Reprinted 1967 by Hafner.]
- Mielke, D. L. 1978. Stand model for upland forests of Southern Arkansas. M. S. thesis, Univ. Tenn., Knoxville, TN.
- Mielke, D. L., H. H. Shugart, and D. C. West. 1978. Stand model for upland forests of Southern Arkansas. Contract W-7405-ENG-26, TM-6225, Oak Ridge National Laboratory, Department of Energy, Oak Ridge, TN. 97 pp.
- Millard, J. J. 1939. Ecologic studies of a typical watershed as a guide to planning wildlife population studies of northern Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Miller, H. 1972. A vegetal reconstruction of early historic northwest Arkansas. Manuscript on file, The Museum, Univ. Ark., Fayetteville, AR.
- Moldenke, H. N. 1978. Notes on new and noteworthy plants, Part 109. Phytologia 38(6):498-499.
- Monette, J. W. 1846. History of the discovery and settlement of the valley of the Mississippi, by the three great European powers, Spain, France and Great Britain, and the subsequent occupation, settlement, and extension of civil government by the United States until the year 1846. 2 vol. Harper & Bros., NY. [Reprinted 1971 by Arnot Press.]
- Moore, D. M. 1939. *Delphinium newtonianum*, a new species from the Arkansas Ozarks. Rhodora 41:193-197.
- Moore, D. M. 1940a. *Selaginella rupestris* (L.) Spring in Arkansas. Amer. Fern J. 30:50-53.
- Moore, D. M. 1940b. Arkansas pteridophyta. Amer. Fern J. 30:105-119.
- Moore, D. M. 1941a. Checklist of the ligneous flora of Arkansas. Proc. Ark. Acad. Sci. 1:41-55.
- Moore, D. M. 1941b. White-flowered forms of some Arkansas wild flowers. Proc. Ark. Acad. Sci. 1:25-27.
- Moore, D. M. 1941c. Some noteworthy fern communities of Arkansas. Amer. Fern J. 31:63-71.
- Moore, D. M. 1941d. A checklist of the grasses of Arkansas. Proc. Ark. Acad. Sci. 1:57-62.
- Moore, D. M. 1942. Conservation of wild plant life in Arkansas: Woody and herbaceous plants. Pp. 246-274, Chapter VI. in R. W. Roberts, G. C. Branner, and M. R. Owens. Arkansas' natural resources - Their conservation and use. Democrat Print. and Litho., Little Rock, AR.
- Moore, D. M. 1947. Further notes on Arkansas pteridophytes. Proc. Ark. Acad. Sci. 2:69-70.
- Moore, D. M. 1950a. A new fern record for Arkansas. Proc. Ark. Acad. Sci. 3:33-34.
- Moore, D. M. 1950b. Grassy Lake: A biologist's paradise. Proc. Ark. Acad. Sci. 3:41-43.
- Moore, D. M. 1951. Some new records for Arkansas flora. Proc. Ark. Acad. Sci. 4:61-63.
- Moore, D. M. 1952. Additional new records of the Arkansas flora, II. Proc. Ark. Acad. Sci. 5:91-93.
- Moore, D. M. 1953. Rediscovery of the bigleaf magnolia in Arkansas. (Abstract) Proc. Ark. Acad. Sci. 6:9.
- Moore, D. M. 1954. An ecological and botanical survey - Table Rock Reservoir. Ed. Serv., Univ. Ark., Fayetteville, AR.
- Moore, D. M. 1955. Observations on *Anemone* in Arkansas. Abstract. Proc. Ark. Acad. Sci. 8:118.
- Moore, D. M. 1956a. *Neviusia alabamensis* Gray (Rosaceae) in Arkansas. Southw. Nat. 1:87-89.
- Moore, D. M. 1956b. *Neviusia alabamensis* in Arkansas. Rhodora 58:187-191.
- Moore, D. M. 1957. New records for the Arkansas flora, III. Proc. Ark. Acad. Sci. 11:6-10.
- Moore, D. M. 1958. New records for the Arkansas flora, IV. Proc. Ark. Acad. Sci. 12:9-16.
- Moore, D. M. 1959. *Mimulus floribundus* Dougl. (Scrophulariaceae) in Arkansas. Southw. Nat. 3:217-219.
- Moore, D. M. 1960. Trees of Arkansas. Rev. Ed. Ark. Forestry Comm., Little Rock, AR.
- Moore, D. M. 1961. Revised and annotated catalog of the grasses of Arkansas. Proc. Ark. Acad. Sci. 15:9-25.
- Moore, D. M. 1972. Trees of Arkansas. Ark. Forestry Comm., Little Rock, AR.
- Moore, D. M. 1977a. Checklist of Arkansas Pteridophytes. Ark. Acad. Science, Ark. Biota Survey Checklist No. 1. 3 pp.
- Moore, D. M. 1977b. Checklist on the Grasses of Arkansas. Ark. Acad. Science, Ark. Biota Survey Checklist No. 2. 8 pp.
- Moore, D. M. 1977c. Checklist of the Orchids of Arkansas. Ark. Acad. Science, Ark. Biota Survey Checklist No. 3. 2 pp.
- Moore, J. E. 1956. *Hedyotis rosea* in Arkansas. Rhodora 58:331.
- Moore, J. E. 1958. A study of the vegetation of Petit Jean Mountain in Central Arkansas. Ph. D. diss. Univ. Tenn., Knoxville, TN.
- Moore, J. E. 1959. Lichens of Arkansas collected by Jewel E. Moore and identified by Mason E. Hale, Museum No. 217286, reported by U. S. Natl. Museum, Washington, DC.
- Moore, J. E. 1965. A study of the vegetation of Petit Jean Mountain in central Arkansas. Castanea 30:1-37.
- Moore, J. E. 1979. Lichens of Arkansas I: A summary of current information. Proc. Ark. Acad. Sci. 33:85-87.
- Moore, J. E. 1981a. Checklist of the Lichens of Arkansas. Ark. Acad. Science, Ark. Biota Survey Checklist no. 30. 15 pp.
- Moore, J. E. 1981b. Key to Arkansas Lichens. Available from Cryptogamic Herbarium, Dept. Biology, Univ. Central Ark., Conway, AR.
- Moore, J. E. 1981c. Lichens of Arkansas II. Additional state records through computer search. Proc. Ark. Acad. Sci. 35:88.
- Moore, J. E. 1982. The Ferns of Arkansas. Available from Cryptogamic Herbarium, Dept. Biology, Univ. Central Ark., Conway, AR.
- Moore, J. E. 1983a. Bryophyte - lichen communities within Hot Springs National Park, Arkansas. Rept. to Hot Springs National Park, Hot Springs, AR.
- Moore, J. E. 1983b. Curatorial notes from the Cryptogamic Herbarium at the University of Central Arkansas. Proc. Ark. Acad. Sci. 37:96-97.
- Moore, J. E., and I. Hartsoe. 1955. A new location for *Ophioglossum crotalophoroides* in Arkansas. Proc. Ark. Acad. Sci. 7:63.
- Moore, J. E., P. L. Redfearn, and S. L. Timme. 1984. Checklist of the Mosses of Arkansas. Ark. Acad. Sci., Ark. Biota Survey Checklist No. 39. 21 pp.
- Moore, J. E., and S. L. Timme. 1983. Bryophyte-lichen communities within Hot Springs National Park, Arkansas I. Proc. Ark. Acad. Sci. 37:96.
- Moore, J. E. and E. B. Whittlake. 1983. Checklist of the Hornworts and Liverworts of Arkansas. Ark. Acad. of Science, Ark. Biota Survey Checklist No. 36. 7 pp.
- Moore, W. G. 1966. Central Gulf States and the Mississippi Embayment. Pp. 287-300, in David G. Frey. Limnology in North America. Madison, WI. 734 pp.
- Moyle, J. B., E. L. Nielson, and O. R. Younge. 1984. Vegetation of artificial lakes in northwestern Arkansas. Rhodora 48:329.
- Nelson, T. C., and W. M. Zillgitt. 1969. A forest atlas of the South. U. S. Forest Serv., Southern and Southeastern Forest Exp. Sta., New Orleans, LA, and Asheville, NC.

## James H. Peck and Carol J. Peck

- Nielson, E. L. 1937. Grass Studies. II. Additions to the flora of Arkansas. *Rhodora* 39:423-424.
- Nielson, E. L. 1941. Grass Studies. IV. Additional species new to Arkansas. *Rhodora* 43:219-220.
- Nightingale, A. A. 1974. An introduction to the compositae (Daisy Family) of the White River Ozarks areas of southwestern Missouri. School Ozarks Press, Point Lookout, MO.
- Nuttall, T. 1821a. A journal of travels into Arkansas territory during the year 1819, with occasional observations on the manners of the aborigines. T. W. Palmer, Philadelphia, PA. 296 pp. [Reprinted 1980 by Univ. Oklahoma Press, Norman, OK.]
- Nuttall, T. 1821b. A description of some new species of plants recently introduced into the gardens of Philadelphia from the Arkansas territory. *J. Phil. Acad. Sci.* 2:114-123.
- Nuttall, T. 1825. Description of two new genera of the natural order Cruciferae. *J. Phil. Acad. Sci.* 5:132-135.
- Nuttall, T. 1835. Collections towards a flora of the territory of Arkansas. *Trans. Amer. Phil. Soc. (n. s.)* 5:139-184.
- Nuttall, T. 1836. Collections towards a flora of the territory of Arkansas. *Trans. Amer. Phil. Soc. (n. s.)* 5:185-203.
- Olmstead, F. E. 1902. A working plan for the forest lands near Pine Bluff, Arkansas. U. S. Bureau Forestry Bull. No. 32. U. S. Dept. Agri., Washington, DC.
- Orzell, S. L., and E. L. Bridges. 1987. Further additions and noteworthy collections in the flora of Arkansas, with historical, ecological, and phytogeographical notes. *Phytologia* 64(2):81-144.
- Orzell, S. L., E. L. Bridges, and S. L. Peacock. 1985. Additions and noteworthy vascular plants from Arkansas, with some ecological notes. *Sida* 11:226-231.
- Orzell, S. L. and J. H. Peck. 1985. Southern woodfern, *Dryopteris Xaustralis*, new to Arkansas. *Proc. Ark. Acad. Sci.* 39:144.
- Orzell, S. L., W. F. Pell, and G. Tucker. 1985. Notes on three palustrine natural community types in the Arkansas Ozarks. *Proc. Ark. Acad. Sci.* 39:141-143.
- Owens, D. D. 1858. First report of a geological reconnaissance of the northern counties of Arkansas. Johnson & Yerkes, State Printers, Little Rock, AR. 256 pp.
- Oxley, A.P. 1924. Mosses found in the region of Fayetteville, Arkansas.
- Palmer, E. J. 1921. The forest flora of the Ozark Region. *J. Arnold Arbor.* 2:216-232.
- Palmer, E. J. 1923. The Red River forest at Fulton, Arkansas. *J. Arnold Arbor.* 4:8-33.
- Palmer, E. J. 1924a. The ligneous flora of Rich Mountain, Arkansas and Oklahoma. *J. Arnold Arbor.* 5:108-134.
- Palmer, E. J. 1924b. Two interesting ferns from Arkansas. *Amer. Fern J.* 14:39-41.
- Palmer, E. J. 1925. Is *Quercus arkansas* a hybrid? *J. Arnold Arbor.* 6:194-201.
- Palmer, E. J. 1926. The ligneous flora of Hot Springs National Park and vicinity. *J. Arnold Arbor.* 7:104-135.
- Palmer, E. J. 1927. On Nuttall's trail through Arkansas. *J. Arnold Arbor.* 8:24-55.
- Palmer, E. J. 1945. *Quercus durandii* and its allies. *Amer. Midl. Nat.* 33:514-519.
- Palmer, E. J. 1948. Hybrid oaks of North America. *J. Arnold Arbor.* 29:1-48.
- Palmer, E. J., and J. A. Steyermark. 1956. Notes on *Geocarpon minimum*. *Bull. Torr. Bot. Club.* 77:268-273.
- Patterson, J. L. 1971. Floods in Arkansas, magnitude and frequency characteristics through 1968. *Ark. Geol. Comm. Water Resour. Res. Center Circ. No. 11.*
- Paulsell, L. K. 1969. The ecology of upland hardwoods of the Ozarks and Ouachitas — with certain management implications. Pp. 117-134, in N. E. Linnartz. The ecology of southern forests. *Proc. Louisiana St. Univ. 17th Annual Forestry Symposium*, Louisiana St. Univ. Press, Baton Rouge, LA.
- Peck, J. H. 1985. *Trichomanes petersii* (Hymenophyllaceae) in an abandoned mine in the Ouachita Mountains of Arkansas. *Southw. Nat.* 30:463-464.
- Peck, J. H. 1986. Second locality for *Dryopteris carthusiana* in Arkansas. *Amer. Fern J.* 76:28-29.
- Peck, J. H., S. Orzell, E. Sundell, and C. J. Peck. 1985. *Dryopteris ludoviciana* and *D. Xaustralis* new to Arkansas. *Amer. Fern J.* 76:28-29.
- Peck, J. H., L. Peacock, and W. Shepherd. 1985. Observations and new records of ferns naturalizing in Arkansas. *Proc. Ark. Acad. Sci.* 39:144-145.
- Peck, J. H., and C. J. Peck. 1986. Additions to the pteridophyte flora of Arkansas. *Arkansas Native Plant Society Occasional Paper No. 6:1-6.*
- Peck, J. H., and C. J. Peck. 1987. Status report on the fern *Woodsia scopulina* in Arkansas. *Proc. Ark. Acad. Sci.* 41:112.
- Peck, J. H., C. J. Peck, S. Orzell, E. Bridges, and C. Amason. 1987. Discovery of *Lycopodium* communities in the Gulf Coastal Plain of Arkansas. *Proc. Ark. Acad. Sci.* 41:112-113.
- Peck, J. H., C. J. Peck, and W. C. Taylor. 1987. Arkansas pteridophyte flora update: a new checklist and additional county-level occurrence records. *Proc. Ark. Acad. Sci.* 41:113-114.
- Peck, J. H., C. J. Peck, and W. C. Taylor. 1987. Checklist of Arkansas ferns and fern allies. *Ark. Acad. Sci., Ark. Biota Survey Checklist No. 47.* 4 pp.
- Peck, J. H., E. Sundell, and C. J. Peck. 1985. Louisiana log fern (*Dryopteris ludoviciana*) new to Arkansas. *Proc. Ark. Acad. Sci.* 39:144.
- Pecotte, A. J. 1981. Aspects of Crowley's Ridge in Arkansas. M. S. thesis, Texas A. & M. Univ., College Station, TX. 134 pp.
- Pell, W. F. 1981. Classification and protection status of remnant natural plant communities in Arkansas. *Proc. Ark. Acad. Sci.* 35:55-59.
- Pell, W. F. 1982. Ecological themes of the Interior Highlands. Report prepared for U. S. Dept. Inter., Natl. Park Serv. and Ark. Nat. Heritage Comm., Little Rock, AR.
- Pell, W. F. 1983. The natural divisions of Arkansas: A revised classification and description. *Natural Areas J.* 3(2):12-23.
- Penfound, W. T. 1952. Southern swamps and marshes. *Bot. Rev.* 18:413-446.
- Pennell, F. W. 1950. Historical botanic collections of the American Philosophical Society and the Academy of Natural Sciences of Philadelphia. *Proc. Amer. Phil. Soc.* 93:137-151.
- Petty, F. D., and A. V. Brown. 1982. Leaf processing in a slough of an Ozark stream. *Proc. Ark. Acad. Sci.* 36:49-51.
- Phipps, R. L. 1979. Simulation of wetland forest vegetation dynamics. *Ecol. Model.* 7:257-288.
- Pierce, R. A., and R. T. Kirkwood. 1977. Evaluation of plantings for wildlife on a power-line right-of-way in southern Arkansas. *Proc. Ark. Acad. Sci.* 31:83-89.
- Pike, Z. M. 1810. An account of the expedition to the sources of the Mississippi and through the western part of Louisiana Territory. [Reprinted 1966 by Univ. Microfilms, Ann Arbor, MI.]
- Pike, Z. M. 1779-1813. Zebulon Pike's Arkansas journal, in search of the southern Louisiana Purchase boundary line. [Edited by Hart, S. H., and A. B. Hulbert.]
- Plank, E. M. 1898-1899. Concerning the plants of southwestern Arkansas. *Plant World* 2:45-47.
- Posey, A. F. 1974. Vegetational habitats of breeding birds in Ozark shrubby old fields. Ph. D. diss., Univ. Ark., Fayetteville, AR. 42 pp.
- Puetz, C. J. Undated. Arkansas county maps. County Maps, Lyndon Station, WI. 152 pp.
- Putnam, J. A., and H. Bull. 1932. The trees of the bottomlands of the Mississippi River Delta region. U. S. Forest Serv., New Orleans, South. For. Expt. Stn. Occ. Pap. No. 27.
- Pyle, H. R. 1939. The herbaceous flora of Magazine Mountain. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Raines, P. L. 1972. An ecological life history of Virginia Wild Rye (*Elymus virginicus* L.) Ph. D. diss., Univ. Ark., Fayetteville, AR.
- Raines, P. L., and E. L. Richards. 1976. Plant resources, plant communities, vascular plant inventory, and endangered plant species.

## A Bibliographic Summary of Arkansas Field Botany

- In* Environmental inventory of the Tyronza River Basin. U. S. Soil Cons. Serv., Little Rock, AR. 41 pp.
- Raines, P. L., and E. L. Richards. 1977. Plant resources, plant communities, vascular plant inventory, and endangered plant species. *In* Environmental inventory of the Village Creek Basin. U. S. Soil Cons. Serv., Little Rock, AR. 41 pp.
- Raup, H. M. 1942. Trends in the development of geographic botany. *Ann. Assoc. Amer. Geogr.* 32:319-354.
- Ray, H. C. 1953. Site characteristics and land-use in the forest-prairie margin of Arkansas. U. S. Dept. Agri., Soil Cons. Comm., Ft. Worth, TX. 28 pp.
- Ray, H. C. 1954. Historical review of prairie and savannah areas of the Ozark and Ouachita Highlands. U. S. Dept. Agri., Soil Cons. Serv., Ft. Worth, TX.
- Ray, H. C., and M. L. Lawson. 1955. Site characteristics as a guide to forest grazing use in the Ozarks. *J. Range Manag.* 8:69-74.
- Read, R. A. 1951. Woodland forage in the Arkansas Ozarks. *J. Range Manag.* 4:391-396.
- Read, R. A. 1952. Tree species occurrence as influenced by geology and soil on an Ozark north slope. *Ecology* 33:239-246.
- Recorc, S. J. 1907. The forests of Arkansas. *For. Quart.* 5:206-301.
- Record, S. J. 1910. The forest resources of Arkansas. Mo. Pac. Land Office, Little Rock, AR.
- Redfearn, P. L., Jr. 1964. Bryophytes of Arkansas I. Species "Lost Valley" and adjacent regions. *Bryologist* 67:196-201.
- Redfearn, P. L., Jr. 1968. Bryophytes from the Interior Highlands. XIII. Additions to the flora. *Bryologist* 71:356-357.
- Redfearn, P. L. 1969. *Marshallia caespitosa* var. *signata* (Compositae) in the Ouachita Mountains of Arkansas. *Sida* 3:450.
- Redfearn, P. L. 1970. Bryophytes of the Interior Highlands XV. Additions to the flora. *Bryologist* 73:716-717.
- Redfearn, P. L. 1972a. Mosses of the Interior Highlands of North America. *Ann. Mo. Bot. Gard.* 59:1-104.
- Redfearn, P. L. 1972b. The valley mandarin, a notable addition to the flora of Arkansas. *Rhodora* 74:523-524.
- Redfearn, P. L. 1979a. Bryophytes of the Interior Highlands of North America. XVI. Species of the Ozark National Forest, Sylamore Division, and adjacent areas in Stone County, Arkansas. *Bryologist* 82:483-486.
- Redfearn, P. L. 1979b. *Spiranthes lucida* in Arkansas. *Castanea* 44:59-60.
- Redfearn, P. L. 1983a. Bryophytes of the Interior Highlands of North America. XVIII. Additions to the flora. *Bryologist* 86:357.
- Redfearn, P. L. 1983b. A checklist of the mosses of the Interior Highlands of North America in Arkansas, Illinois, Missouri, and Oklahoma. Ozark regional herbarium, Dept. Biol., Southwest Missouri St. Univ., Springfield, MO.
- Redfearn, P. L., G. L. Pyrah, W. R. Weber, and C. Pope. 1979. Botanical survey of the Morris, Sutton, and Big Foot areas of Hempstead and Nevada counties, Arkansas. Southwest Missouri St. Univ., Springfield, MO. (mimeo.)
- Reed, P. B. 1986. Wetland plants of the state of Arkansas. Report for National Wetlands Inventory, U. S. Fish Wildl. Serv., St. Petersburg, FL. (In conjunction with U. S. Fish Wildl. Serv., U. S. Army Engineers, U. S. Envir. Protect. Agen., and U. S. Soil Cons. Serv.) 31 pp.
- Reinhold, R. O. 1969. Climate of the states: Arkansas. *In*: Climatology of the United States No. 60-3 by U. S. Dept. Comm., ESSA, Environmental Data Services. Washington, DC.
- Rettig, J. H. 1979. Primary growth-limiting factors in communities of *Nelumbo lutea* (Willd.) Pers. M. S. thesis, Ark. St. Univ., College Station, AR. 37 pp.
- Rettig, J. H. 1982. Seven significant vascular plant records for Arkansas. *Proc. Ark. Acad. Sci.* 36:98.
- Rettig, J. H. 1983. A new station for *Geocarpum minimum* MacKenzie (Caryophyllaceae). *Bull. Torrey Bot. Club.* 110:213.
- Reynolds, J. H., and D. Y. Thomas. 1910. History of the University of Arkansas. University of Arkansas, Fayetteville, AR. 555 pp.
- Reynolds, R. R. 1950. Sidelights on managing mixed pine-hardwood stands under the selection systems. *J. For.* 48:108-111.
- Rhodes, D. and F. Tainter. 1979. Abstract: Interaction of precipitation, temperature, and annual radial growth of white oak in Northeast Arkansas. *Phytopathology* 69:531.
- Richards, E. L. 1972. Vascular plants. *In* Environmental inventory of the Strawberry River Basin. U. S. Army Engineers, Little Rock, AR. 22 pp.
- Richards, E. L. 1973a. Vascular plants and endangered plant species. *In* Environmental impact report on the Cache-Bayou DeView drainage system. Midwest Research Institute, Kansas City, MO. 11 pp.
- Richards, E. L. 1973b. Vascular plants and endangered plant species. *In* Environmental inventory of the White River Basin. U. S. Army Engineers, Little Rock, AR. 36 pp.
- Richards, E. L. 1974a. Vascular plants and endangered plant species. *In* Environmental inventory study for Eastman Kodak near Batesville, AR. 15 pp.
- Richards, E. L. 1974b. Vascular plants and endangered plant species. *In* Environmental inventory of Village Creek basin. U. S. Army Engineers, Little Rock, AR. 15 pp.
- Richards, E. L. 1975. Vascular plants and endangered species and plant communities. *In* Environmental inventory of the Upper Strawberry River. U. S. Soil Cons. Serv., Little Rock, AR. 17 pp.
- Richards, E. L. 1978a. Environmental inventory of vascular plants. *In* Environmental impact statement of proposed transmission line from Batesville Southside to Alonzo in Independence County. Report prepared for Arkansas Power and Light Co., Little Rock, AR. 21 pp.
- Richards, E. L. 1978b. Vascular plants and environmental assessment. *In* Environmental assessment of the North Fork River downstream of the Norfolk Dam. Report to U. S. Army Engineers, Little Rock, AR. 13 pp.
- Richards, E. L. 1980. Vascular plants and endangered plants. *In* Environmental inventory and brief report of the Caney Creek study area, West Helena, AR. Report prepared for A. C. Young and Associates, Inc. Tulsa, OK. 9 pp.
- Richards, E. L. 1982. New and interesting plants for the Arkansas flora from northeastern Arkansas. *Proc. Ark. Acad. Sci.* 36:99.
- Richards, E. L. 1985. New and interesting plants for the Arkansas flora. *Proc. Ark. Acad. Sci.* 39:147-148.
- Richards, E. L., and S. L. Orzell. 1987. New locations for Ponberry (*Lindera melissifolia*) in Arkansas. *Proc. Ark. Acad. Sci.* 41:114.
- Rickett, H. W. 1966. Wildflowers of the United States. II. The southwestern states. 2 vols. New York. 688 pp.
- Roberts, J. L. 1978. The sandhills region of south Arkansas. Report prepared for Arkansas Natural Heritage Commission, Little Rock, AR. (mimeo.)
- Roberts, J. L. 1979. The Arkansas blackland region. Report prepared for Arkansas Natural Heritage Commission, Little Rock, AR. (mimeo.)
- Roberts, R. W., G. C. Branner, and M. R. Owens. 1942. Arkansas' natural resources — their conservation and use. Democrat Print and Litho. Co., Little Rock, AR.
- Robinson, A. 1959. The flora of IZard County. *Proc. Ark. Acad. Sci.* 13:9-14.
- Robinson, A. 1964. Report on the Graminae of the Arkansas Salem Plateau. *Kansas Acad. Sci.* 67:460-469.
- Robinson, A. 1968. Report on the Graminae of the Arkansas Springfield Plateau. *Proc. Ark. Acad. Sci.* 22:76-87.
- Robison, H. W., and K. L. Smith. 1982. The endemic flora and fauna of Arkansas. *Proc. Ark. Acad. Sci.* 36:52-57.
- Rosen, H. R. 1926. A new *Amanita* from Arkansas. *Mycologia* 18:97-99.
- Rosen, R. 1976. A preliminary checklist of Arkansas Acrasieae. *Proc. Ark. Acad. Sci.* 30:75.
- Rosen, R. 1980. Checklist of the Cellular Slime Molds (Acrasieae) of Arkansas. *Ark. Acad. Sci.*, *Ark. Biota Survey Checklist* No. 28. 1 p.
- Ruby, E. S. 1953. Prairie vegetation in northwest Arkansas. *Proc. Ark. Acad. Sci.* 6:31-35.



## James H. Peck and Carol J. Peck

- Sargent, C. S. 1884. Report on the forests of North America (exclusive of Mexico). 10th U.S. Census (Arkansas) 9:543-544. Washington, D.C. [Includes map showing distribution of Arkansas forests.]
- Sargent, C. S. 1918. Notes on North American trees. II. *Carya*. Bot. Gaz. 66:229-258.
- Saucier, R. T. 1970. Origin of the St. Francis Sunk Lands, Arkansas and Missouri. Geol. Soc. Amer. Bull. 81:2847-2854.
- Saucier, R. T. 1974. Quaternary geology of the Lower Mississippi Valley. Ark. Archaeol. Surv., Res. Ser. 6.
- Saucier, R. T. 1978. Sand dunes and related eolian features of the lower Mississippi River valley. Geosci. Man. 19:23-40.
- Schoolcraft, H. R. 1821. Journal of a tour into the interior of Missouri and Arkansas, from Potosi, or Mine a Burtin, in Missouri Territory, in a south-west direction, toward the Rocky Mountains; performed in the years 1818 and 1819. Sir R. Phillips and Co., London. 102 pp.
- Schoolcraft, H. R. 1853. Scenes and adventures in the semi-alpine regions of the Ozark Mountains of Missouri and Arkansas, which were first traversed by De Soto, in 1541. Lippincott, Grambo, & Co., Philadelphia, PA. 256 pp.
- Schick, D. 1979. Vegetation studies of north and south exposures on sandstones of the Buffalo River Area, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Schulman, E. 1942. Dendrochronology in pines of Arkansas. Ecology 23:309-318.
- Scott, R., and E. E. Dale, Jr. (undated). Vegetation of adjacent grazed and ungrazed sites, Washington County, Arkansas. University of Arkansas, Fayetteville, AR. (mimeo.)
- Scully, F. J. 1937. Ferns of Hot Springs National Park. Amer. Fern J. 27:59-62.
- Scully, F. J. 1939. Ferns of Hot Springs National Park and vicinity. J. Hot Springs Nat. Hist. Assoc. 5:1-37.
- Scully, F. J. 1941. The mosses of Hot Springs National Park and vicinity. Bryologist 44:125-128.
- Scully, F. J. 1942a. Grasses of Hot Springs National Park, Arkansas and vicinity. Rhodora 44:70-71.
- Scully, F. J. 1942b. Sedges and rushes of Hot Springs National Park, Arkansas, and vicinity. Torreya 42:129-130.
- Sealander, J. A. 1979. A guide to Arkansas mammals. River Road Press, Conway, AR.
- Sears, P. B., and G. G. Couch. 1932. Microfossils in an Arkansas peat bog and their significance. Ohio J. Sci. 32:63-68.
- Segelquist, C. A. and R. E. Pennington. 1972. Browse resources of the Ouachita National Forest in Arkansas. U. S. Forest Serv. Res. Note SO 140:1-4.
- Severin, T. 1968. Explorers of the Mississippi. Knopf, NY. 294 pp.
- Shantz, H. L., and R. Zon. 1924. Natural vegetation. Atlas of American agriculture. Part 1. Section E. U. S. Dept. Agri., Forest Serv., New Orleans, LA.
- Shelford, V. E. 1926. Naturalist's Guide to the Americas. Williams and Wilkins Company. Baltimore. [Includes section on Arkansas by J. T. Buchholz.]
- Shepard, R. D., and W. R. Boggess. (undated). The oak-hickory forest region of the eastern deciduous forest including an inventory of significant natural areas. National Park Service contract No. 14-10-9-900-187.
- Shepherd, W. 1986. Visiting Royalty (*Silene regia*). Ark. Nat. 4(1):16-19.
- Shepherd, W., K. L. Smith, W. F. Pell, J. H. Rettig, R. H. Davis, and H. W. Robison. 1984. Arkansas' Natural Heritage. August House, Little Rock, AR.
- Sheviak, C. J. 1987. On the occurrence of *Plantanthera leucophaea* in Louisiana and Arkansas. Rhodora 89:347-350.
- Sherif, A. S. 1983. Floristic study of the Gramineae (Poaceae) of Arkansas. Ph. D. diss., Dept. Botany, Univ. Ark., Fayetteville, AR.
- Shinners, L. H. 1956. *Hypochaeris glabra* L. (Compositae) in Arkansas and Louisiana. Southwest Nat. 1:88.
- Shinners, L. H. 1962. Evolution of Gray's and Small's Manual ranges. Sida. 1:1-31.
- Shinners, L. H. 1969. *Pterorhagia prolifera*, *Dianthus prolifera*, *D. tunica* (Caryophyllaceae) in Arkansas and Texas. Sida 3:345-346.
- Shreve, R. W. 1924a. *Iris cristata*. Flower Grower 11:301.
- Shreve, R. W. 1924b. Native irises of the Ozarks. Flower Grower 11:385-386.
- Shugart, H. H. 1968. Ecological succession of breeding bird populations in northwest Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Shugart, H. H., and D. James. 1973. Ecological succession of breeding bird populations in northwestern Arkansas. Auk 90:62-77.
- Shugart, H. H., and D. C. West. 1981. Long-term dynamics of forest ecosystems. Amer. Sci. 69:647-652.
- Small, J. K. 1933. Manual of the southeastern flora. J. K. Small, New York. 1554 pp. [Reprinted by Univ. N. Carolina Press, Chapel Hill, NC.]
- Smith, A. I. 1979. A guide to wildflowers of the Mid-South. Memphis St. Univ. Press, Memphis, TN
- Smith, A. R. 1971. The *Thelypteris normalis* complex in the southeastern United States. Amer. Fern J. 61:21-32.
- Smith, E. B. 1968. The spring wildflowers of northeastern Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Smith, E. B. 1969. A survey of the Arkansas Campanulaceae (including the Lobeliaceae). Proc. Ark. Acad. Sci. 23:126-130.
- Smith, E. B. 1970. Additions to the Arkansas flora. Proc. Ark. Acad. Sci. 24:37-39.
- Smith, E. B. 1972. Keys to the compositae of Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Smith, E. B. 1973. An annotated list of the Compositae of Arkansas. Castanea 38:79-109.
- Smith, E. B. 1973. A biosystematic study of *Coreopsis saxicola* (Compositae). Brittonia 25:200-208.
- Smith, E. B. 1975. An atlas of the compositae of Arkansas. In: A partial inventory of Arkansas biota, 9th Annual Ark. Biology Curriculum Development Conf., Hendrix College, Conway, AR. Ark. Biol. Curr. Dev. Conf. No. 2. 53 pp.
- Smith, E. B. 1976a. A biosystematic survey of *Coreopsis* in eastern United States and Canada. Sida 6:123-215.
- Smith, E. B. 1976b. *Hedyotis ouachitana* (Rubiaceae): A new species from the Ouachita Mountains of Arkansas and Oklahoma. Brittonia 28:453-459.
- Smith, E. B. 1977a. Checklist of the Saxifragaceae (Saxifragales) of Arkansas. Ark. Acad. Science, Ark. Biota Survey Checklist No. 4. 1 p.
- Smith, E. B. 1977b. Checklist of the Rubiaceae (Madders) of Arkansas. Ark. Acad. Science, Ark. Biota Survey Checklist No. 5. 1 p.
- Smith, E. B. 1977c. Notes on the Arkansas Saxifragaceae. Proc. Ark. Acad. Sci. 31:100-102.
- Smith, E. B. 1978. An atlas and annotated list of the vascular plants of Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Smith, E. B. 1979a. A new variety of *Galium arkansanum* (Rubiaceae) endemic to the Ouachita Mtns. of Arkansas. Brittonia 31:279-283.
- Smith, E. B. 1979b. An atlas and annotated list of the vascular plants of Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR [Revised Second Printing.]
- Smith, E. B. 1979c. An atlas and annotated list of the vascular plants of Arkansas, Supplement 1:1-21. Dept. Botany, Univ. Ark., Fayetteville, AR. [Reprinted as Occ. Pap. Ark. Nat. Plt. Soc. No. 1:1-21.]
- Smith, E. B. 1980. An atlas and annotated list of the vascular plants of Arkansas, Supplement 2:1-11. Dept. Botany, Univ. Ark., Fayetteville, AR. [Reprinted as Occ. Pap. Ark. Nat. Plt. Soc. No. 2:1-11.]
- Smith, E. B. 1981a. An atlas and annotated list of the vascular plants of Arkansas, Supplement 3:1-9. Dept. Botany, Univ. Ark., Fayetteville, AR. [Reprinted as Occ. Pap. Ark. Nat. Plt. Soc. No. 3:1-9.]
- Smith, E. B. 1981b. New combinations in *Croptilon* (Compositae-Asteraceae). Sida 9:59-63.
- Smith, E. B. 1982a. An atlas and annotated list of the vascular plants of Arkansas, Supplement 4:1-17. Dept. Botany, Univ. Ark., Fayetteville, AR.



## A Bibliographic Summary of Arkansas Field Botany

- etteville, AR. [Reprinted as Occ. Pap. Ark. Nat. Plt. Soc. No. 4:1-17.]
- Smith, E. B. 1982b. Juvenile and adult leaflet phases in *Aralia spinosa* L. Sida 9:330-332.
- Smith, E. B. 1982c. A new variety of *Cardamine angustata* (Cruciferae) from the Ouachita Mountains of Arkansas. Brittonia 34:376-380.
- Smith, E. B. 1983a. Collecting vascular plants. Ark. Nat. 1(10):1-3, 10-11.
- Smith, E. B. 1983b. *Cypripedium candidum* muhl. ex Wild. (Orchidaceae) in Arkansas. Sida 10:189.
- Smith, E. B. 1986. An atlas and annotated list of the vascular plants of Arkansas, Supplement 5:1-21. [Reprinted as Occ. Pap. Ark. Nat. Plt. Soc. No. 5:1-21.]
- Smith, E. B., and M. G. Barber. 1979. Additions, deletions and corrections for the atlas and annotated list of the vascular plants of Arkansas. Proc. Ark. Acad. Sci. 33:91.
- Smith, E. B., and B. L. Lipscomb. 1975. Some new and noteworthy plants of the Arkansas flora. Proc. Ark. Acad. Sci. 29:64-66.
- Smith, E. B., and H. M. Parker. 1971. A biosystematic study of *Coreopsis tinctoria* and *C. cardaminefolia* (Compositae). Brittonia 23:161-170.
- Smith, J. L. 1960. Hardwood removal lessens litter-humus in Ozarks. S. Forest Res. 1(1):9-10.
- Smith, R. A. 1951. Exploration of the Arkansas River by Benard de la Harpe, 1721-1722: extracts from his journal and instructions. Ark. Hist. Quart. 10:339-363.
- Smith, T. 1979. Ecological studies of prairie restoration at Pea Ridge National Military Park, Benton County, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Society of American Foresters. 1967. Forest cover types of North America (exclusive of Mexico). SAF, Washington, D.C.
- Spellman, D. L. 1980. *Sarcostemma cynanchoides* (Asclepiadaceae) in Arkansas, USA. Sida 7:92.
- Stahle, D. W. 1982. Development of modern tree-ring chronologies in the midwest: Arkansas, North Texas, Oklahoma, Kansas, and Missouri. Final report submitted to Climate Dynamics Program, NSF, Washington, DC.
- Stahle, D. W., M. K. Cleaveland, and J. G. Hehr. 1985. A 450-year drought reconstruction for Arkansas, United States. Nature 316:530-532.
- Stahle, D. W., J. G. Hehr, G. G. Hawks, M. K. Cleaveland, and J. R. Baldwin. 1985. Tree-ring chronologies for southcentral United States. Tree-ring Laboratory and Office of State Climatologist, Dept. Geogr., Univ. Ark., Fayetteville, AR.
- State of Arkansas. 1974. Arkansas Natural Area Plan. Arkansas Natural Heritage Commission, Little Rock, AR.
- State Data Center. 1986. Arkansas statistical abstract — 1986. Geography and Environment, Pp. 49-74. SDC, Research & Publi Serv. Unit, Univ. Ark. — Little Rock, Little Rock, AR. 499 pp.
- Sternitzke, H. S. 1960. Arkansas forests. So. For. Surv. Release 84. U. S. Forestry Serv., So. For. Exp. Stn., New Orleans, LA.
- Sternitzke, H. S., and J. F. Christopher. 1970. Land clearing in the lower Mississippi Valley. Southeastern Geographer 10:63-66.
- Steyermark, J. A. 1938. Two undescribed plants from Arkansas. Rhodora 40:71-72.
- Steyermark, J. A. 1940. *Draba aprica* in the Ozarks of southwestern Missouri. Rhodora 42:32-33.
- Steyermark, J. A. 1949. *Lindera melissifolia*. Rhodora 51:152-162.
- Steyermark, J. A. 1958. Another station for *Geocarpon minimum*. Bull. Torr. Bot. Club 85:124-127.
- Steyermark, J. A. 1959. Vegetational history of the Ozark forest. University of Missouri Studies, Columbia, MO.
- Steyermark, J. A., J. W. Voight, and R. H. Mohlenbrock. 1959. Present biological status of *Geocarpon minimum* MacKenzie. Bull. Torrey Bot. Club 86:228-235.
- Steyermark, J. A. 1963. Flora of Missouri. Iowa State Univ. Press, Ames. 1728 pp.
- Stoller, K. M. 1932. Timber types in the Kiamichi and Ozark regions. J. For. 30:69-71.
- Stroud, H. B. and G. T. Hanson. 1981. Arkansas geography: the physical landscape and the historical-cultural setting. Rose Publishing Co., Little Rock. 90 pp.
- Sullins, J. P. 1970. Vegetation of selected sites in deer enclosures of the Sylamore District, Ozark National Forest, Arkansas. M. A. thesis, Univ. Ark., Fayetteville, AR.
- Sullivan, J. R. 1978. Composition and abundance of vegetation of the water fluctuation zones of Beaver and Bull Shoals lakes, northwest Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Sundell, E. 1983. Two additions to the Arkansas flora from Warren Prairie. Sida 10:188-189.
- Sundell, E. 1986. Noteworthy vascular plants from Arkansas. Castanea 51:211-215.
- Swartz, D. 1942. Conservation of wild plant life in Arkansas: Fungi, algae, and mosses. Pp. 274-288. Chapter VI in R. W. Roberts, G. C. Branner, and M. R. Owens. Arkansas' natural resources — Their conservation and use. Democrat Print. and Litho., Little Rock, AR.
- Sweeny, J. M., M. E. Garner, and R. P. Burkert. 1984. Analysis of white-tailed deer use of forest clear-cuts. J. Wildl. Manag. 48:652-655.
- Taylor, R. J., and C. E. Taylor. 1981. Plants new to Arkansas, Oklahoma, and Texas. Sida 9:25-28.
- Taylor, W. C. 1976. Arkansas pteridophyta: description and. Ph. D. diss., Univ. Southern Illinois, Carbondale, IL.
- Taylor, W. C. 1981. Ferns of the tufa deposits on Hot Springs Mountain, Hot Springs National Park: inventory, status, and maintenance. Report to Eastern Natl. Park & Monument Assoc., Philadelphia, PA.
- Taylor, W. C. 1982. Dr. Demaree and the Palmer *Dryopteris*. Sida 9:287-289.
- Taylor, W. C. 1984. Arkansas ferns and fern allies. Milwaukee Public Museum. Milwaukee, WI. 262 pp.
- Taylor, W. C., and D. Demaree. 1979. Annotated list of the ferns and fern allies of Arkansas. Rhodora 81:503-548.
- Taylor, W. C., and D. M. Johnson. 1979. *Thelypteris* in Arkansas. Amer. Fern J. 69:26-28.
- Templeton, G. E. 1962. A list of the smut fungi of Arkansas. Proc. Ark. Acad. Sci. 16:17-18.
- Templeton, G. E. 1977. Checklist of the Smut Fungi of Arkansas. Ark. Acad. Sci., Ark. Biota Survey Checklist No. 7. 1 p.
- Teskey, R. O., and T. M. Hinckley. 1977. Impact of water level changes on woody riparian and wetland communities. Vol. II: Southern Forest Region. U. S. Fish and Wildlife Service.
- Theriot, R. F. 1988. Flood tolerance indices of plant species of southeastern bottomland forests. Technical Report, U. S. Army Engineer Waterways Expt. Station, Vicksburg, Mississippi.
- Timme, S. L. 1986. Distribution of bryophytes in selected western Missouri and western Arkansas prairies. Pp. 61-64. in G. K. Clambey and R. H. Pemble. The prairie, past, present and future. Proceedings Ninth North American Prairie Conference. Tri-college University, Center for Environmental Studies, Fargo, ND/Moorehead, MN.
- Thomas, P. E., and P. L. Redfearn. 1976. Bryophytes of the interior highlands. Part 16: new distributional records for Arkansas and Missouri, USA. Bryologist 79:100-101.
- Thomas, R. D. 1978. Three additions to the Ophioglossaceae of Arkansas. Bull. Torr. Bot. Club 105:234-235.
- Thomas, R. D., and S. Hooks. 1985. *Limnoscidium pumilum* new to Arkansas. Phytologia 57:374.
- Thomas, R. D., S. Leslie, and S. Hooks. 1985. *Seymeria cassioides* (Walt.) Blake new to Arkansas. Phytologia 59:81-82.
- Thompson, P. 1984. A new orchid for Arkansas. Ark. Nat. 2(1):1-3,10.
- Thompson, R. L. 1977. The vascular flora of Lost Valley, Newton County, Arkansas. Castanea 42:61-94.
- Thornbury, W. D. 1965. Regional geomorphology of the United States. Wiley, NY. 609 pp.
- Timme, S. L., and J. E. Moore. 1983. New county and state records of mosses from Arkansas. Proc. Ark. Acad. Sci. 37:100-101.

- Torrey, J. 1853. Description of the plants collected during the expedition to the Red River of Louisiana in 1852). In: R. B. Marcy, Exploration of the Red River of Louisiana.
- Torrey, J. and A. Gray. 1838-1843. A flora of North America; containing abridged descriptions of all the known indigenous and naturalized plants growing north of Mexico; arranged according to the natural system. Wiley and Putnam, NY. 2 vol.
- Torrey, J. and A. Gray. 1855. Botanical report upon the collections made by Captain Gunnison, Topographical Engineers, in 1853, and by Lieutenant E. G. Beckwith, Third Artillery, in 1854. Part II. In: Report of explorations and surveys...for a railroad from the Mississippi River to the Pacific Ocean, etc. Vol. II. House of Representatives Ex. Doc. No. 91, 33rd Congress, 2nd Session.
- Troutman, F. H., and R. L. Porterfield. 1974. The role of Arkansas forests in the state's economy. Prepared for Ark. State Chamber of Comm. and Associated Indus. of Ark., by Indus. Research and Ext. Center, College of Bus. Admin., Univ. Ark. Little Rock, Little Rock, AR. Publ. No. D-16.
- Troutman, F. H., S. G. Breshears, J. L. Greene, and J. C. Geisler. 1981. Forests and the Arkansas economy. Indus. Research and Ext. Center, Univ. Ark. Little Rock, Little Rock, AR. Publ. No. D-17.
- Tucker, G. E. 1969. Some noteworthy species of the Arkansas flora. Proc. Ark. Acad. Sci. 23:142-144.
- Tucker, G. E. 1971. *Selaginella arenicola* ssp. *riddellii* (Selaginellaceae) in Arkansas. Sida 4:275.
- Tucker, G. E. 1972. The vascular plants of Magazine Mountain. Report prepared for U.S. Forest Serv., Ozark Natl. Forest, Russellville, AR.
- Tucker, G. E. 1974a. *Caperonia palustris* (Euphorbiaceae) in Arkansas. Sida 5:286.
- Tucker, G. E. 1974b. *Lindera melissaefolium* in Arkansas. Rhodora 76:525.
- Tucker, G. E. 1974c. The vascular plant family Lauraceae in Arkansas. Proc. Ark. Acad. Sci. 28:74-75.
- Tucker, 1974d. Threatened native plants of Arkansas. In Arkansas Natural Area Plan. Ark. Dept. Planning, Little Rock, AR.
- Tucker, G. E. 1975a. A guide to the woody flora of Arkansas. In: A partial inventory of Arkansas biota, 9th Annual Arkansas Biology Curriculum Development Conf., Hendrix College, Conway, AR. Ark. Biol. Curr. Dev. Conf. No. 1. 207 pp.
- Tucker, G. E. 1975b. *Castanea pumila* var. *ozarkensis* (Ashe) Tucker, comb. nov. Proc. Ark. Acad. Sci. 29:67-69.
- Tucker, G. E. 1976. A guide to the woody flora of Arkansas. Ph. D. diss., Univ. Ark., Fayetteville, AR.
- Tucker, G. E. 1979. Checklist of the woody plants of Arkansas. Ark. Acad. Sci., Ark. Biota Survey Checklist No. 21. 9 pp.
- Tucker, G. E. 1983a. Status report on *Trillium pusillum* var. *ozarkanum* (Palmer & Steyermark) Steyermark. Report to U. S. Fish Wildl. Service. 42 pp.
- Tucker, G. E. 1983b. A survey of Overcup Oak — and Pin Oak — dominated wetlands in the Boston Mountains of Arkansas. Unpubl. manuscript, Dept. Biology, Arkansas Tech Univ., Russellville, AR.
- Tucker, G. E. 1984a. In memoriam, Richard Harley Davis, 1946-1983. Sida 10:265-267.
- Tucker, G. E. 1984b. Status survey *Castanea ozarkensis*. Report to U. S. Fish and Wildl. Serv. 33 pp.
- Tucker, G. E. 1984c. Status survey *Delphinium newtonianum*. Report to U. S. Fish and Wildl. Serv. 46 pp.
- Tucker, G. E. 1984d. Status survey *Delphinium treleasei*. Report to U. S. Fish and Wildl. Serv. 37 pp.
- Tucker, G. E. 1984e. Status survey *Dodecatheon frenchii*. Report to U. S. Fish and Wildl. Serv. 30 pp.
- Tucker, G. E. 1984f. Status survey *Draba aprica*. Report to U. S. Fish and Wildl. Serv. 29 pp.
- Tucker, G. E. 1984g. Status survey *Eriocaulon kornickianum*. Report to U. S. Fish and Wildl. Serv. 31 pp.
- Tucker, G. E. 1984h. Status survey *Geocarpum minimum*. Report to U. S. Fish and Wildl. Serv. 32 pp.
- Tucker, G. E. 1984i. Status survey *Heuchera arkansana*. Report to U. S. Fish and Wildl. Serv. 31 pp.
- Tucker, G. E. 1984j. Status survey *Leitneria floridana*. Report to U. S. Fish and Wildl. Serv. 47 pp.
- Tucker, G. E. 1984k. Status survey *Lindera melissifolia*. Report to U. S. Fish and Wildl. Serv. 45 pp.
- Tucker, G. E. 1984l. Status survey *Neviusia alabamensis*. Report to U. S. Fish and Wildl. Serv. 39 pp.
- Tucker, G. E. 1984m. Status survey *Oenothera pilosella* ssp. *sessilis*. Report to U. S. Fish and Wildl. Serv. 19 pp.
- Tucker, G. E. 1984n. Status survey *Penstemon cobaea* var. *purpureus*. Report to U. S. Fish and Wildl. Serv. 12 pp.
- Tucker, G. E. 1984o. Status survey *Thalictrum debile*. Report to U. S. Fish and Wildl. Serv. 23 pp.
- Tucker, G. E., and B. Grabill. 1970. Floristic elements of the Pope County, Arkansas area. Proc. Ark. Acad. Sci. 24:39-41.
- Turner, L. M. 1935a. Catastrophes and pure stands of southern shortleaf pine. Ecology 16:213-215.
- Turner, L. M. 1935b. Notes on forest types of northwestern Arkansas. Amer. Midl. Nat. 16:417-421.
- Turner, L. M. 1935c. The status of the shortleaf pine in the northwestern Ozark region. Trans. Ill. Acad. Sci. 28:115-16.
- Turner, L. M. 1936a. Factors influencing the rate of growth of pine in Arkansas. Ecology 17:227-240.
- Turner, L. M. 1936b. A comparison of roots of southern shortleaf pine in three soils. Ecology 17:649-658.
- Turner, L. M. 1936c. Root growth of seedling of *Pinus echinata* and *Pinus taeda*. J. Agri. Res. 53:145-149.
- Turner, L. M. 1937a. Some soil characteristics influencing the distribution of forest types and rate of growth on trees in Arkansas. J. For. 35:5-11.
- Turner, L. M. 1937b. Trees of Arkansas. Coll. Agric. Univ. Ark. and U. S. Dept. Agri. Ext. Circ. No. 180.
- Twain, M. 1904. Life on the Mississippi. Harper & Bros., NY. 465 pp.
- University of Arkansas. 1972. Environmental evaluation report on the Big Mulberry Creek Basin in Franklin, Madison, Newton, Johnson, and Crawford counties, Arkansas. Appendix A. Principal forest communities. Prepared for U. S. Army Engineers, Little Rock District, Little Rock, AR.
- University of Arkansas. 1974. An ecological inventory of Devil's Den State Park, Arkansas. National Science Foundation Student-orig. Studies. Univ. Ark., Fayetteville, AR.
- U. S. Army Engineers. 1974. Cache River basin project: a waterfowl habitat preservation program. Final Environmental Impact Statement. U. S. Army Engineers, Memphis District, Memphis, TN. 2 vol.
- U. S. Army Engineers. 1978. Preliminary guide to wetlands of the Gulf Coastal Plain. Technical Report Y-78-5. Waterways Expt. Station, Vicksburg, MS.
- U. S. Army Engineers. 1982. Preliminary guide to the onsite identification and delineation of wetlands of the interior United States. Technical Report Y-78-6. Waterways Expt. Station, Vicksburg, MS.
- U. S. Dept. Agri. 1941. Climate and man. The 1941 Yearbook of Agriculture. U. S. Dept. Agri, GPO, Washington, DC.
- U. S. Dept. Agri., Forest Service. 1960. Management and inventory of southern hardwoods. Agric. Handbk. No. 181.
- U. S. Dept. Agri., Forest Service. 1969. A forest atlas of the south. So. For. Exper. Sta., New Orleans and Southeast. For. Exper. Sta., Asheville, NC.
- U. S. Dept. Agri., Forest Service. 1986. Ouachita National Forest Land and Resources Management Plan and Environmental Impact Statement. 2 vol. Southern Region, Forest Service, USDA, Washington, DC.
- U. S. Dept. Agri., Forest Service. 1986. Ozark-St. Francis National Forest Land and Resources Management Plan and Environmental Impact Statement. 2 vol. Southern Region, Forest Service, USDA, Washington, DC.
- U. S. Dept. Agri., Soil Conservation Service. 1967. Soil association map: State of Arkansas. SCS, Little Rock, AR.

## A Bibliographic Summary of Arkansas Field Botany

- U. S. Dept. Agri., Soil Conservation Service. 1982. National list of scientific plant names. 2 vol. 1: List of Plant Names. 2: Synonymy. SCS-Technical Publ. 159, Washington, DC.
- U. S. Dept. Agri., Soil Conservation Service. Soil Surveys of Arkansas Counties. Ark. Agri. Expt. Stat., Forest Serv., Soil Conserv. Serv., and U. S. Dept. Agri., Washington, DC.
- U. S. Dept. Agri., Weather Bureau. 1916. Summary of the climatological data for the United States, by sections: Arkansas. U. S. Dept. Agri., Weather Bur., GPO, Washington, DC.
- U. S. Dept. Commerce, Natl. Oceanic Atmosph. Admin. 1976. Climate of Arkansas. Natl. Climatic Center, Asheville, NC.
- U. S. Dept. Commerce, Natl. Oceanic Atmosph. Admin. 1969-1987. Climatological Data: Annual summary, Arkansas. GPO, Washington, DC.
- U. S. Dept. Commerce, Natl. Oceanic Atmosph. Admin. 1979. Outstanding tornadoes in Arkansas. Natl. Weather Serv. Forecast Off., North Little Rock, AR.
- U. S. Dept. Inter., Fish and Wildlife Service. 1954. Wetlands of Arkansas in relation to their wildlife value. Bur. Sport Fish. Wildlife, Atlanta, GA.
- U. S. Dept. Inter., Fish and Wildlife Service. 1978. Bottomland hardwood preservation program Lower Mississippi River Delta Habitat Category 7. U. S. Fish Wildl. Serv., Atlanta, GA.
- U. S. Dept. Inter., Fish and Wildlife Service. 1984. Cache River Basin: A waterfowl habitat preservation proposal: Jackson, Monroe, Prairie, and Woodruff counties, Arkansas. Final environmental impact statement. U. S. Fish Wildl. Serv., Atlanta, GA.
- Van Dover, B. 1962. Root habits of broomsedge (*Andropogon virginicus* L.). Unpublished research report. National Science Foundation Undergraduate Research Participation Program. Dept. Botany, Univ. Ark., Fayetteville, AR.
- Van Hees, W. S. 1980. Arkansas forests; trends and prospects. U. S. Dept. Agri. For. Serv. Resour. Bull. SO-77, South. For. Exp. St., New Orleans, LA. 32 pp.
- Van Sickle, C. C. 1970. Arkansas forest resource patterns. U. S. For. Serv. Res. Bull. SO-24, South. For. Exp. St., New Orleans, LA. 34 pp.
- Vanderpool, S. S. 1984. A comparative study of the vascular plants from selected bogs of Crowley's Ridge in Greene and Clay counties, Arkansas. M. S. thesis, Ark. St. Univ., State University, AR. 77 pp.
- Vines, R. A. 1960. Trees, shrubs, and woody vines of the Southwest. Univ. Texas Press, Austin, TX.
- Wackerman, A. G. 1929. Why prairies in Arkansas and Louisiana? J. For. 27:726-734.
- Wade, R. G. 1977. Arkansas wildflowers. White Pub. Co., Paragould, AR. 92 pp.
- Waggoner, G. S. 1975. Eastern deciduous forest. Vol. 1. Southeastern evergreen and oak-pine region. Natl. Park Serv. Nat. Hist. Theme Studies, No. 1. U. S. Gov. Printing Office, Washington, DC.
- Wagner, W. H. 1962. *Trichomanes boschianum* in Arkansas. Amer. Fern J. 52:85.
- Wagner, W. H., and W. C. Taylor. 1976. *Dryopteris X leedsii* and its westernmost station. Sida 6:224-234.
- Wahlenberg, W. G. 1948. Effect of forest shade and openings on loblolly pine seedlings. J. For. 46:832-834.
- Warder, J. A. 1880. Notes from Arkansas. Bot. Gaz. 6:188.
- Watts, W. A. 1980. The late Quaternary vegetation history of the southeastern United States. Ann. Rev. Ecol. Syst. 11:387-409.
- Watts, W. A., and M. Stuiver. 1980. Late-Wisconsin climate of northern Florida and the origin of species-rich deciduous forest. Science 210:325-327.
- Webb, T., and J. H. McAndrews. 1976. Corresponding patterns of contemporary pollen and vegetation in central North America. Pp. 267-299, in R. M. Clive and J. D. Hay. Investigations of late quaternary paleoecology and paleoclimatology. Geol. Soc. Amer. Mem. 145.
- Wells, P. V. 1965. Scarp woodlands, transported grassland soils, and concept of grassland climate in the Great Plains. Science 148:245-249.
- Wells, P. V. 1970. Historical factors controlling vegetation patterns and floristic distributions in central plains region of North America. Pp. 211-221, in W. Dordt and J. K. Jones. Pleistocene and recent environments of the central Great Plains. Dept. Geol. Univ. Kansas Spec. Publ. No. 3., Univ. Kansas Press, Lawrence, KS. 433 pp.
- Wells, P. V. 1970. Postglacial vegetational history of the Great Plains. Science 167:1574-1582.
- Weniger, D. 1970. Cacti of the Southwest: Texas, New Mexico, Oklahoma, Arkansas and Louisiana. Univ. Texas Press, Austin, TX. 249 pp.
- Werth, C. R., and C. W. Taylor. 1980. *Asplenium X gravesii* discovered in Arkansas. Amer. Fern J. 70:28.
- Wharton, C. H., W. M. Kitchens, E. C. Pendleton, and T. W. Stipe. 1982. The ecology of bottomland hardwood swamps of the southeast: a community profile. FWS/OBS-81/37. U. S. Fish Wildl. Serv., Office Biological Services, Washington, DC.
- Wherry, E. T. 1935. An Ozark variety of *Phlox pilosa*. Amer. Midl. Nat. 16:413-416.
- Wilhelm, P. 1835. Erste Reise nach dem nordlichen Amerika in den Jahren 1822 bis 1824. J. G. Cotta'schen, Tubigen. [Trans. by W. R. Nitske, ed. by S. Lottinville. Paul Wilhelm, Duke of Wurttemberg, Travels in North America, 1822-1824. Publ. in 1973 by Univ. Oklahoma Press, Norman, OK; Vol. 63 of American Exploration and Travel Series.]
- Whitehead, D. R. 1963. "Northern" elements in the Pleistocene of the Southwest. Ecology 44:403-406.
- Whitehead, D. R. 1965. Palynology and Pleistocene phytogeography of unglaciated eastern North America. Pp. 417-432, in H. E. Wright, and D. G. Frey. The Quaternary of the United States. Princeton Univ. Press, Princeton, NJ. 922 pp.
- Whitehead, D. R. 1967. Studies of full-glacial vegetation and climate in southeastern United States. Pp. 237-248, in E. J. Cushing and H. E. Wright. Quaternary Paleocology. Yale Univ. Press, New Haven, CN. 433 pp.
- Whitehead, D. R. 1973. Late Wisconsin vegetational changes in unglaciated eastern North America. Quat. Res. 3:621-631.
- Wilcox, W. H. 1973. A survey of the vascular flora of Crittenden County, Arkansas. Castanea 38:286-297.
- Williams, J. F. 1890. Distribution of the timber and its relation to the underlying rock formations. (Magnet Cove region). Ann. Rep. for 1889, Part 2. (Igneous rocks). Ark. Geol. Surv. for 1890. 2:167-170. Little Rock, AR.
- Wittlake, E. B. 1950a. Preliminary report on Arkansas bryophytes. Proc. Ark. Acad. Sci. 3:35-37.
- Wittlake, E. B. 1950b. The bryophytes of Spy Rock Hollow. Proc. Ark. Acad. Sci. 3:39-40.
- Wittlake, E. B. 1951a. A new record for *Petalophyllum lamellatum* (Nees) Lindb. Bryologist 54:76.
- Wittlake, E. B. 1951b. Preliminary report on the Hepaticae of Arkansas. Proc. Ark. Acad. Sci. 4:65-68.
- Wittlake, E. B. 1954. The Hepaticae of Arkansas. I. Bryologist 57:7-18.
- Wittlake, E. B. 1972. Bryophytes of Strawberry River Basin. Appendix C of Environmental Inventory, Strawberry River Basin. Prepared by Ark. St. Univ., College Station, for U. S. Army Engineers, Little Rock District, Little Rock, AR.
- Wolff, S. E. 1954. A guide to plant names in Texas, Oklahoma, Louisiana, and Arkansas. Rev. by C. A. Rechenhain. U. S. Dept. Agr., Soil Conser. Serv. 91 pp.
- Wood, W. R., and R. B. McMillan. 1976. Prehistoric man and his environments: a case study in the Western Ozark Highlands. Academic Press, NY.
- Woodson, R. E. 1943. A new *Amsonia* from the Ozarks of Arkansas. Rhodora 45:328-329.
- Wright, C. A., G. E. Bradford, and D. E. Classen. Undated. Final report on vegetation of Pea Ridge, National Military Park, Benton County, Arkansas. U. S. Dept. Inter., National Park Service.
- Wright, H. E. 1970. Vegetational history of the Central Plains. Pp. 157-172, in W. Dordt and J. K. Jones. Pleistocene and recent environments of the central Great Plains. Dept. Geol., Univ. Kansas Sp. Publ. 3. 433 pp.



## James H. Peck and Carol J. Peck

- Wright, H. E. 1976. The dynamic nature of Holocene vegetation: a problem in paleoclimatology, biogeography, and stratigraphic nomenclature. *Quat. Res.* 6:581-596.
- Wright, R. D. 1984. Some studies on introducing *Castilleja coccinea*, Indian Paintbrush, into prairie vegetation. *Proc. Ark. Acad. Sci.* 38:85-87.
- Wright, R., and D. Culwell. 1982. Early stages of prairie restoration on a 1.5 hectare field in Faulkner County, Arkansas. *Proc. Ark. Acad. Sci.* 36:80-81.
- Wyatt, T. M. 1972. Vascular flora of Mississippi County, Arkansas. M. S. thesis, Ark. St. Univ., State University, AR. 46 pp.
- Yocum, H. A. 1968. Shortleaf pine seed dispersal. *J. For.* 66:422.
- Yocum, H. A., and E. L. Little. 1976. Another Arkansas colony of *Neviusia*. U. S. Forest Serv. Res. Note SO-211 pp 1-3. S. Forest Expt. Stn., New Orleans, LA.
- Youree, J. T. 1969. The vegetation and soils of selected sites near Lake Wedington, Arkansas. M. S. thesis, Univ. Ark., Fayetteville, AR.
- Zachry, D. L., E. E. Dale, R. A. Berry, and R. H. Davis. 1979. Potential national natural landmarks of the Interior Highlands physiographic region, central United States. U.S. Dept. Inter., Natl. Park Serv. 272 pp.
- DWYER, J. D. 1970. The universities of the state of Missouri and botany in middle America. *Trans. Mo. Acad. Sci.* 4:29-32.
- EGLER, F. E. 1961. Cartographic guide to selected regional vegetational literature.—Where plant communities have been described. Part II. Southeastern United States. *Sarracenia* 6:1-87.
- EILERS, L. J. 1975. History of studies on the Iowa vascular flora. *Proc. Iowa Acad. Sci.* 82:59-64.
- EWAN, J. 1967. A bibliography of Louisiana botany. *Southwestern Louisiana J.* 7:2-83.
- FULLER, M. J. 1979. Field botany in Kentucky: a reference list. *Trans. Kentucky Acad. Sci.* 40:43-51.
- GUNN, C. R. 1956. A guide to some recent state floras. *Castanea* 21:33-38.
- MacROBERTS, D. T. 1984. The vascular plants of Louisiana. An annotated checklist and bibliography of the vascular plants reported to grow without cultivation in Louisiana. Bull. No. 6. Museum Life Sci., Louisiana St. Univ., Shreveport, LA.
- PECK, J. H. and D. M. ROOSA. 1983. Bibliography of Iowa aquatic and wetland plant literature. *Proc. Iowa Acad. Sci.* 90:72-77.
- PECK, J. H. and M. M. SMART. 1985. Bibliography to Upper Mississippi River aquatic and wetland plant literature. *Proc. Iowa Acad. Sci.* 92:78-84.
- RISSE, P. G. 1984. Bibliography of Illinois vegetation. Ill. Nat. Hist. Surv. Biol. Note No. 121. 51 pp.
- ROOSA, D. M. and J. H. PECK. 1986. Annotated bibliography of Iowa prairie literature. *Proc. Iowa Acad. Sci.* 93:54-69.
- SMITH, E. B. 1978. An atlas and annotated list of the vascular plants of Arkansas. Dept. Botany, Univ. Ark., Fayetteville, AR.
- SUNDELL, E. 1983. A bibliography of Louisiana botany: 1951-1975. *Tulane Stud. Zool. Bot.* 21(1):1-66.
- WEHER, W. and J. RAVEILL. 1986. Missouri botanical record. *Misourensis* 7(1):23-39.
- WOOD, C. E. 1983. Indexes to papers 1 to 100 published as parts of the generic flora of the southeastern United States. *J. Arnold Arbor.* 64:547-563.

## LITERATURE CITED

ANDRE, J. E. 1971. The history of systematic botany in Tennessee: 1770-1942. MS thesis, Univ. Tenn., Knoxville, TN. 117 pp.

BATES, V. 1985. The vascular flora of Tennessee: a taxonomic and geographic guide to the floristic literature. *J. Tenn. Acad. Sci.* 60(3):66-76.

BROWNE, E. T. 1965. Botany in Kentucky since 1914. *Trans. Kentucky Acad. Sci.* 25(3):77-82.

BUCHHOLTZ, J. T. and E. J. PALMER. 1926. Supplement to the catalogue of Arkansas plants. *Trans. Acad. Sci. St. Louis* 25:1-164.

CORGAN, J. X. 1977. Tennessee's early technical and scientific journals, 1825-1861. *J. Tenn. Acad. Sci.* 52:23-26.

DALE, E. E. 1963. Literature on the vegetation of Arkansas. *Proc. Ark. Acad. Sci.* 17:40-49.

DAVIES, P. A. 1953. The status of floristic studies in Kentucky. *Trans. Kentucky Acad. Sci.* 14(2):49-58.

DUNCAN, W. H. 1953. Taxonomic collections of vascular plants in the southeastern United States — their abundance and relation to production of flora. *Rhodora* 353-358.



# DISTRIBUTION, ABUNDANCE, STATUS AND PHYTOGEOGRAPHY OF LOG FERNS (*DRYOPTERIS*: WOODSIACEAE) IN ARKANSAS

JAMES H. PECK and CAROL J. PECK  
Department of Biology and Office of Testing Services  
and Student Life Research  
University of Arkansas at Little Rock  
Little Rock, AR 72204

## ABSTRACT

A study of the distribution, abundance, status, and phylogeography of the six taxa of Log Ferns (*Dryopteris*: Woodsiaceae) that are known to occur in Arkansas was conducted from 1981-1986. Five of these ferns are generally quite rare in Arkansas. Except for *D. marginalis*, all exist in Arkansas as small, peripheral populations that are marginal, outlier populations to the west and south or west and north of their metropolis. Two sterile, triploid hybrid taxa (*D. X australis* and *D. X leedsii*) each occur at only one locality, and there with but one of their parent taxa. The population of the putatively sterile hybrid *D. X australis* has a large number of juvenile plants that were not asexually produced by rhizome expansion. The microhabitat of *D. X australis* is suggested to favor gametophyte establishment. It is speculated that some level of pseudomeiotic spore production and/or apogamy may be involved in the production of numerous juvenile sporophytes.

## INTRODUCTION

The ferns in the homosporous fern genus *Dryopteris*, commonly known as Wood Ferns, Shield Ferns, and Log Ferns, are conspicuous in eastern North America, are well collected, and well studied ferns that occur at outcrops, forests, and swamps (Carlson and Wagner, 1982; Montgomery, 1982; Montgomery and Paulson, 1981; Small, 1938). The plants are medium to large in size. Fronds are wintergreen, 2-3 times pinnate, 0.5-2 m in length, with one to eight fronds per plant. Generally no more than one-half of the fronds of a plant are sporiferous. The frond petiole contains 3-6 vascular traces. The indusium is reniform; spores are bilateral, saccate, and 30-60 micrometers in longest axis. Of the 36 taxa in the genus, two-thirds are hybrids. Although the basic species are distinct, hybrids plants are generally indistinct, intermediate, and thoroughly baffling to the non-specialist taxonomist (Dowell, 1908; Tryon and Britton, 1966); therefore, they are collected out of proportion to their occurrence and abundance (Wagner, 1971). Although the occurrence of the hybrids initially rendered the taxonomy of the genus to a level near chaos, it offered unusually rewarding opportunities for biosystematic study in the 1950s-1970s, when relative nomenclatural stability was reached (Lellinger, 1984).

The 15 sexual taxa in North America include nine diploids and six polyploid taxa (Carlson and Wagner, 1982). The taxa display a diverse array of distributional patterns, primarily temperate, boreal, and arctic affinities. Vicarious affinities suggest that the major source of North American diversity was perhaps eastern Asia, with high latitude migration during the Tertiary or during interglacial periods during the Pleistocene. Pleistocene glaciation may have played a major role in the origins of the polyploid taxa by creating conditions that brought sexual taxa together, and thusly, facilitating hybridization. Whenever in close proximity, hybridization frequently results in the production of plants of hybrid origin (Carlson, 1979; Tryon, 1986). The hybrids are readily distinguished in the field by 1) comparison of frond morphology which is typically intermediate, 2) by their general rarity of plants to the more abundant "typical" form of plants at that locality, and in the laboratory, 3) by recognition of abortive spores that vary in size and shape of the hybrids compared to the uniform size and shape of spores of the "typical" plants.

The 13 northern sexual taxa are known to form 29 different hybrids out of a possible 78. These hybrids plants often are quite persistent and may in fact outnumber the plants of their parental sexual taxa in some locations (Carlson, 1979). Consequently, the ecologic staying power of the hybrids may in fact exceed that of the parent sexual taxa, resulting in populations of hybrid plants where one or both parent taxa are no longer present, a condition referred to as "hybridization by remote control" by Wagner (1943). The relative abundance of hybrids, their intermediate morphology, the extent of inter-connectedness of the hybrids

(sharing genomes of 1-4 sexual taxa) have resulted in an extensive literature reporting on the floristics and taxonomic status of *Dryopteris* in the state, regional, and national literatures.

Studies that have aided appreciably in our understanding of the genus include comparative foliar morphology (Wagner, 1971), gametophyte ecology (Cousens, 1975; Cousens and Horner, 1970), spore morphology (Barrington *et al.*, 1986; Crane, 1953, 1955, 1956, 1960; Reed, 1954; Whittier and Wagner, 1971), spore abortion (Wagner and Chen, 1965; Wagner *et al.*, 1986), cytology (Hickok and Klekowski, 1973; Manton and Walker, 1953; Walker, 1969; Wagner, 1971), flavinoid chemistry (Scora and Wagner, 1954; Widen *et al.*, 1975), and more recently, electrophoresis of foliar proteins (Euw *et al.*, 1980; Gastony, 1986). The systematic research has led to the postulation of a number of comprehensive theories on the reticulation of diploid, triploid, tetraploid, pentaploid, and hexaploid cytotypes into a genus-wide compilespecies involving repeated events of hybridization and polyploidy (Lovis, 1977; Wagner, 1971, 1983; Wagner and Wagner, 1980). Taxonomic and systematic efforts are currently aimed at relating North American taxa with those taxa to the east in Europe and to the west in Japan and China. Ecologic efforts must address the character of the local population and those environmental conditions or events which favor hybridization, polyploidy, and must address the means by which sterile hybrid plants outnumber sexual taxa in the local population (Carlson, 1979; Nickrant *et al.*, 1978; Wagner and Whitmire, 1957).

Six taxa in the genus *Dryopteris* occur in Arkansas. Taylor and Demaree (1979) and Taylor (1984) reported four taxa, including three sexual species and one sterile hybrid. Field study by the authors and by others resulted in the addition of one sexual species and one sterile hybrid taxa to the flora, the location of additional populations of the rarer taxa, and a clearer depiction of the distribution of the genus in Arkansas (Peck and Peck, 1986; Peck *et al.*, 1987a, b). The existence of *Dryopteris* as generally rare, local, and disjunct in Arkansas is a condition similar to that found for *Dryopteris* in other southern states (Small, 1938). In that the genus *Dryopteris* in Arkansas occurs primarily as a series of small, local, isolated populations, peripheral to or disjunct from the metropolis of the taxa to the east in the southern and northern Appalachians, the field status of plants and populations of Arkansas *Dryopteris* was surveyed and inventoried to summarize our current knowledge of their distribution, abundance, and status in Arkansas.

## MATERIALS AND METHODS

Herbarium specimens were inspected to complete the survey initiated by W. C. Taylor. Field search was conducted to relocate known populations of rarer taxa and to locate additional populations. Field census

was conducted on populations of each taxa by census of all plants within a 10 m sq plot, a size that circumscribed all plants of all populations of the rare taxa. For more abundant taxa, sample plots of the same dimensions were established. A plant was defined as a shoot apex; excavation was conducted to determine whether vegetative expansion of plants into colonies was evident for selected plants in close proximity. Plants were scored as fertile (sporiferous) adults, sterile adults, and juvenile sporophytes. Spores were collected for subsequent study. A literature review was conducted to interpret phytogeographic relations of Arkansas taxa and to compare them with taxa in neighboring states and the southeastern United States.

Table 1. Comparison of ploidy level, genome code, U.S. range, and Arkansas status of Log Ferns (*Dryopteris*).

Dryopteris Taxon	Ploidy Level	Genome Code	U. S. Range	Arkansas Status	
				Habitat	# Co. Comments
<i>goldiana</i>	2n	GG	NEUS	mesic, rocky woods	0 not known ARK.
<i>ludoviciana</i>	2n	LL	SEUS	swamps	1 one locality
<i>marginalis</i>	2n	NM	NEUS	xeric, rocky woods	34 frequent & abundant
<i>carthusiana</i>	4n	IISS	NEUS	mesic, rocky woods	2 two localities
<i>celsa</i>	4n	GGLL	SEUS	acid, wooded seeps	4 ten localities
<i>X australis</i>	3n	GLL	SEUS	acid, wooded seeps	1 one locality
<i>X leedsii</i>	3n	GLM	SEUS	mesic, rocky woods	1 one locality

## RESULTS AND DISCUSSION

Results are presented in summary tables with biosystematic, habitat, and phytogeographic data in Table 1 and census data in Table 2.

### *Dryopteris carthusiana* (Villars) H. P. Fuchs

The Spinulose Woodfern (Table 1), known earlier as *Dryopteris spinulosa* (O. F. Muell.) Watt, is a circumboreal, amphiatlantic plant that is an allotetraploid ( $4n = 164$ ) denoted by the genome IISS (Manton and Walker, 1953). It reaches its southwestern periphery of its range in Arkansas. Although found in swampy woods and moist wooded slopes in eastern North America, it is restricted in habitat in Arkansas, being found at one locality in each of two counties in Arkansas (Peck, 1986a, 1986b). This taxa occurs in Arkansas with not much more than two dozen plants (Table 2). This taxa may be at considerable risk in Arkansas (Table 2) in that few juvenile plants were recorded. Approximately three out of five plants are sporiferous, but no evidence of currently successful reproduction was noted.

### *Dryopteris celsa* (Palmer) Small

The Log Fern (Table 1) is a North American endemic that is an allotetraploid ( $4n = 164$ ) denoted the genome GGLL (Walker, 1959, 1962, 1969; Britton, 1972). The epithet means "elevated", referring to the habit of the plant to occur on nurse logs in swamps and seeps. The parents of this taxon are two sexual diploids (*D. goldiana* × *D. ludoviciana*). The ranges of these taxa do not overlap today; it seems likely that during Pleistocene glaciation plant migration, the two ranges combined and hybrids were formed. The sterile, diploid hybrids (genome code GL) underwent polyploidy to become the present day fertile taxon GGGLL. Today *D. celsa* occupies a range latitudinally and altitudinally intermediate between its parents (Wagner, 1972). It occurs from New Jersey (Montgomery, 1975) to its southwestern periphery in Arkansas, Louisiana (Thomas *et al.*, 1973), and Texas, being rare, infrequent, and discontinuous across that range (Wagner, 1972). A completely disjunct segment of the range occurs in the Great Lakes region of Michigan (Wagner *et al.*, 1969) and New York (Wagner and Wagner, 1965).

The Texas population has long been misnamed as *Dryopteris cristata* (L.) Gray (Correll, 1955; Correll and Johnson, 1970; Correll, 1972; Correll and Correll, 1972). There is occurs in Bowie Co. at the margin of a bog near Texarkana, where it was collected on 27 Oct 1925 by E. J. Palmer (29404, MO, GH) and misnamed. The Texas plant is *D. celsa*.

Table 2. Census data from 10 m sq plots established within 25 populations of Log Ferns (*Dryopteris*).

Dryopteris Taxon	County	Plots n	Apices/Plot		Juvenile Apices		Nonfertile Adults		Fertile Adults	
			n	%	n	%	n	%	n	%
<i>goldiana</i>	Webster	4	28	0	0	0	0	28	100	
<i>ludoviciana</i>	Bradley	2	35	31	89	0	0	4	11	
<i>marginalis</i>	Garland	1	28	0	0	0	0	28	100	
	Logan	4	27	0	0	4	15	23	85	
	Montgomery	1	30	0	0	4	13	26	87	
	Polk	4	30	0	0	1	3	29	97	
	Stone	1	31	0	0	4	13	27	87	
<i>carthusiana</i>	Van Buren	1	38	0	0	4	11	34	89	
	Logan	1	14	0	0	6	43	8	57	
<i>celsa</i>	Stone	1	12	0	0	4	25	8	75	
	Garland	1	16	0	0	5	31	11	69	
<i>X australis</i>	Montgomery	1	30	0	0	4	13	26	87	
	Polk	1	12	0	0	2	17	10	83	
<i>X leedsii</i>	Garland	1	321	297	93	0	0	24	7	
<i>X leedsii</i>	Van Buren	1	10	0	0	4	40	6	60	
Totals		25	662	328		42		292		
Species Means (n=13)			25	2	8	3	12	20	80	
Hybrids Means (n=2)			166	148	90	2	1	15	9	

*D. cristata* is found north of the unglaciated region, and has been excluded from the southern Mississippi Valley (Thomas, Wagner, and Mesler, 1973).

In Arkansas, *D. celsa* was discovered 24 May 1925 by B. C. Marshall (9, US) at York Springs, located south of Imboden, Lawrence Co.; specimens were sent to W. Maxon, who correctly identified the plant. That population is now extirpated, with the area being heavily pastured; the spring marker now acts as a cenotaph marking the location. It was subsequently located at four populations in Polk County (Moore, McWilliams, *Itis* 52040, US, MO; Peck 84705, LRU, MICH, MIL), two populations in Montgomery Co. (Peck 84705, LRU, MIL, MICH), and one population in Garland Co. (Peck 84680, LRU, MICH, MIL). At one of the extant populations are either parental sexual species present. *D. goldiana* is not known from Arkansas, occurring to the north of Arkansas in Iowa and Missouri (Iffrig, 1979); its genes are present in Arkansas only as an expression of its derived hybrid taxa *D. celsa*. The other parental taxa, *D. ludoviciana* does not occur in Arkansas, but is geographically separated from *D. celsa*.

This taxa occurs as small populations (Table 2), without juveniles, but with most plants sporiferous. Although conditions are generally good for gametophyte growth, based on the generally moist substrate, no indication of gametophyte establishment or sporophyte recruitment was noted. These populations are thus ecologically fragile.

### *Dryopteris ludoviciana* (Kunze) Small

The Louisiana Log Fern (Table 1) is a fertile, sexual diploid ( $2n = 82$ ) denoted by genome LL (Walker, 1959). Geographically, it is a North American endemic. Its epithet refers to its initial discovery in Louisiana, although the plant is clearly more abundant in Florida, from where it was renamed erroneously as *D. floridanum*. The plant frequents swamps and damp woods on the Atlantic Coastal Plain and Gulf Coastal Plain of the Southeastern United States. It was recently located in Arkansas (Sundell & McIntyre 2864, UAM; Peck & Peck 84641, LRU, MICH, MIL). The Arkansas population is the fourth located west of the Mississippi River (Peck *et al.*, 1985; Peck *et al.*, 1985); the three other populations are 350 km disjunct from the Arkansas population in

Distribution, Abundance, Status, and Phytogeography of Log Ferns (*Dryopteris*: Woodsiaceae) in Arkansas

Bradley Co., being found earlier in Louisiana (one population) and Texas (two populations). The Arkansas population is the most northwestern population of this taxon. This taxon differs in population structure from other fertile species of *Dryopteris* in Arkansas. Juvenile sporophytes were found (Table 2); however, few sporophytes plants are sporiferous. Substrate conditions are generally favorable for gametophyte establishment. Although vegetative expansion is likely, no evidence of connections among plants could be found. It thus seems likely that sexual reproduction of this taxon occurs in Arkansas, but that it is slowly successful in producing plants that live long enough to reach reproductive maturity. Conditions for this plant may be close to its tolerance limits, but may not be limiting reproductive phenomena. Drought conditions or cold weather may hinder the survival of sporophytes more than the successful maturation from spore to gametophyte to sporophyte.

*Dryopteris marginalis* (L.) A. Gray

The Marginal Shield Fern (Table 1) is a fertile, sexual diploid ( $2n=82$ ), denoted by genome code MM (Manton and Walker, 1953). It is a North American endemic that frequents rocky, wooded slopes and ravines. It occurs in 34 counties in the northwestern one-half of Arkansas in the Ozark and Ouachita mountains. It is the only widespread and abundant *Dryopteris* taxa in Arkansas. Populations of this taxon (Table 2) are often quite extensive, consisting of hundreds of plants, most of which are fertile, but consist of surprisingly few juvenile plants. It is not clear why this plant is so much more widely distributed and locally abundant than the other plants based on reproductive structure of its populations. Although its habitat is abundant, conditions on dry rocks can hardly be thought of as being highly conducive to fern reproduction. Characterization of the microhabitat which does lead to successful establishment of new plants might well be very informative to the reproductive biology of this genus.

*Dryopteris* × *australis* (Wherry) Small

The Southern Wood Fern (Table 1) is a sterile hybrid, being a triploid ( $3n=82+41$ ) denoted by the genome code LLG. It is the backcross hybrid (Wagner and Musselman, 1982; Walker, 1962) between the fertile allotetraploid *D. celsa* (LLGG) and the fertile diploid *D. ludoviciana* (LL). *D. × australis*, first discovered in 1927 in Alabama (Small, 1938; Wherry, 1937, 1961), is a North American endemic that occurs across the southeastern United States. The Arkansas population was the eighth known in North America; Arkansas was the fifth state known to have this taxon: North Carolina (two populations), South Carolina (one population), Alabama (two populations), and Louisiana (two populations). Both Louisiana populations are now extirpated; the Arkansas population, the third located west of the Mississippi River, is now the only extant population west of the Mississippi River. Since its discovery in Arkansas, one population each was located in Georgia, Tennessee, Virginia, and Mississippi (pers. comm., W. Wagner and C. Werth, 1988). In Arkansas, it occurs in Garland Co. (Orzell 1429, UARK; Peck & Peck 84680, LRU, MICH, MIL). The Arkansas population co-occurs with one parental taxon, *D. celsa* (Orzell and Peck, 1985; Peck et al., 1985), with the other parental taxon (*D. ludoviciana*) not present in Arkansas except 200 km distant in Bradley Co. The nearest population of *D. × australis* occurred 50 km to the south in Louisiana; presently, the nearest extant population occurs 500 km to the southeast in Mississippi.

The population structure of this taxon in Arkansas is quite unexpected (Table 2). Far more juvenile plants were found at one population of this "sterile" hybrid than for all populations of all fertile species combined. The local substrate was moist, but it was equally moist at locations where *D. celsa* occurred, but where juveniles were not encountered. These juveniles were not produced by vegetative expansion from existing plants: connections were not encountered. Some plants were small and appeared to have gametophyte tissue attached. It seems reasonable to speculate that these plants may have originated from spore production that in some way was not "sterile", possibly by pseudomeiotic reduction (De Benedictus, 1969; Morzenti, 1962; Whittier, 1970), producing good spores, and apogamy of gametophytes to produce sporophyte plants. Alternatively, they may represent arrested develop-

ment of plants that initiated colonization at the time of the successful adult plants, but have been held back by unknown genetic, physiologic, or developmental phenomena. This requires additional study to clarify whether either of these alternative explanations is sufficient and valid for this population.

*Dryopteris* × *leedsii* Wherry

Leeds' Wood Fern (Table 1) is a sterile, triploid ( $3n=41+41+41$ ) hybrid taxon endemic to North America. Its genome code is GLM. It is the backcross hybrid (Wagner and Wagner 1965, 1966; Walker, 1962) between the fertile allotetraploid *D. celsa* (GGLL) and the fertile diploid *D. marginalis* (MM). It frequents steep, rocky, wooded slopes, seeps, and swamps. Significantly, the Arkansas population was the first discovered, and was designated the type locality of the taxon (Wagner and Taylor, 1976). Six populations are now known from four states in North America: Arkansas (one population), Maryland (two populations), New York (two populations), and Pennsylvania (one population). Its distribution is sympatric with its parental taxa, being distributed along the interior highlands of southeastern United States.

In Arkansas, it occurs in Van Buren Co. (Palmer 33216, NY, US; Demaree 10039, US; Moore 350441, NY, US; Taylor 2597, SIU; Wagner & Wagner 74164, MICH; Redfearn 29403, SMS; Peck & Peck 84721, LRU, MICH, MIL) at a moist, rocky, wooded slope where only one (*D. marginalis*) of its two parental taxa occurs. It was discovered by E. J. Palmer on 30 Mar 1928; its taxonomic status was problematic, being often called the "Palmer" *Dryopteris*. The plants were inspected by Demaree in 1932, and D. Moore, in 1935. The importance of the plant was realized in the early 1960s, but it could not be relocated. An exciting tale of its eventual rediscovery in 1972 by Taylor and Demaree has been recorded by Wagner and Taylor, 1976; Taylor, 1982). This hybrid has occupied the same location for over 60 years; it is over 600 km disjunct from its nearest population. Based on discussions with Demaree, Taylor, and Wagner, the present status of the population is unchanged, or a few apices less than when first discovered (Table 2). Juveniles were never seen; from limited inspection, the plants appear to have a connection, suggesting that the population is the vegetative expansion of one plant.

## CONCLUSIONS

The wood fern genus *Dryopteris* is represented in Arkansas by plants that have limited capability to quickly replace themselves. Consequently, the long-term persistence of plants is extremely important to the continued success of that population. Populations of the fertile, sexual species generally did not have juvenile sporophytes present: only *D. ludoviciana* had juveniles, and that population was characterized by having the fewest number of fertile sporophytes, suggesting that adult survivorship is limited. Based on these observations, all collectors should take great care never to collect entire plants of this fern. One frond is sufficient to obtain a confirmation of its identity and voucher its presence by deposition in an herbarium. It is quite important to continue to search for and document any new populations of this genus in Arkansas. Arkansas populations are peripheral to the range of all of these taxa, and provide outstanding opportunities to conduct studies of local population dynamics of these ferns.

The population structure of the "sterile" triploid hybrid *D. × australis* is astounding. It consists of very large fertile adults surrounded by a large number of immature, juvenile sporophytes. The moist conditions of the seepage area certainly would enhance the opportunity for any good spores of this sterile taxon to have a chance to establish a gametophyte and produce a sporophyte. The moist conditions would enhance gamete transfer, and certainly would not hinder apogamy. It is possible that pseudomeiotic reproduction occurred and that unreduced spore mother cells developed into giant spores, and gave rise to gametophytes and sporophytes. The genetic constitution of these juveniles is intriguing, as to their ploidy level and the identity of the genomes that they carry. Alternatively, the juveniles might be as old as the adult plants, but are suppressed in development by unidentified factors. The alternative that the juveniles represent vegetative expan-



sions from the adults was ruled out by excavation. Additional study is essential to ascertain the ecologic and reproductive events which led to this peculiar structure of a population of a sterile hybrid.

## ACKNOWLEDGEMENTS

The authors thank the Arkansas Department of Natural Heritage for permission to study populations on their preserves, the University of Arkansas at Little Rock for a faculty research grant to defray some of the costs of the travel involved in this study, and Drs. W. C. Taylor, Warren H. Wagner, and Charles Werth for discussing the national status of *Dryopteris* taxa and in their encouragement of this project.

## LITERATURE CITED

- BARRINGTON, D. S., C. A. PARIS, and T. A. RANKER. 1986. Systematic inferences from spore and stomate size in the ferns. *Amer. Fern J.* 76:149-159.
- BRITTON, D. M. 1972. The spores of *Dryopteris clintoniana* and its relatives. *Can. J. Bot.* 50:2027-2029.
- CARLSON, T. M. 1979. The comparative ecology and frequencies of interspecific hybridization in Michigan woodferns. *Mich. Bot.* 18:47-56.
- CARLSON, T. M. and W. H. WAGNER. 1982. The North American distribution of the genus *Dryopteris*. *Contr. Univ. Mich. Herb.* 15:141-162.
- CORRELL, D. S. 1955. Pteridophyta. Vol. 1(1), in C. L. Lundell, *Flora of Texas*. University Press in Dallas, Southern Methodist University, Dallas, Texas.
- CORRELL, D. S. 1972. A manual of the vascular plants of Texas I. Additions and corrections. *Amer. Midl. Nat.* 88:490-496.
- CORRELL, D. S. and H. S. CORRELL. 1972. Aquatic and wetland plants of southeastern United States. GPO, Washington, DC. 1777 pp.
- CORRELL, D. S. and M. C. JOHNSTON. 1970. Manual of the vascular plants of Texas. 1881 pp. Texas Research Foundation, Renner, Texas.
- COUSENS, M. 1975. Gametophyte sex expression in some species of *Dryopteris*. *Amer. Fern J.* 65:39-42.
- COUSENS, M. and H. T. HORNER. 1970. Gametophyte ontogeny and sex expression in *Dryopteris ludoviciana*. *Amer. Fern J.* 60:13-27.
- CRANE, F. W. 1953. Spore studies in *Dryopteris*, I. *Amer. Fern J.* 43:159-169.
- CRANE, F. W. 1955. Spore studies in *Dryopteris*, II. *Amer. Fern J.* 45:14-16.
- CRANE, F. W. 1956. Spore studies in *Dryopteris*, III. *Amer. Fern J.* 46:127-130.
- CRANE, F. W. 1960. A key to American *Dryopteris* species based on characteristics of the perispore. *Amer. Fern J.* 50:270-275.
- DEBENEDICTUS, V. M. M. 1969. Apomixis in ferns with special reference to sterile hybrids. Ph.D. dissertation, Uni. Mich., Ann Arbor, MI.
- DOWELL, P. 1908. New ferns described as hybrids in the genus *Dryopteris*. *Bull. Torrey Bot. Club* 35:135-140.
- EUW, J. V., M. LOUSANSAMA, T. RIECHSTEIN, and C. J. WIDEN. 1980. Chemotaxonomy in *Dryopteris* and related fern genera. Review and evolution of analytic methods. *Stud. Geobot.* 4:275-311.
- GASTONY, G. J. 1986. Electrophoretic evidence for the origin of fern species by unreduced spores. *Amer. J. Bot.* 73:1563-1569.
- HICKOK, L. G., and E. J. KLEKOWSKI. 1973. Abnormal reductional and non-reductional meiosis in *Ceratopteris*: alternatives to homosporous meiosis in *Ceratopteris*: alternatives of homozygosity and hybrid sterility in homosporous ferns. *Amer. J. Bot.* 60:1010-1022.
- HICKOK, L. G. and E. J. KIEKOWSKI. 1975. Chromosome behavior in hybrid ferns: a reinterpretation of Appalachian *Dryopteris*. *Amer. J. Bot.* 62:560-569.
- IFFRIG, G. F. 1979. The distribution of *Dryopteris goldiana* and *D. marginalis* in Missouri. *Amer. Fern J.* 69:29-30.
- LELLINGER, D. 1984. Ferns of North America. Smithsonian Institution, Washington, D.C.
- LOVIS, J. D. 1977. Evolutionary patterns and processes in ferns. Pp. 229-415, in R. D. Reston and H. W. Woolhouse (eds.) *Advances in Botanical Research* 4:229-415. Academic Press, NY.
- MANTON, I., and S. WALKER. 1953. Cytology of the *Dryopteris spinulosa* complex in eastern North America. *Nature* 171:1116-1118.
- MONTGOMERY, J. D. 1975. *Dryopteris celsa* and *D. clintoniana* in New Jersey. *Amer. Fern J.* 65:65-69.
- MONTGOMERY, J. D. 1982. *Dryopteris* in North America. Part II: the hybrids. *Fiddlehead Forum* 9(4):23-30.
- MONTGOMERY, J. D., and E. M. PAULTON. 1981. *Dryopteris* in North America. *Fiddlehead Forum* 8(4):25-31.
- MORZENTI, V. M. 1962. A first report on pseudomeiotic sporogenesis, a type of spore reproduction by which "sterile" ferns produce gametophytes. *Amer. Fern J.* 52:69-78.
- NICKRENT, J. D., L. J. MUSSELMAN, L. A. PITCHFORD, and D. W. SAMPSON. 1978. The distribution and ecology of *Dryopteris* in southeastern Virginia and adjacent North Carolina. *Amer. Fern J.* 68:45-51.
- ORZELL, S., and J. H. PECK. 1985. Southern woodfern, *Dryopteris* × *australis*, new to Arkansas. *Proc. Ark. Acad. Sci.* 39:144.
- PECK, J. H. 1986a. *Dryopteris carthusiana* in Arkansas. *Proc. Ark. Acad. Sci.* 40:94.
- PECK, J. H. 1986b. Second locality for *Dryopteris carthusiana* in Arkansas. *Amer. Fern J.* 76:28-29.
- PECK, J. H., S. ORZELL, E. SUNDELL, and C. J. PECK. 1985. *Dryopteris ludoviciana* and *D.* × *australis* new to Arkansas. *Amer. Fern J.* 75:71.
- PECK, J. H., and C. J. PECK. 1986. Additions to the pteridophyte flora of Arkansas. *Ark. Nat. Plt. Soc. Occ. Pap.* 6:1-4.



Distribution, Abundance, Status, and Phylogeography of Log Ferns (*Dryopteris*: Woodsiaceae) in Arkansas

- PECK, J. H., C. J. PECK, and W. C. TAYLOR. 1987a. Checklist of the pteridophyte flora of Arkansas. Ark. Acad. Sci. Biota Surv. Checklist No. 47. 4 pp.
- PECK, J. H., C. J. PECK, and W. C. TAYLOR. 1987b. Update on the pteridophyte flora of Arkansas. Proc. Ark. Acad. Sci. 41:113-114.
- PECK, J. H., E. SUNDELL, and C. J. PECK. 1985. Louisiana Log Fern (*Dryoptera ludoviciana*) new to Arkansas. Proc. Ark. Acad. Sci. 39:144.
- REED, C. F. 1954. Spores, sporangia, and indusia of the genus *Dryopteris* in North America, north of Mexico. *Bartonia* 27:47-56.
- SCORA, R. W., and W. H. WAGNER. 1964. A preliminary chromatographic study on Eastern American *Dryopteris*. Amer. Fern J. 54:105-113.
- SMALL, J. K. 1938. Ferns of the Southeastern United States. Science Press, Lancaster, PA. 517 pp.
- TAYLOR, W. C. 1982. Dr. Demaree and the Palmer *Dryopteris*. SIDA 9:287-289.
- TAYLOR, W. C. 1984. Arkansas ferns and fern allies. Milwaukee Public Museum, Milwaukee, WI.
- TAYLOR, W. C., and D. DEMAREE. 1979. Annotated list of the ferns and fern allies of Arkansas. *Rhodora* 81:503-548.
- THOMAS, R. D., W. H. WANGER, and M. R. MESSLER. 1973. Log fern (*Dryopteris celsa*) and related species in Louisiana. *Castanea* 38:269-274.
- TRYON, R. M. 1986. The biogeography of a species, with special reference to ferns. *Bot. Rev.* 52:117-156.
- TRYON, R., and D. M. BRITTON. 1966. A study in the variation in the cytotypes of *Dryopteris spinulosa* *Rhodora* 8:59-92.
- WAGNER, F. S. and L. J. MUSSELMAN. 1982. The occurrence of the southern woodfern, *Dryopteris* × *australis* (Wherry) Small. *Castanea* 47:182-190.
- WAGNER, W. H. 1943. Hybridization by remote control. Amer. Fern J. 33:71-73.
- WAGNER, W. H. 1971. Evolution of *Dryopteris* in relation to the Appalachians. Pp. 147-192, in P. C. Holt (ed.) The distributional history of the biota of the southern Appalachians. Part 2: Flora. Virginia Polytechnic Inst. & St. Univ. Research Div. Monograph No. 2.
- WAGNER, W. H. 1972. Disjunctions in homosporous vascular plants. *Annals Missouri Bot. Gard.* 59:203-217.
- WAGNER, W. H. 1983. Reticulistics: the recognition of hybrids and their role in cladistics and classification. Chapter 8, in N. I. Platnick and V. A. Funk. *Advances in cladistics*, Vol. 2. Columbia Univ. Press, NY.
- WAGNER, W. H., and K. L. CHEN. 1965. Abortion of spores and sporangia as a tool in the detection of *Dryopteris* hybrids. Amer. Fern J. 55:9-29.
- WAGNER, W. H., and W. C. TAYLOR. 1976. *Dryopteris* × *leedsii* and its westernmost station. *Sida* 6:224-234.
- WAGNER, W. H., and F. S. WAGNER. 1965. Rochester area log ferns (*Dryopteris celsa*) and their hybrids. Proc. Rochester Acad. Sci. 57-71.
- WAGNER, W. H., and F. S. WAGNER. 1980. Polyploidy in pteridophytes. Pp. 199-214, in W. H. Lewis. *Polyploidy: biological relevance*. Plenum Press, NY.
- WAGNER, W. H., F. S. WAGNER, and D. J. HAGENAH. 1969. The log fern (*Dryopteris celsa*) and its hybrids in Michigan — a preliminary report. *Mich. Bot.* 8:137-145.
- WAGNER, W. H., F. S. WAGNER, and W. C. TAYLOR. 1986. Detecting abortive spores in herbarium specimens of sterile hybrids. Amer. Fern J. 76:129-140.
- WAGNER, W. H., and R. S. WHITMIRE. 1957. Spontaneous production of a morphologically distinct, fertile allopolyploid by a sterile diploid of *Asplenium ebenoides*. *Bull. Torrey Bot. Club* 84:79-89.
- WALKER, S. 1962. Further studies in the genus *Dryopteris*: the origin of *D. clintoniana*, *D. celsa*, and related taxa. Amer. J. Bot. 49:497-503.
- WALKER, S. 1962. The problem of *Dryopteris leedsii*. Amer. J. Bot. 49:971-974.
- WALKER, S. 1969. Identification of a diploid ancestral genome in the *Dryopteris spinulosa* complex. *Brit. Fern. Gaz.* 10:97-99.
- WHERRY, E. T. 1937. Southern occurrences of *Dryopteris clintoniana*. Amer. Fern J. 27:1-5.
- WHERRY, E. T. 1961. Supplementary notes on *Dryopteris* hybrids. Amer. Fern J. 51:33-35.
- WHITTIER, D. P. 1970. The rate of gametophyte maturation in sexual and apogamous species of ferns. *Phytomorphology* 20:30-35.
- WHITTIER, D. P., and W. H. WAGNER. 1971. The variation in spore size and germination in *Dryopteris* taxa. Amer. Fern J. 61:123-127.
- WIDEN, C. J., D. M. BRITTON, W. H. WAGNER, and F. S. WAGNER. 1975. Chemotaxonomic studies on hybrids of *Dryopteris* in eastern North America. *Can. J. Bot.* 33:1554-1567.

# DISTRIBUTION AND STATUS OF THE BRAZILIAN FREE-TAILED BAT (*TADARIDA BRASILIENSIS CYNOCEPHALA*) IN ARKANSAS

DAVID A. SAUGEY<sup>1</sup>, GARY A. HEIDT<sup>2</sup>, DARRELL R. HEATH<sup>2</sup>,  
TIM W. STEWARD<sup>3</sup>, DANIEL R. ENGLAND<sup>4</sup>, and V. R. McDANIEL<sup>1</sup>

<sup>1</sup>United States Forest Service, P.O. Box 1270  
Hot Springs, AR 71902

<sup>2</sup>Department of Biology, University of Arkansas at Little Rock  
Little Rock, AR 72204

<sup>3</sup>Department of Biology, Arkansas State University  
State University, AR 72467

<sup>4</sup>Department of Biology, Southern Arkansas University  
Magnolia, AR 71753

## ABSTRACT

Investigations of building infestations, mist netting activities, and specimens submitted to the Arkansas Department of Health document the Brazilian free-tailed bat to be found in 14 Arkansas counties. Both overwintering and maternity colonies were examined. Numbers of individuals ranged from one to several thousand.

## INTRODUCTION

Until 1982, the known Arkansas range of the Brazilian free-tailed bat (*Molossidae: Tadarida brasiliensis cynocephala*) was limited to Ashley, Hempstead, and Pulaski counties where individual specimens were found roosting solitarily or in colonies of the evening bat, *Nycticeius humeralis* (Sealander, 1979; Sealander and Price, 1964).

Saughey *et al.* (1983) reported the first known occurrences of maternity colonies, added two new county records extending the northern distribution approximately 40 km, and firmly established the Brazilian free-tailed bat as an Arkansas resident mammal. Steward *et al.* (1986) reported the occurrence of the bat from seven additional southwestern Arkansas counties, and Saughey *et al.* (1988) reported the capture of seven *Tadarida* while investigating the bat fauna of Hot Springs National Park in Garland County.

Heidt *et al.* (1987), reporting on bat rabies in Arkansas, indicated the exact range and status of this bat in Arkansas was unknown. The purpose of this paper is to present the known distribution and status of the Brazilian free-tailed bat in Arkansas.

## METHODS AND MATERIALS

Data for this study were derived from specimens submitted to the Arkansas Department of Health Rabies Laboratory (ADHRL), investigating infestations of buildings and homes, mist netting pools in perennial streams, and consolidating published literature.

## RESULTS AND DISCUSSION

The known distribution of the Brazilian free-tailed bat, *Tadarida brasiliensis cynocephala*, in Arkansas is shown in Figure 1. Annotations for the 14 counties follow:

**ASHLEY COUNTY:** Two free-tailed bats were captured in June and May, 1960 and 1961, respectively, from an attic of a residence in Crossett. Both animals were found in a small maternity colony of evening bats (Sealander and Price, 1964).

**CLARK COUNTY:** Seven individuals have been submitted to the ADHRL. On 3 March 1983 and 24 March 1984, individual males were submitted, and on 2 April 1984, five females together with four big brown bats, *Eptesicus fuscus* (two of each sex) were submitted from a single locality. Submissions of these same two species from Garland County were recorded during the same time period.

**FAULKNER COUNTY:** Saughey *et al.* (1983) reported the occurrence of a large maternity colony in old dormitory building on the campus of Central Baptist College in Conway, and briefly discussed roost characteristics and the significance of this maternity site. Since

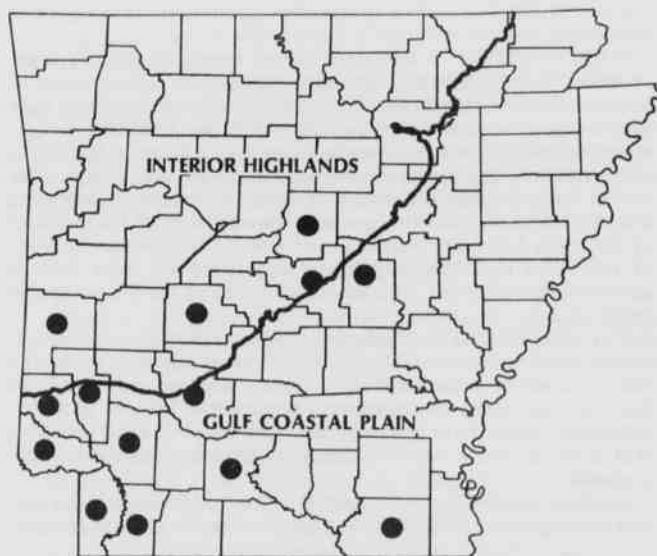


Figure 1. Counties with documented occurrence of *Tadarida brasiliensis cynocephala* in Arkansas.

that date, more data have been collected and will be reported elsewhere. This colony, however, numbered between 1500 and 3000 individuals and used the roost throughout the year. Big brown bats were found in association with the free-tailed bats.

**GARLAND COUNTY:** The first occurrence of *Tadarida* in this county was reported by Saughey *et al.* (1983) when they reported a maternity colony of approximately 100 individuals roosting with a maternity colony of the evening bat. This colony was located in the attic of an old two story apartment building in downtown Hot Springs. Since then, several other colonies have been located in the Hot Springs area, numbering up to 5000 individuals. Between 1983 and 1986, 96 specimens have been tested by the ADHRL, with one animal testing positive for rabies (Heidt *et al.*, 1987). Saughey *et al.* (1988) captured seven *Tadarida* (6 males/1 female) in mist nets while conducting a survey of bats in Hot Springs National Park.

**HEMPSTEAD COUNTY:** Sealander (1979) made reference to a male(s) free-tailed having been collected from an evening bat colony in the city of Hope. Other than this brief reference, however, published data as to time of year, number of specimens removed, and collector are unknown.

HOWARD COUNTY: One male bat was collected from a church steeple in Nashville on 8 May 1986.

LAFAYETTE COUNTY: A number of male specimens were extracted from cracks and crevices in the Highway 313 bridge located 13.5 km southeast of Lewisville on 8 October 1983. This small colony was dispersed throughout suitable areas within the structure of the bridge and was found in association with *Eptesicus*.

LITTLE RIVER COUNTY: A colony numbering over 600 individuals was observed in an abandoned two story frame house in the community of Winthrop from November, 1984 through June, 1985. Large quantities of guano and many skeletons and decaying bats indicated that this colony had occupied the house for a long period. The house was utilized throughout the year and *Eptesicus* were found in conjunction with the *Tadarida*. When revisited in October, 1987, the house was badly deteriorated and had been abandoned by the bats.

LONOKE COUNTY: A single male specimen from the city of Lonoke was submitted to the ADHRL in February, 1984.

MILLER COUNTY: Previously reported by Steward *et al.* (1986), a single male specimen was submitted to the ADHRL in September, 1983. Since then, a colony of males were discovered roosting in a bridge spanning the Red River. In addition, one male was taken from a house in Texarkana on 19 June 1986.

OUACHITA COUNTY: One male was collected from Camden in July, 1983.

POLK COUNTY: A temporary colony consisting of 14 *Tadarida* (4 males/10 females) was found roosting with an equal number of *Eptesicus* during October, 1986 in the main pavilion area of Shady Lake Recreation Area on the Ouachita National Forest. Forest Service personnel indicated that the colony had been much larger in late spring and early summer and had diminished toward autumn. The pavilion was an open structure and unheated during winter months rendering it unsuitable for overwintering quarters. Approximately 65 km southwest of the Shady Lake site, Hardisty *et al.* (1987) found an active colony of free-tailed bats in a building at Beaver's Bend State Park in southeastern Oklahoma. This was the first record for this subspecies in Oklahoma.

PULASKI COUNTY: Sealander and Price (1964) reported the capture of an adult female in October, 1962. This animal was captured on the University of Arkansas Medical Sciences Campus and represented the first state record for the species. A number of colonies as well as individual records have been reported from the Little Rock area since that time. In many instances *Eptesicus* have been associated with *Tadarida*.

SEVIER COUNTY: An estimated colony of 1500-2000 individuals was investigated in 1986-87 in the high school gymnasium at Horatio.

#### DISCUSSION

The data reported in this study demonstrate that *Tadarida brasiliensis cynocephala* has become widely distributed in Arkansas. Maternity sites are located in several widespread localities and at least a portion, if not most, of the general population overwinters in the state. Many of the single specimens that have been sent to the ADHRL may actually be indicative of yet undiscovered significant local populations. The species is often found in association with evening and/or big brown bats.

Free-tailed bats apparently utilize a wide variety of structures for roosting sites, as bats were found in bridges and open pavilions in addition to closed buildings (both occupied and unoccupied). In extensive surveys, however, no free-tailed bats have been found in abandoned mines or caves (Heath *et al.*, 1986).

Davis *et al.* (1962) hypothesized that *Tadarida* would overwinter only in a favorable building (which they implied should be heated above freezing) and in an area which rarely received frost. Spennath and LaVal (1974) speculated that in reality, food and temperature were probably both limiting factors and that some *Tadarida* may winter as far north as favorable sites and dependable food supplies are available. Relatively mild winters, the protracted period during the year when plentiful insect prey are available, and the abundance of suitable roost and foraging habitats will probably contribute to the eventual statewide occurrence of this species.

#### ACKNOWLEDGEMENTS

Appreciation is expressed to R. Giddings, J. Mawk, S. Neal, D. Pless, D. G. Saugey, B. Sikes, D. Sugg, B. Wunderlin-Jonak for various aspects of field work. Employees of Hot Springs Animal Control and T. McChesney and M. Edelmann of the Arkansas Department of Health provided specimens and records.

#### LITERATURE CITED

- DAVIS, R. B., C. F. HERREID II, and H. L. SHORT. 1962. Mexican free-tailed bats in Texas. *Ecol. Monog.* 32:311-346.
- HARDISTY, R. M., W. CAIRE, and K. E. LACEY. 1987. *Tadarida brasiliensis* (Chiroptera: Molossidae) from southeastern Oklahoma. *Proc. Okla. Acad. Sci.* 67:77-79.
- HEATH, D. R., D. A. SAUGEY, and G. A. HEIDT. 1986. Abandoned mine fauna of the Ouachita Mountains, Arkansas: Vertebrate taxa. *Proc. Ark. Acad. Sci.* 40:33-36.
- HEIDT, G. A., D. A. SAUGEY, and S. R. BRADFORD-LUCK. 1987. Reported bat rabies in Arkansas. *Proc. Ark. Acad. Sci.* 41:105-107.
- SAUGEY, D. A., D. R. HEATH, C. EFAW, G. A. HEIDT, and T. E. BEGGS. 1983. First report of Brazilian free-tailed bat maternity colonies in Arkansas. *Proc. Ark. Acad. Sci.* 37:98-99.
- SAUGEY, D. A., D. G. SAUGEY, G. A. HEIDT, and D. R. HEATH. 1988. The bats of Hot Springs National Park, Arkansas. *Proc. Ark. Acad. Sci.* 42:81-83.
- SEALANDER, J. A., JR., 1979. A guide to Arkansas mammals. River Road Press, Conway, AR. 313 pp.
- SEALANDER, J. A., JR., and J. F. PRICE. 1964. Free-tailed bat in Arkansas. *J. Mamm.* 45:152.
- SPENRATH, C. A., and R. K. LaVAL. 1974. An ecological study of a resident population of *Tadarida brasiliensis* in eastern Texas. *Occas. Paper No. 21.* The Museum, Texas Tech Univ. 14 pp.
- STEWART, T. W., V. R. McDANIEL, D. A. SAUGEY, and D. R. ENGLAND. 1986. Elements of bat fauna of southwestern Arkansas. *Proc. Ark. Acad. Sci.* 40:95-96.



# THE BATS OF HOT SPRINGS NATIONAL PARK, ARKANSAS

DAVID A. SAUGEY<sup>1</sup>, DIANNE G. SAUGEY<sup>1</sup>,  
GARY A. HEIDT<sup>2</sup>, and DARRELL R. HEATH<sup>2</sup>

<sup>1</sup>United States Forest Service, P.O. Box 1270  
Hot Springs, AR 71902

<sup>2</sup>Department of Biology, University of Arkansas at Little Rock  
Little Rock, AR 72204

## ABSTRACT

A survey was conducted from June 1982 through January 1987 to determine the occurrence of bat species in Hot Springs National Park, Garland County, Arkansas; an area of approximately 2025 hectares. A total of 309 bats in the families Molossidae and Vespertilionidae were captured. Species represented included: *Eptesicus fuscus*, *Lasiurus borealis*, *Lasiurus cinereus*, *Nycticeius humeralis*, *Pipistrellus subflavus*, and *Tadarida brasiliensis cynocephala*.

## INTRODUCTION

From June, 1982 through January, 1987 we conducted a survey of bat species occurring in Hot Springs National Park (Garland County), an area of approximately 2025 hectares. Located in the Ouachita Mountains of west-central Arkansas, the park is somewhat unusual in that it partially surrounds and partially lies within the city of Hot Springs. This arrangement provided considerable diversity of potential bat habitat, ranging from occupied to unoccupied man-made structures, relatively undisturbed north slope hardwoods (*Quercus/Carya* spp.), south slope shortleaf pine (*Pinus echinata*), and mixed hardwood-pine forest types.

Two perennial streams, Bull Bayou and Gulpha Creek, and a number of ponds, both within and adjacent to the park boundary, provided riparian habitat and foraging sites. Additional habitat was provided by two abandoned mine drifts. One drift occurred within the park boundary near DeSoto Park, a city property. The other drift was located near the city waterworks facilities, north of Hot Springs. These drifts offered the only subterranean, "cave-like" habitat in the immediate area.

Published information concerning the bat fauna known to occur within the park is scarce. Gregg (1937) reported the occurrence of two specimens of the hoary bat (*Lasiurus cinereus*). Sealander and Polechla (1981) reported specimens of the red bat (*Lasiurus borealis*), evening bat (*Nycticeius humeralis*), the eastern pipistrelle (*Pipistrellus subflavus*) and a "flying" sight record for the little brown bat (*Myotis lucifugus*) and a sight record for the big brown bat (*Eptesicus fuscus*).

Additional information concerning the occurrence and distribution of bats in the Ouachita Mountains in and adjacent to the park, Hot Springs, and Ouachita National Forest have been reported by Davis *et al.* (1955), Heath *et al.* (1983, 1986), McDaniel *et al.* (1986), Saugey *et al.* (1983), Sealander (1956, 1979), and Sealander and Young (1955).

The purpose of this study was to determine and provide natural history data concerning the bat fauna common to Hot Springs National Park. Furthermore, since the study area is located within the Ouachita Mountains and contains habitat typically found in that physiographic province, the data contained herein should provide important additions to the understanding of chiropteran biology in the Ouachita Mountains.

## MATERIALS AND METHODS

Collection was primarily by mist netting as described by Tuttle (1976). A total of 30 net nights (a net night is one mist net opened into the capture position for the evening's activities) were generated on 18 different dates, with one to three net nights per date. Nets of different lengths (5.5, 12.8, and 18.3 meters) were erected and opened into the capture position prior to dusk and checked at five minute intervals until midnight (occasionally until 0100 hours). Actual netting periods varied from three to six hours depending upon time of year. Netting primarily occurred over shallow pools in Gulpha Creek in the Gulpha Gorge Campground. Each bat was removed from the net and species, sex, age, reproductive condition, time of capture, and ambient temperature were recorded. In addition, two abandoned mine drifts

were visited on several occasions during winter months to determine their use as hibernacula. In accordance with National Park Service policy, all individuals were released at the conclusion of the evening's netting activities.

Assignment of bats into age classes was determined by closure of phalangeal epiphyses. Bats were designated as juveniles on the basis of small overall size, as well as visual observation of incomplete ossification of the epiphyses.

Reproductive condition of males was determined by the position of the epididymides. Scrotal males were characterized by complete descent of the epididymides into pigmented sheaths dorsolateral to the tail and by the presence of enlarged testes. Females bats were diagnosed as pregnant by examination of an obviously enlarged abdomen and lactation was determined on the basis of teat examination.

## RESULTS AND DISCUSSION

A total of 309 bats representing two families, five genera, and six species were captured during the study. Two abandoned mine drifts were examined and found to be utilized intermittently by two species.

### Family Vespertilionidae

#### *Nycticeius humeralis* (Rafinesque)

Baker and Ward (1967) considered the evening bat to have been the second most common bat in southeastern Arkansas while Gardner and McDaniel (1978) found this species to be relatively uncommon, but present in small numbers during much of the year in northeastern Arkansas. Heath *et al.* (1983) reported twelve new county records, including Garland County, and McDaniel *et al.* (1986) reported on the occurrence and distribution of the species in southwestern Arkansas. During this study, 136 evening bats (74 males and 62 females) representing 44% of all bats captured were netted.

Two pregnant females weighing 12g each were netted on 23 May 1983. The following week (1 June) three pregnant females were netted and ranged in weight from 10.5 to 12.3g. A juvenile male, weighing 6g, was netted on 30 June 1982 and on 1 July, two additional juvenile males, weighing 5g and 6g, were netted along with a postlactating female. On 13 July, four postlactating females were captured. By 26 August, juveniles of both sexes averaged 8g with adults 2-3g heavier.

The average weight of adult males ranged between 8-9g from spring until late August when they began to rapidly gain weight. By late fall, the average adult male weighed 12.3g, an increase of 34%. Adult non-pregnant females gained an average of 29% of their body weight from 9g in spring and summer to a late fall weight of 12.7g. Adult and juvenile males were observed to be scrotal in mid-August with juveniles exhibiting testes as large as the adults. Similar observations were made by Baker and Ward (1967).

An interesting behavior was observed for this species on 11 October 1986, when bats were frequently captured in small groups of three or four individuals. The first group captured was composed of two females and two scrotal males. They struck the net simultaneously in a space



## The Bats of Hot Springs National Park, Arkansas

approximately 0.5 meters in diameter; indicating they had been flying very close to one another. Approximately twenty minutes later a second similarly composed group was captured. Fifteen minutes later two small groups composed of two and three scrotal males were captured when they simultaneously struck the net at opposite ends. The significance of this behavior was probably associated with late summer/early fall swarming activities.

Although common throughout the study, *Nycticeius* were netted in greatest numbers from the last week in August until the second week of October. Baker and Ward (1967) netted this bat in December and indicated the species was most likely a winter resident of southeastern Arkansas. Sealander (1960) reported the occurrence of this bat near Fayetteville (Washington County) in mid-February. The capture of an adult male on 30 January 1987 probably indicates this species, at least in limited numbers, is a winter resident of west-central Arkansas.

The sex ratio for all evening bats netted during this study was 54:46, very similar to the 59:41 ratio reported for southeastern Arkansas by Baker and Ward (1967). The relative abundance of this species was probably due to the large number of older homes and buildings in and adjacent to the park. According to Watkins and Shump (1981), most specimens of *Nycticeius* have been found in buildings.

*Lasiurus borealis* (Muller).

Ninety-one red bats were captured with males (N = 59) encountered nearly twice as often as females (N = 32). LaVal and LaVal (1979) made similar observations regarding red bats in Missouri. Females were better represented in samples taken in May, June, and July, but were absent or occurred less frequently in samples during late summer and fall.

Pregnant females were captured on 16 May 1984 (13.3g), 23 May 1983 (2 weighed 14g each) and 1 June 1983. Lactating females were captured on 30 June and 18 July, 1982 and on 8 July 1983. Two postlactating females were captured on 1 July 1982 and one was captured on 8 July 1983. Volant juveniles were first observed on 30 June 1982 when a very small female weighing 5g was captured. Late October weights for females averaged 12g.

Males were captured on every occasion and were most abundant from mid-July through September. Two males were netted and several other red bats sighted on 30 January 1987 after a brief winter warming period. Males averaged 11.3g in late October.

As reported by Baker and Ward (1976), red bats often landed on and hovered near a pillow case used to retain captured red bats, apparently attracted by calls made from those inside. The only observed mortality involving any bat during the study occurred when a red phase screech owl (*Otus asio*) was captured as it attacked and killed a male red bat that had been netted only seconds before. The owl was released and later flew back down the creek and again became entangled in the net. Predation of bats by this and other species of owls has been well documented and reviewed by Barclay *et al.* (1982).

*Eptesicus fuscus* (Palisot de Beauvois).

The big brown bat was the third most common species. Sixty-six individuals, 33 males and 33 females were captured. Two pregnant females weighing 21.5g and 23.5g were captured on 23 May 1983, and one pregnant female was captured a week later on 1 June. Lactating females weighing 17g and 20g were netted on 26 June 1982; one of which exhibited worn canines, indicating considerable age. Four days later on 30 June, another lactating female weighing 19g was netted. The first postlactating female was captured one day later on 1 July. The first volant juvenile captured was a 13g female netted on 26 June 1982. Numerous maternity colonies of this species have been located throughout Hot Springs and Garland County. Heath *et al.* (1986) reported the occurrence of this bat from the abandoned mine drift near DeSoto Park.

Body weight of adult males and females was very similar in late October when the average was 22.5g. Interestingly, juveniles, although nearly as large as adults, weighed considerably less at 15.5 to 17.3g and gave the appearance of having very little body fat. One adult female was captured on 30 January 1987 over a shallow pool in Gulpha Creek.

*Pipistrellus subflavus* (F. Cuvier).

Six eastern pipistrelles were captured during the study. Two lactating females, weighing 4g and 6g, were netted on 30 June 1982, indicating the occurrence of a maternity site nearby. The first volant juvenile was captured two weeks later on 13 July when a 4g male was netted at the same locality. Two early August captures in 1982 and 1983 yielded an average body weight of 5g. Examination of the abandoned mine drift near DeSoto Park revealed limited use during most of the year, with more use in winter.

*Lasiurus cinereus* (Palisot de Beauvois).

The hoary bat was first reported from the park by Gregg (1937) when a large female was found frozen on the exterior door facing of the utilities building on 12 February 1936. The second specimen was recorded on 20 April of the same year when a live animal was captured by a city employee at the Hot Springs pumping plant, approximately 2 miles northwest of the city. Three hoary bats were netted during this study. A large, pregnant female was captured on 1 June 1983; on 26 August, a scrotal male weighing 20g and a large female weighing 26g were netted.

## Family Molossidae

*Tadarida brasiliensis cynocephala* (Le Conte).

Sealander and Price (1964) first reported this species in Arkansas from three widely spaced counties. Sealander and Polechla (1981) did not record free-tailed bats during a small-mammal investigation in the park, but predicted occurrence based on its known Arkansas distribution. Saugey *et al.* (1983) reported the first known maternity colonies for the species in the state (which included Garland County), expanded the known Arkansas range of the animal, and firmly established this bat as a resident species.

Captures of the free-tailed bats within the park occurred on June 30, 1 July, 26 August, and 23 September of 1982. A total of seven bats (6 males/1 female) were captured with never more than two captured on any evening. Interestingly, the largest known maternity colony of this species ever found in Arkansas (estimated at several thousand individuals) was located approximately 1 air mile away (Saugey *et al.*, 1988). The lack of captures of this species within the park may be attributable to their foraging tactics as described by Krutzsch (1955). He found their foraging routes at various heights, commonly from 5m to treetop level and on occasion, as high as 34m — far above the 2m level of single mist nets. Barbour and Davis (1969) reported *Tadarida brasiliensis mexicana* often traveled great distances, up to 65 kilometers each night, to feed along a river. While the foraging area of the large maternity colony was unknown, one might suspect these bats to have utilized one of the several large reservoirs or the Ouachita River and adjacent forested hills for watering and feeding purposes.

## ACKNOWLEDGEMENT

Appreciation is expressed to Park Superintendent Roger Giddings, his staff, and the Volunteer In Parks program for encouragement and support during the study. Special appreciation is also extended to Belinda Wunderlin-Jonak for valuable assistance in the field. These data represent a part of a large scale investigation of the ecology of the bats in the Ouachita region and were supported, in part, by the United States Forest Service, a University of Arkansas at Little Rock Faculty Research Grant (GAH) and the UALR College of Science's Office of Research, Science, and Technology.

## LITERATURE CITED

- BAKER, R. J., and C. M. WARD. 1967. Distribution of bats in southeastern Arkansas. *J. Mamm.* 48:130-132.

- BARBOUR, R. W., and W. H. DAVIS. 1969. Bats of America. Univ. Press of Kentucky, Lexington. 286 pp.
- BARCLAY, R. M. R., C. E. THOMSON, and F. J. S. PHELAN. 1982. Screen owl, *Otus asio*, attempting to capture little brown bats, *Myotis lucifugus*, at a colony. Can. Field-Nat. 96(2):205-206.
- DAVIS, W. H., W. Z. LIDICKER, JR., and J. A. SEALANDER. 1955. *Myotis austroriparius* in Arkansas. J. Mamm. 36:288.
- GARDNER, J. E., and V. R. McDANIEL. 1978. Distribution of bats in the Delta region of northeastern Arkansas. Proc. Ark. Acad. Sci. 32:46-48.
- GREGG, H. R. 1937. Occurrence of the hoary bat at Hot Springs National Park, Arkansas. J. Mamm. 18:98.
- HEATH, D. R., G. A. HEIDT, D. A. SAUGEY, and V. R. McDANIEL. 1983. Arkansas range extensions of the seminole bat (*Lasiurus seminolus*) and eastern big-eared bat (*Plecotus rafinesquii*) and additional county records for the hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*) and evening bat (*Nycticeius humeralis*). Proc. Ark. Acad. Sci. 37:90-91.
- HEATH, D. R., D. A. SAUGEY, and G. A. HEIDT. 1986. Abandoned mine fauna of the Ouachita Mountains, Arkansas: Vertebrate taxa. Proc. Ark. Acad. Sci. 40:33-36.
- KRUTZSCH, P. H. 1955. Observations on the Mexican free-tailed bat, *Tadarida mexicana*. J. Mamm. 36:236-242.
- LAVAL, R. K., and M. L. LAVAL. 1979. Notes on the reproduction, behavior and abundance of the red bat, *Lasiurus borealis*. J. Mamm. 60:209-212.
- McDANIEL, V. R., D. A. SAUGEY, D. R. ENGLAND, and T. W. STEWARD. 1986. Elements of the bat fauna of southwestern Arkansas. Proc. Ark. Acad. Sci. 40:95-96.
- SAUGEY, D. A., D. R. HEATH, C. EFAW, G. A. HEIDT, and T. E. BEGGS. 1983. First report of Brazilian free-tailed bat maternity colonies in Arkansas. Proc. Ark. Acad. Sci. 37:98-99.
- SAUGEY, D. A., D. R. HEATH, G. A. HEIDT, T. W. STEWARD, D. R. ENGLAND, and V. R. McDANIEL. 1988. Distribution and status of the Brazilian free-tailed bat, *Tadarida brasiliensis cynocephala*, in Arkansas. Proc. Ark. Acad. Sci. 42:79-80.
- SEALANDER, J. A., JR. 1956. A provisional checklist and key to the mammals of Arkansas (with annotations). Amer. Midl. Nat. 56:257-296.
- SEALANDER, J. A., JR. 1960. Some noteworthy records of Arkansas mammals. J. Mamm. 41:525-526.
- SEALANDER, J. A., JR. 1979. A guide to Arkansas mammals. River Road Press, Conway, Arkansas. 313 pp.
- SEALANDER, J. A., JR. and P. J. POLECHLA. 1981. A small mammal survey of Hot Springs National Park, Arkansas. Unpubl. Final Report to U.S.D.I. National Park Service. 37 pp.
- SEALANDER, J. A., JR. and J. F. PRICE. 1964. Free-tailed bat in Arkansas. J. Mamm. 45:152.
- SEALANDER, J. A., JR. and H. YOUNG. 1955. Preliminary observations on the cave bats of Arkansas. Proc. Ark. Acad. Sci. 7:21-31.
- TUTTLE, M. D. 1976. Collecting techniques. Pp. 71-86. In Baker, R. J., J. K. Jones, Jr., and D. C. Carter (eds.). Biology of bats of the New World family Phyllostomatidae. Part I. Spec. Publ. Mus., Texas Tech Univ. No. 10. 218 pp.
- WATKINS, L. C., and K. A. SHUMP. 1981. Behavior of the evening bat, *Nycticeius humeralis*, at a nursery roost. Amer. Midl. Nat. 105:258-268.

# EGGTOOTH DEVELOPMENT AND MORPHOLOGY IN THE SIX-LINED RACERUNNER, *CNEMIDOPHORUS SEXLINEATUS* (SAURIA: TEIIDAE), USING SCANNING ELECTRON MICROSCOPY

STANLEY E. TRAUTH

Department of Biological Sciences  
Arkansas State University  
State University, AR 72467

## ABSTRACT

Eggtooth development and morphology in the six-lined racerunner, *Cnemidophorus sexlineatus*, were examined using scanning electron microscopy. The anlage of the embryonic eggtooth emerges from the anterior surface of the palate relatively late during embryonic development. The eggtooth proper erupts through an epithelial sheath and grows anteriorly to project beyond the rostral scale. The mature eggtooth is hollow, has a wall made of enamel and dentine, possesses a sharply-curved body and has a flattened, pointed tip. The eggtooth is shed within several days after the young hatch.

## INTRODUCTION

The embryonic eggtooth of squamates (lizards and snakes) is a specialized, deciduous tooth found at the tip of the snout and is attached to the premaxillary bone. It is used to pierce, cut or break through the eggshell (or egg membranes) at the time of hatching or birth (Bellairs, 1970). Squamate eggteeth are similar to their regular teeth, except that they are much larger, are usually one in number (gekkonid lizards may have two) and are curved forward, projecting slightly away from the snout. Chelonians, crocodylians and birds lack a true embryonic egg tooth; however, they do possess a specialized horny, epidermal structure, the egg caruncle, which serves the same function as the eggtooth.

Fioroni (1962) provided the most comprehensive literature survey on the occurrence, structure and development of the reptilian eggtooth. Nearly all references he cited dealt with species outside the continental United States. The few exceptions included three snakes (*Crotalus atrox*, *Nerodia sipedon* and *Sistrurus catenatus*) as reported by Smith *et al.* (1953). Fioroni (1962) omitted a fourth snake (*Coluber constrictor*) as investigated by Weinland (1858). The only study describing eggtooth structure in the lizard genus *Cnemidophorus* was by Muller (1841). The present study addresses the chronological changes in lizard eggtooth development and structure in the six-lined racerunner, *Cnemidophorus sexlineatus*, using scanning electron microscopy (SEM). This work is the first to document embryonic eggtooth development for any North American lizard using SEM.

## MATERIALS AND METHODS

Eggs of the six-lined racerunner, *Cnemidophorus sexlineatus*, were excavated (see excavation methods in Trauth [1983]) from nests buried in red clay roadside embankments along rural highways in Johnson and Madison counties, Arkansas, in July 1986. Over 100 eggs representing at least 25 egg clutches were collected. Each clutch numbered from one to five eggs, and these clutches yielded embryos in a variety of embryonic stages. In addition, hatchling lizards (32-35 mm in snout-vent length) were taken from burrow systems within the nesting habitats. Eggs and hatchlings were fixed in 10% formalin within 24 hr after collection and were later stored in 70% ethanol.

Embryos were dissected from their eggs, placed in separate vials and assigned a descriptive morphological stage following Dufaure and Hubert (1961). These stages, based upon developmental criteria rather than length of incubation time, provided a means of categorizing advancement in embryonic growth. Standard laboratory techniques were used to prepare tissues for SEM. Upper jaws of selected individuals were excised just anterior to the eyes; in more advanced specimens, the eggtooth was extracted with a pair of jeweler's forceps. All specimens were dehydrated in a graded series of ethanol and amyl acetate, dried

with a Samdri critical point dryer, coated with gold/palladium in a Hummer IV sputter coater and viewed with a JEOL 100 CXII TEM-SCAN electron microscope at an accelerating voltage of 40 kV.

## RESULTS AND DISCUSSION

Eggtooth development and morphology in *C. sexlineatus* is shown in Fig. 1. The earliest observation of an eggtooth was in an embryo with a crown-to-rump length of 15 mm (Fig. 1A). This size roughly corresponds to Stage 36 in embryonic development (Dufaure and Hubert, 1961) and is characterized by the lack of body pigmentation and by little scale differentiation. At this stage, an anlage of the eggtooth bulges at the anterior terminus of the trabecula communis (de Beer, 1937). At Stage 37, the rapidly-growing eggtooth pushes from its medial position anteriorly toward the newly-formed rostral scale (Fig. 1B & C). The exposed body of the eggtooth now appears broad, and the lateral surfaces gradually taper to form an apex. The entire eggtooth is covered by an epithelial sheath. A terminal cap (Fig. 1B) is distinguishable from the main body of the eggtooth.

Eruption of the eggtooth proper begins in the region of the terminal cap as evidenced by a sloughing of the epithelium (Fig. 1D). This process exposes the tip of the eggtooth which may exhibit a serrated edge. As the embryo nears hatching (Stage 40), the mature eggtooth has shed most of its epithelial covering (Fig. 1E & I). Its exposed length is a little over twice its width. A rounded and relatively smooth tip was observed in most specimens; however, some specimens exhibited a lancet-like tip (Fig. 1I). In all cases, the eggtooth extends anterior to the rostral scale.

The destruction and subsequent loss of the eggtooth occurs within a few days after hatching (Fig. 1F & G). In Fig. 1F (from a hatchling 33 mm in snout-vent length), the eggtooth appears to have been sheared in half. Debris or possibly eggtooth material has accumulated around the remaining stump. Horizontal fracture lines are evident along the base of the stump. The rest of the eggtooth is discarded, perhaps, as hatchlings begin foraging for insects. The ventral edge of the rostral scale (Fig. 1G) will eventually assume a normal shape leaving no trace of the eggtooth.

The morphology of the extracted eggtooth is shown in Fig. 1H & I). The body is oval in cross section and has a hollow central cavity which extends into the flattened tip. The eggtooth wall is relatively thin and consists of two layers approximately equal in thickness. These layers are made of enamel (outer) and dentine (inner). Internally, the lining of the cavity is quite porous; a mat-like network of minute fibers lies on this surface. All mature eggteeth exhibit a curved body. The convex or exposed surface may flare along the lateral edges prior to the tip. Most of the concave surface (normally hidden from view, but evident in H & I) is covered by a thin layer of squamous epithelium.



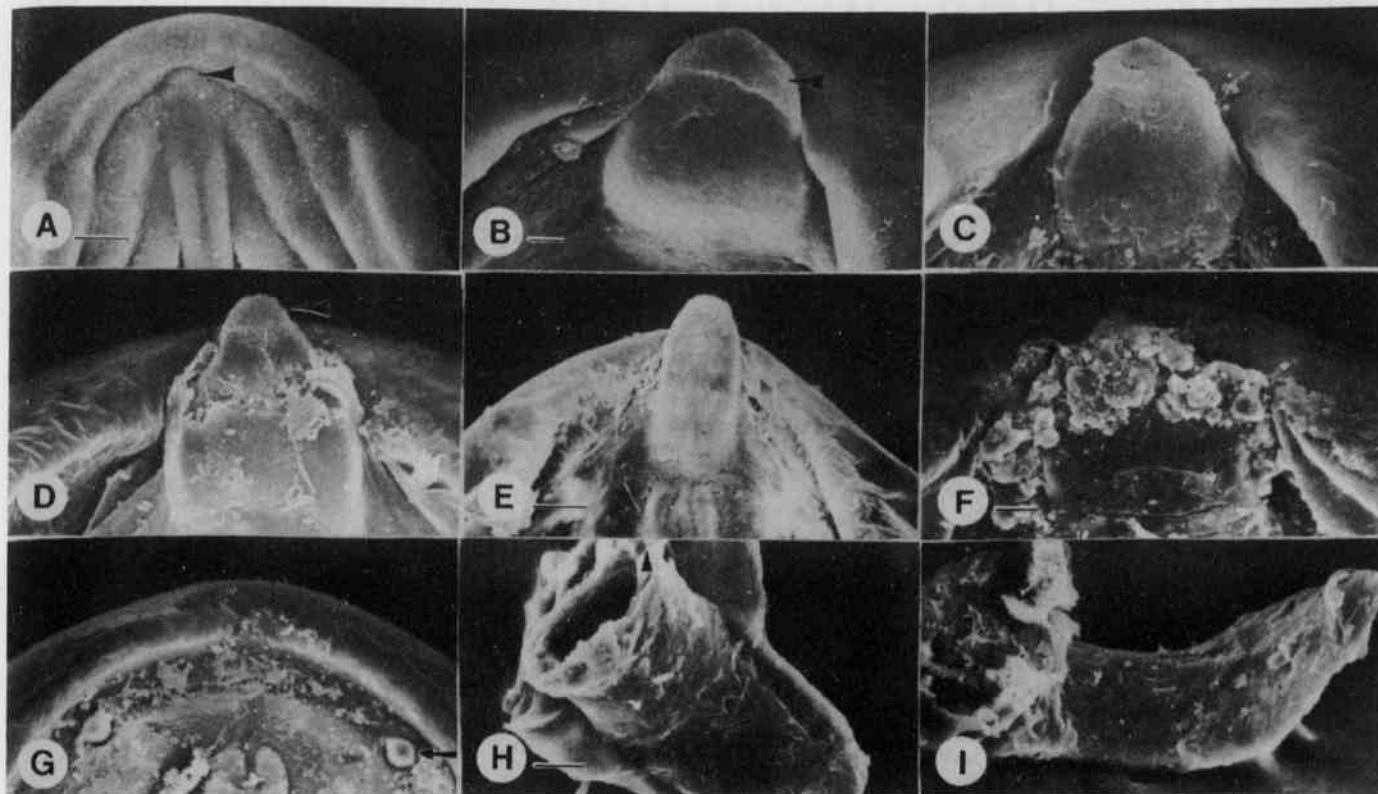


Figure 1. Scanning electron micrographs of eggtooth development and morphology in *Cnemidophorus sexlineatus*. A. Anterior region of the palate of an embryo (crown-to-rump length = 15 mm). Pointer denotes the initial appearance of the primordial eggtooth. Line = 100  $\mu$ m. B. Magnification of eggtooth bud as it grows ventrally and pushes anteriorly. An epidermal cap (pointer) is separated from the body of the eggtooth by a transverse groove. Line = 50  $\mu$ m for B - D. C. Eggtooth bud showing loosened epithelial cells in the region of the epidermal cap. D. Eruption of the eggtooth proper through the epithelial sheath. A serrated edge (pointer) is present at the tip of the eggtooth at this stage. E. Mature eggtooth of an embryo nearing hatching. Line = 100  $\mu$ m for E & G. F. Destruction of the eggtooth following hatching. G. Morphology of the anterior palate of a hatchling following complete sloughing of the eggtooth. Notice the absence of any premaxillary teeth in the region of the lost eggtooth. Arrow points to the anteriormost left premaxillary tooth. H. Extracted mature eggtooth showing the hollow nature of the tooth. Pointer refers to the separation of the two layers of the eggtooth wall. Line = 50  $\mu$ m for H & I. I. Right lateral view of mature eggtooth revealing the marked curvature of the body.

Early developmental structure of the eggtooth in *C. sexlineatus* is similar to the condition found in a European lacertid lizard (*Lacerta muralis*) as illustrated by Fioroni (1962). In both species the eggtooth eventually curves sharply forward and tapers to a point (as in Fig. 11). These common features are not surprising as these lizards are closely related (Camp, 1923). Although some adult lizards may possess enlarged, medially-positioned premaxillary teeth (amphisbaenids and some agamids), which may or may not be a vestige of eggteeth (Santonja and Bons, 1972; Smith *et al.*, 1953), *C. sexlineatus* completely sheds the eggtooth following hatching. No premaxillary teeth ever replace or fill the gap occupied by the eggtooth.

#### LITERATURE CITED

- BELLAIRS, A. 1970. *The Life of Reptiles*. Vol. II. The Universe Natural History Series. Universe Books, New York.
- CAMP, C. L. 1923. Classification of the lizards. *Bull. Amer. Mus. Nat. Hist.* 48:289-481.
- de BEER, G. R. 1937. *The Development of the Vertebrate Skull*. Clarendon Press, Oxford.
- DUFAURE, J. P., and J. HUBERT. 1961. Table de développement du lézard vivipare: *Lacerta (Zootoca) vivipara* Jacquin. *Arch. Anat. Microscop. Morphol. Exp.* 50:309-328.
- FIORONI, P. 1962. Der eizahn und die eischwiele der reptilien. *Acta Anat.* 49:328-366.
- MULLER, J. 1841. Über eine eigentümliche Bewaffnung des Zwischenkiefers der reifen Embryonen der Schlangen und Eidechsen. *Arch. Anat. Physiol.* pp. 329-331.
- SANTONJA, J., and J. BONIS. 1972. Différenciation et évolution de la dent de l'éclosion chez le lézard *Agama bibroni* Dum. *Bull. Soc. Zool. France* 97:719-725.
- SMITH, M. A., A. d'A. BELLAIRS, and A. E. W. MILES. 1953. Observations on the premaxillary dentition of snakes with special reference to the egg-tooth. *J. Linn. Soc. (Zool.)* 42:260-268.
- TRAUTH, S. E. 1983. Nesting habitat and reproductive characteristics of the lizard *Cnemidophorus sexlineatus* (Lacertilia: Teiidae). *Amer. Midl. Nat.* 109:289-299.
- WEINLAND, D. F. 1858. On the egg-tooth of the snakes and lizards. *Proc. Essex Inst.* 2:28-32.



# TOE TIP SURFACE MORPHOLOGY IN SIX SPECIES OF SALAMANDERS, GENUS *AMBYSTOMA* (CAUDATA: AMBYSTOMATIDAE), FROM ARKANSAS USING SCANNING ELECTRON MICROSCOPY

STANLEY E. TRAUTH and J. D. WILHIDE  
Department of Biological Sciences  
Arkansas State University  
State University, AR 72467

## ABSTRACT

The toe tip friction surface in six species of *Ambystoma* (*A. annulatum*, *A. maculatum*, *A. opacum*, *A. talpoideum*, *A. texanum*, and *A. tigrinum*) from Arkansas was examined using scanning electron microscopy. We found no sexual dimorphism in cell surface ultrastructure. Variation within and between species was considerable. The most active burrower, *A. tigrinum*, possessed the most disorganized cell surface, whereas the least active burrowers (*A. annulatum*, *A. maculatum*, and *A. opacum*) had morphologically similar and relatively smooth toe tips. In *A. talpoideum* and *A. texanum*, cell surfaces exhibited microprojections. Only these two species possessed mucous pores in close proximity to the friction surface. The microstructure of cell surfaces transcended species groups in *Ambystoma* and would not represent a reliable taxonomic tool.

## INTRODUCTION

By most general accounts, mole salamanders (genus *Ambystoma*) of the family Ambystomatidae are regarded as leading a burrowing, subterranean existence most their lives, surfacing only during the seasonal breeding migrations (Bishop, 1943; Conant, 1975). Studies have shown, however, that the burrowing abilities and behavior in *Ambystoma* greatly vary among the species examined thus far (Gruberg and Stirling, 1972; Semlitsch, 1983). Like many burrowing toads, terrestrial and some aquatic salamanders possess a thickened, cornified epidermal covering on the friction surface of their toe tips. The epidermal covering is darkly pigmented in some salamander species (Bishop, 1943; Caldwell and Trauth, 1979; Juterbock, 1984). Adults and larvae of ambystomatid salamanders, likewise, exhibit both thickened and/or partially horny digital tips (Duellman and Trueb, 1987; Noble, 1931). In *Ambystoma*, this feature undoubtedly assists or protects digits during the excavation of underground retreats by adults or allows for the seeking of secluded refugia in ponds by larvae.

In the present study, we examined the toe tips of six species of *Ambystoma* (*A. annulatum*, *A. maculatum*, *A. opacum*, *A. talpoideum*, *A. texanum*, and *A. tigrinum*) native to Arkansas using scanning electron microscopy. Our primary objectives were to determine: 1) the ultrastructure of the toe tip friction surface, 2) whether interspecific differences in toe tip morphology are related to the burrowing tendencies of these species, and 3) the usefulness of toe tips as a taxonomic tool.

## MATERIALS AND METHODS

We examined the toe tip friction surface of adult specimens (N = 43) of six species of *Ambystoma* (*A. annulatum*—4 males, 4 females; *A. maculatum*—4 males, 4 females; *A. opacum*—4 males, 4 females; *A. talpoideum*—3 males, 2 females; *A. texanum*—4 males, 4 females; *A. tigrinum*—4 males, 2 females) using scanning electron microscopy (SEM). All animals were collected from localities in Arkansas during 1985-87. Individual toes or portions of the entire left hind foot were excised from animals which had been previously killed in a dilute chloretone solution, fixed in 10% formalin, and stored in 70% ethanol. Laboratory techniques used to prepare toes for SEM followed routine procedures (Dawes, 1979) and included dehydration in a series of ethanol with amyl acetate serving as the transition solvent. Samples were dried in a Samdri critical point dryer and coated with gold/palladium in a Hummer IV sputter coater from 2 - 5 min. A JEOL 100 CXII TEM-SCAN electron microscope was used to view toe tips at an accelerating voltage of 20 kV. All specimens and preparations are deposited in the Arkansas State University Museum of Zoology.

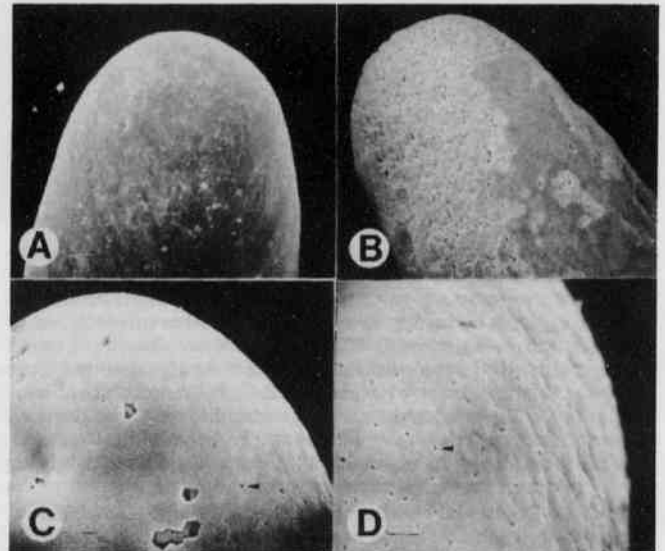


Figure 1. Scanning electron micrographs of toe tip friction surfaces of *Ambystoma opacum* (A), *A. maculatum* (B), *A. talpoideum* (C), and *A. texanum* (D). Line in A = 100  $\mu$ m for A & B; in C, 50  $\mu$ m; in D, 35  $\mu$ m. Notice the numerous mucus pores (tips of pointers) between cells in C and D.

## RESULTS AND DISCUSSION

### Toe Tip Surface Morphology

The cornified friction surfaces of the toe tips of the six indigenous species of *Ambystoma* in Arkansas are shown in Figs. 1 & 2. We found no sexual dimorphism in cell surface ultrastructure. The range of variation within and among species was considerable and possibly indicated degree of wear or age of the epithelium. Toe tip surface topography ranged from very smooth or gently contoured to relatively rough, whereas cell surface microstructure was less variable and showed few modifications. For example, *A. opacum* (Fig. 1A) normally exhibited a smooth squamous epithelium as did *A. maculatum*; however, one specimen of *A. maculatum* (Fig. 1B) had a fractured, scuffed tip. Both species possessed a similar surface microstructure on their cells (Fig.

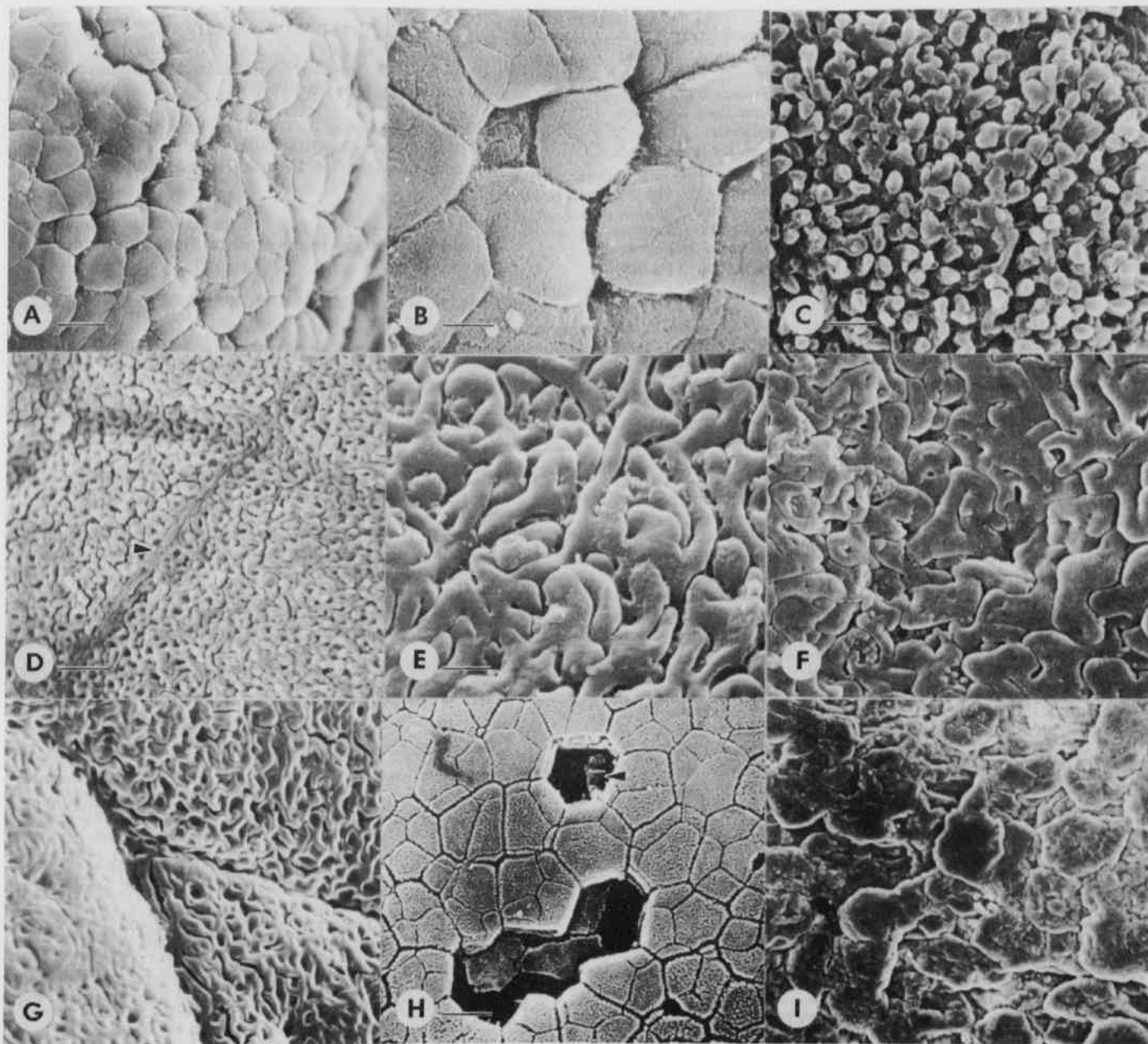


Figure 2. Scanning electron micrographs of the toe tip cells and cell surface ultrastructure in six species of *Ambystoma*. A - C. *A. texanum*; line in A = 35  $\mu\text{m}$ ; in B, 12  $\mu\text{m}$ ; in C, 1  $\mu\text{m}$ . D & E. *A. maculatum*. Pointer indicates a cell border impression on a cell surface following the sloughing of cells; line in D = 2  $\mu\text{m}$ ; in E, 0.5  $\mu\text{m}$ . F. *A. annulatum* (magnification same as E). G. *A. opacum*; line = 1  $\mu\text{m}$ . H. *A. talpoideum*. Notice depression left by sloughed cell (pointer) remains surrounded by well-defined cells; line = 20  $\mu\text{m}$ . I. *A. tigrinum*. A relatively rough area of poorly-defined cells is evident (magnification same as A).

2D & G). Two species, *A. talpoideum* and *A. texanum*, possessed similar tips in that both showed a gently contoured tip (Fig. 1C & D; Fig. 2A) and identical microprojections on cell surfaces (Fig. 2C & H). Of the other two species, *A. annulatum* (Fig. 2F) had a toe tip surface very similar to *A. opacum* and *A. maculatum*; *A. tigrinum* exhibited the roughest toe surface morphology (Fig. 2I) of all species studied.

#### Mucous Pores and Sloughing of Cells

Only two species, *A. talpoideum* and *A. texanum*, exhibited mucous pores in areas directly adjacent to the friction surfaces (Fig. 1C & D). No mucous pores were observed on the friction surface. Since mucous pores occur between cells, mucous secretions could possibly be distributed onto the surface of toe tips via the myriad of prominent

Toe Tip Surface Morphology in Six Species of Salamanders, Genus *Ambystoma* (Caudata: Ambystomatidae)

intercellular spaces. Much is known about mucous pores, glands, and secretions of the enlarged toe pads of tree-dwelling anurans, especially species of tree frogs (*Hyla*, *Rhacophorus*, and other genera; Ernst 1973a, b; Green, 1981; McAllister and Channing, 1983; Welsch *et al.*, 1974). The presence and/or nature of mucous pores and secretions in regions near the digital tips is poorly understood in salamanders.

The shedding or molting of the skin (ecdysis) can occur every 4-5 days in *Ambystoma* (Ling, 1972). The shedding of individual cells or cell clusters was observed in most species. In *A. talpoideum*, cells can be lost without causing disruption to contiguous cells (Fig. 1C; magnification in Fig. 2H). The method of sloughing and replacement of cells is illustrated in Fig. 2H. Each epithelial cell bears the impressions of formerly discarded cells, and an overlapping pattern of replacement is apparent.

#### Burrowing Tendency

Semlitsch (1983) reported on the burrowing activities of five of the six species of *Ambystoma* in our present study. He found that *A. tigrinum* always attempted to burrow regardless of the type of experimental substrate, whereas *A. talpoideum* actively dug only 50% of the time. The other species (*A. annulatum*, *A. maculatum*, and *A. opacum*) were passive burrowers preferring to enlarge crevices or cracks rather than attempt to dig underground.

Our data suggest a casual relationship between burrowing proclivities in these species of *Ambystoma* and the nature of the toe tip morphology; i.e., the greater the tendency to burrow, the more calloused and disrupted the cell friction surface layer. *Ambystoma tigrinum* whose mostly pointed toe tips are ideal for penetrating substrates had a disorganized toe friction surface. *Ambystoma talpoideum* (and *A. texanum*) bears microprojections on cells. These microstructures could aid in locomotion or possibly digging, but their function is unknown. The other three species which prefer to dig passively possess mostly blunt toes and smooth friction surfaces.

#### Taxonomic Considerations

According to Tihen (1958), the six species of *Ambystoma* we investigated belong to four different species groups: *mexicanum* (*A. tigrinum*), *opacum* (*A. opacum* and *A. talpoideum*), *maculatum* (*A. maculatum*) and subgenus *Linguelapsus* (*A. annulatum* and *A. texanum*). Because *A. annulatum*, *A. maculatum*, and *A. opacum* have similar cell surface morphologies on toe tips, and, at the same time, are classified in separate taxa, the microstructure of cells of the friction surface is, in all likelihood, a pleisomorphic character state and has no bearing on taxonomic affinities within *Ambystoma*. The similar specialization in design of the cell surface ultrastructure observed in *A. talpoideum* and *A. texanum* is noteworthy. Interestingly, some species of *Desmognathus*, a genus of mostly semi-aquatic, burrowing plethodontid salamanders, also exhibit microprojections on cells of toe tips (Caldwell and Trauth, 1979).

#### ACKNOWLEDGMENTS

We thank Brian P. Butterfield, Bob Cox, and Walter E. Meshaka for their field assistance.

#### LITERATURE CITED

- BISHOP, S. C. 1943. Handbook of salamanders. Comstock Publ. Co., Inc. Ithaca, New York. 555 pp.
- CALDWELL, R. S., and S. E. TRAUTH. 1979. Use of the toe pad and tooth morphology in differentiating three species of *Desmognathus* (Amphibia, Urodela, Plethodontidae). *J. Herpetol.* 13:491-498.
- CONANT, R. 1975. A field guide to the reptiles and amphibians of eastern and central North America. Houghton Mifflin Co., Boston. 429 pp.
- DUELLMAN, W. E. and L. TRUEB. 1986. Biology of amphibians. McGraw-Hill, Inc. New York. 670 pp.
- ERNST, V. V. 1973a. The digital pads of the treefrog, *Hyla cinerea*. I. The epidermis. *Tissue Cell* 5:83-96.
- ERNST, V. V. 1973b. The digital pads of the treefrog, *Hyla cinerea*. II. The mucous glands. *Tissue Cell* 5:97-104.
- GREEN, D. M. 1981. Adhesion and the toe-pads of treefrogs. *Copeia* 1981:790-796.
- GRUBERG, E. R., and R. V. STIRLING. 1972. Observation on the burrowing habits of the tiger salamander (*Ambystoma tigrinum*). *Herpetol. Rev.* 4:85-89.
- JUTERBOCK, J. E. 1984. Evidence for the recognition of specific status for *Desmognathus welteri*. *J. Herpetol.* 18:240-255.
- LING, J. K. 1972. Adaptive function of vertebrate molting cycles. *Amer. Zool.* 12:77-93.
- McALLISTER, W., and A. CHANNING. 1983. Comparison of toe pads of some southern African climbing frogs. *S. Afr. J. Zool.* 18:110-114.
- NOBLE, G. K. 1931. The biology of the Amphibia. McGraw-Hill, Inc. New York, 577 pp.
- SEMLITSCH, R. D. 1983. Burrowing ability and behavior of salamanders of the genus *Ambystoma*. *Can. J. Zool.* 61:616-620.
- TIHEN, J. A. 1958. Comments on the osteology and phylogeny of ambystomatid salamanders. *Bull. Fla. State Mus. Bio. Sci.* 3:1-50.
- WELSCH, U., V. STORCH, and W. FUCHS. 1974. The fine structure of the digital pads of rhacophorid tree frogs. *Cell Tiss. Res.* 148:407-416.



# COMMENTS ON ESTIMATING POPULATION RATE OF INCREASE FROM AGE FREQUENCY DATA

RENN TUMLISON

Oklahoma Cooperative Fish and Wildlife Research Unit  
and Department of Zoology  
Oklahoma State University  
Stillwater, OK 74078

and

V. RICK McDANIEL

Department of Biological Sciences  
Arkansas State University  
State University, AR 72467

## ABSTRACT

Although many papers have described assumptions and calculations of  $r$  from different kinds of data, none has compared estimates of  $r$  for the same real data set under different assumptions. We used the age distributions of gray foxes collected during six trapping seasons to estimate and compare  $r$  and  $l_x$  series derived under different assumptions. Because trapped foxes are killed, they are believed by some to represent death history data. We found this treatment underestimates mortality so overestimates survivorship and leads to erroneous conclusions about the population. Use of a projection matrix allowed prediction of population size and thus allowed us to predict "observed" rate of increase. Use of projection matrices also resulted in the most conservative estimated of  $r$ .

## INTRODUCTION

Since the early 1960's mammalogists have become increasingly interested in population dynamics. Caughley and Birch (1971) pointed out that many of the estimates of rate of increase ( $r$ ) in papers resulting from this interest were inaccurate because "time-specific" data were used. Construction of time-specific life tables is based on the assumptions that 1) the population has a stable age distribution, 2) there is no bias in the data, and 3)  $r = 0$ . Estimation of  $r$  in time-specific analysis approximates zero because the calculation "retrieves an assumption and disguises it as a conclusion" (Caughley and Birch, 1971). Tait and Bunnell (1980) noted that this statement is not true if age-specific probability of survival from birth ( $l_x$ ) is estimated from the distribution of ages at death of animals found dead. Still, they concluded that while  $r$  was possible to estimate in theory, it is virtually impossible to estimate in practice. Given these usually untenable assumptions, it might seem that there is no point in attempting to estimate rate of increase from life table data. Michod and Anderson (1980) indicated, however, that by calculating  $r$  and  $l_x$  jointly questions concerning population dynamics, the data, or the validity of the model can be addressed.

Several authors have offered logic for the calculation of population parameters. Leslie (1945; 1948) used matrices to project future age structure and population size. Conley (1978), Downing (1980), Michod and Anderson (1980), Tait and Bunnell (1980), and Lenski and Service (1982) discussed calculation of population parameters from different kinds of data. One approach lacking in these treatments is a comparison of estimates of  $r$  calculated for the same real data set under various assumptions. The purposes of this paper are to estimate and compare  $l_x$  series and  $r$  calculated under different assumptions for trapped samples of gray fox (*Urocyon cinereoargenteus*).

## METHODS AND MATERIALS

Skulls of gray foxes were obtained from furbuyers in Arkansas during six December-January trapping seasons from 1977-78 through 1982-83. Age estimates were made using dental criteria (Tumlison and McDaniel, 1984). Accuracy of age estimates affects the calculated values of population parameters, but this was not considered to be a major source of bias because foxes are among the easiest mammals to age (Matson, 1981). Age structure for each sample is given in Table 1.

Three approaches for the development of an  $l_x$  series were used with these data. A large sample, obtained during year 2 (1978-79), was used

Table 1. Age structure of samples of gray fox taken during December-January trapping seasons in Arkansas. Year 1 was 1977-78, year 6 was 1982-83.

Age Class	Trapping Season						Total
	1	2	3	4	5	6	
0	31	143	86	22	13	40	335
1	23	50	34	8	2	13	130
2	4	23	10	1	3	8	49
3	2	12	13	0	1	0	28
4	1	6	4	2	2	3	18
5	2	10	2	0	0	0	14
6+	0	4	1	0	0	1	6
	63	248	150	33	21	65	580

to develop a time-specific  $m_x$  series in which  $r$  is usually assumed to be zero. The approach of Leslie (1945) and Michod and Anderson (1980) does not require an assumption of stability, therefore  $r$  was estimated from the single sample using fecundities of the type termed  $F_x$  (Leslie, 1945) rather than the usual  $m_x$  fecundities.

Because most animal populations are not truly stable, variation in the initial size of the cohorts represented is often reflected in age structure determined from a single sample. Downing (1980) indicated that a composite of several years of census data largely avoids the problem of unequal cohorts. To evaluate the potential difference, another time-specific analysis was made using a composite sample of the 6 years of data. Year 2 contributed significantly to the size of the composite sample, and reduced the differences between  $l_x$  schedules. Again,  $r$  was estimated as described above.

Finally, a dynamic analysis in which stability is not assumed is possible using data from years 2 and 3. During the analysis, the sample size of year 3 was made equal to that of year 2 and proportioned among age classes. By following age class 0 of year 2 to age class 1 of year 3, survival rate for that cohort during sample year 2 was estimated. Survival



## Comments on Estimating Population Rate of Increase From Age Frequency Data

rates for each cohort in the sample were used to construct an  $l_x$  series that did not assume stability.

Each of the above approaches treats the data as a sample of the living. Although trapped foxes were killed, they are usually considered to represent a sample from the living population (Caughley, 1966). However, in some exploited furbearer populations trapping may be the major source of mortality. Hence, it might be argued that a trapped sample more accurately reflects a sample of the dying. Each of the 3  $l_x$  series described above was recalculated with this assumption for comparison. Methods for calculation of  $l_x$  given life or death assumptions were described by Downing (1980).

To calculate  $r$ , both  $l_x$  and  $m_x$  are required. No  $m_x$  values were obtained with the fox age data, so  $m_x$  values were estimated. Life tables traditionally are constructed to represent the female portion of the population. Pielou (1977:53) stated that populations with a 1:1 sex ratio and identical age distribution between the sexes do not need to be treated separately. Our data indicated that these assumptions were not violated, therefore the data were pooled and all specimens were treated as females. As a result, calculated  $m_x$  values represented the number of female offspring. Wood (1958) provided  $m_x$  data on gray foxes which Michod and Anderson (1980) later used. Their  $m_x$  values were based on placental scars and embryo counts, and the percentage of foxes not breeding. By using the Leslie matrix, an  $m_x$  schedule was developed for our analysis which is proportional to Wood's (1958) data as given by Michod and Anderson (1980) and which made the age structure for the dynamic sample stable (i.e.,  $F_x$  in the Leslie matrix projected the same future age structure and population size as that obtained in the dynamic sample). The dynamic sample was chosen for stabilization merely because it does not assume stability. Because this treatment to derive the schedule caused the dynamic analysis to indicate stability ( $r=0$ ), the dynamic data may now be used as an heuristic device for comparison of other estimates of  $r$ . We expect that all estimates of  $r$  should approximate 0 if assumptions of the particular model are not violated.

The discrete time version of the demographic equation (i.e., the characteristic equation of the Leslie matrix) is

$$1 = \sum_{x=1}^{\eta} e^{-\alpha x} l_x m_x \quad \text{Equation (1)}$$

(Murray and Garding, 1984). Michod and Anderson (1980), using harvested animals for analysis, gave the equation

$$1 = \sum_{x=0}^{\eta-1} \lambda^{-(x+1)} \frac{l_x}{l_0} F_x \quad \text{Equation (2)}$$

They incorporated into their equation for the solution of  $\lambda$  the term  $l_0$ , representing average survivorship of newborn to their first harvest season. The number of age 0 individuals could then be treated in the first age class after having accounted for the difference between the number of age 0 individuals sampled and mortality between birth and sampling (i.e., they used  $F_x$  data). Their approach allowed simultaneous calculation of  $\lambda$  and  $l_x$  without any assumption concerning the growth rate. Note:  $r = \ln \lambda$ .

## RESULTS AND DISCUSSION

The  $l_x$  series calculated under each assumption are provided in Table 2. We tested the hypothesis that trapping was the major source of mortality using the G-statistic and a 7x2 contingency test (Sokal and Rohlf, 1969) to compare  $l_x$  series developed under both life and death data assumptions. If trapping is the major source of mortality, the age structure must reflect such a reality. Conversely, treatment as a sample of the living incorporates all forms of mortality into population structure.

Comparison of the one-year and dynamic series were each significantly different ( $P < 0.005$ ) while the composite sample was significant only between the 0.25 and 0.10 levels. Comparisons of  $l_x$  series may not be meaningful because an error in the frequency of the first age class results in distortion of each  $r$  below it in the series (Caughley, 1966). However, values of  $q_x$  are independent of frequencies in younger age classes and may serve as more sensitive measures for comparison. In our analyses, all comparisons between  $q_x$  series, calculated under life and death base assumptions, were highly significant ( $P < 0.005$ ).

Table 2. The probability of survival from age 0 to age  $x$  ( $l_x$  series) calculated for each treatment of age data. Life or death base data assumptions are indicated.

Age class	Time Specific				Dynamic	
	Total Sample		Year 2		(Years 2 & 3)	
	Life	Death	Life	Death	Life	Death
0	1.000	1.000	1.000	1.000	1.000	1.000
1	.388	.388	.350	.473	.392	.430
2	.146	.182	.161	.222	.133	.207
3	.084	.104	.084	.129	.119	.131
4	.054	.060	.042	.081	.070	.064
5	.042	.032	.070	.057	.035	.024
6+	.018	.010	.028	.016	.007	.004

Some statistical problems appeared using life-based assumptions with the 1978-79 sample. Unequal cohort size may have been responsible for the larger size of the 5-year class, but this translates mathematically into a negative  $q_x$  value; a biological impossibility. For the contingency test, we set the value of  $q_x$  for the 5-year class equal to the corresponding value in the contingency table. This procedure removed the contribution of the class to independence and decreased the calculated significance level, but differences were still sufficient for significance. We conclude from these analyses that the trapped sample of foxes does not represent death data, because sources other than harvest mortality affect the population. Harvest data *cannot* represent a sample of the dying.

Each of the 3 life-based  $l_x$  series were tested in all combinations for independence. Comparison of the 6-year composite and 1-year samples showed significant differences ( $P < 0.05$ ). This observation indicates that yearly fluctuations in Arkansas gray fox populations reduce the predictive usefulness of single samples. The  $l_x$  series of the composite and dynamic samples were also different ( $P < 0.05$ ). While the dynamic treatment does not assume stability, it is based on relatively static data (2 years). A comparison of the 1-year and dynamic series was highly significant ( $P < 0.005$ ). The greater significance level is probably due to variation from each of these latter series being absorbed in the composite sample, making comparison with the composite series relatively less significant. All comparisons of corresponding  $q_x$  series were highly significant ( $P < 0.05$ ).

As mentioned earlier, the dynamic  $l_x$  series was used to develop a  $m_x$  series that would stabilize that age structure, thus we expect  $r=0$ . Rate of increase was calculated by Eq. 1 to be 0.002. Our treatment to develop a  $l_x$  series necessarily set  $l_0=1$ , thus rate of increase estimated by Eq. 2 was 0.005.

The Leslie matrix projects future population characteristics assuming constant survivorship and fecundity schedules. By projecting next year's population size based on our sample and observing differences between this estimate and our sample size, an estimate of  $r$  (in this case, observed rate of increase) can be obtained. For our "stabilized dynamic" sample this value was 0.003. We have shown that, given some rounding error,  $r=0$  for the dynamic data using our derived fecundity schedule.

Equation 1 cannot be applied to the composite or one-year samples because the  $l_x$  series for these samples are based on the assumption of stability. Equation 2 or Leslie matrices may be used, however. Rate of increase estimated by Eq. 2 for the composite sample indicated a decline ( $r = -0.029$ ), as did the one-year sample ( $r = -0.020$ ). Observed  $r$  estimated by projecting the population for next year via the Leslie matrix also predicted declines ( $r = -0.017$  and  $-0.012$ , respectively). Estimates of  $r$  by Eq. 2 compared to those derived from Leslie projections were appreciably different. We used the age structure represented by the  $l_x$  series as the column vector multiplicand of the Leslie matrix. Solution of Eq. 2 or calculation of the first position in the projected age structure estimates the agreement between recruitment and the

characteristic value of the first age class of the  $l_x$  series (i.e., 1.000). For example, if there are 1000 individuals in the first age class at time  $t$ , Eq. 2 predicts the number expected to be present at time  $t+1$ . If  $\lambda = 0.971$  ( $r = -0.029$ ), recruitment is 971 individuals, which does not replace the age class. The value of  $r$  indicates a loss of 29 individuals from the age class at  $t+1$ . Notice that this is a change of 29 per 1000. Since observed rate of increase is based on change in numbers between  $t$  and  $t+1$ , we sum both the sample and projected  $l_x$  series to simulate our "population" sizes. For the above example the sums at  $t$  and  $t+1$  were 1732 and 1703, respectively. This still represents a loss of 29 individuals, but it is now 29 per 1732. Now,  $\lambda = 0.983$  and  $r = -0.017$ .

The hypothesis that the data represent death history was refuted earlier. To examine the effect of erroneously accepting that hypothesis,  $r$  was estimated by Eq. 2 and by the change in the projected population size. These estimates were, respectively: 0.133, 0.076 (dynamic); 0.030, 0.017 (composite), and 0.213, 0.123 (one-year). Because treatment of the data as death history underestimates mortality, survivorship ( $l_x$ ) is overestimated; consequently,  $r$  appears more favorable. This type of treatment would lead to a more positive, but invalid, conclusion about the population.

### CONCLUSIONS

The method one uses to estimate  $r$  depends on the kinds of data available for analysis. Although Eqs. 1 and 2 are mathematically identical, the data required for solution are different. Equation 1 can be used only if an  $l_x$  series can be obtained that does not assume stability. Since many data sets are based on single samples and Eq. 2 makes no assumptions concerning the growth rate, it has greater utility. Further, it allows the simultaneous calculation of  $r$  and an  $l_x$  series that accounts for population changes. However, it requires extra effort to obtain  $l_0$ . As Michod and Anderson (1980) point out, "... it may be more reasonable to assume some value for  $l_0$  rather than assume  $\lambda = 1$ , or  $r = 0$ , as is often done." Investigators should note, if they choose to use Eq. 2, that  $r$  deals with changes in recruitment into the first age class, whereas observed  $r$  deals with changes in recruitment into the population. Because of larger sample size, observed  $r$  is the more conservative estimate. If we continue to use the  $l_x$  series to represent the age structure of the population, "observed"  $r$  based on matrix projections will always provide the more conservative estimate of  $r$ .

### ACKNOWLEDGMENTS

This project was funded by the Arkansas Game and Fish Commission through Pittman-Robertson funds made available by the U. S. Fish and Wildlife Service. We thank Lew Johnston, Mike Cartwright, and Barry McArdle for providing data, skulls from foxes, and other support. J. H. Shaw and S. E. Trauth offered helpful suggestions concerning the manuscript.

### LITERATURE CITED

- CAUGHLEY, G. 1966. Mortality patterns in mammals. *Ecology* 47:906-918.
- CAUGHLEY, G. and L. C. BIRCH. 1971. Rate of increase. *J. Wildl. Manage.* 35:658-663.
- CONLEY, W. 1978. Population modeling. Pp. 305-320, in Schmidt, J. L. and D. L. Gilbert (eds.). *Big game of North America: ecology and management*. Wildl. Manage. Inst. and Stackpole Books, Harrisburg, Pennsylvania. 494 pp.
- DOWNING, R. L. 1980. Vital statistics of animal populations. Pp. 247-267, in Schemnitz, S. D. (ed.). *Wildlife Management Techniques Manual*. The Wildlife Society, Washington, D. C. 686 pp.
- LENSKI, R. E., and P. M. SERVICE. 1982. The statistical analysis of population growth rates calculated from schedules of survivorship and fecundity. *Ecology* 63:655-662.
- LESLIE, P. H. 1945. On the use of matrices in certain population mathematics. *Biometrika* 33:183-212.
- LESLIE, P. H. 1948. Some further notes on the use of matrices in population mathematics. *Biometrika* 35:213-245.
- MATSON, G. M. 1981. *Workbook for cementum analysis*. Matson's, Milltown, Montana. 30 pp.
- MICHOD, R. E. and W. W. ANDERSON. 1980. On calculating demographic parameters from age frequency data. *Ecology* 61:265-269.
- MURRAY, B. G., JR., and L. GARDING. 1984. On the meaning of parameter  $x$  of Lotka's discrete equations. *Oikos* 42:323-326.
- PIELOU, E. C. 1977. *Mathematical ecology*. John Wiley and Sons, New York. 385 pp.
- SOKAL, R. R., and F. J. ROHLF. 1969. *Biometry*. W. H. Freeman and Co., San Francisco. 776 pp.
- TAIT, D. E. N., and F. L. BUNNELL. 1980. Estimating rate of increase from age at death. *J. Wildl. Manage.* 44:296-299.
- TUMLISON, R., and V. R. McDANIEL. 1984. Gray fox age classification by canine tooth pulp cavity radiographs. *J. Wildl. Manage.* 48:228-230.
- WOOD, J. E. 1958. Age structure and productivity of a gray fox population. *J. Mammal.* 39:74-86.

# SEX RATIOS IN BOBCAT POPULATIONS

RENN TUMLISON

Department of Zoology  
Oklahoma State University  
Stillwater, OK 74078  
and

V. RICK McDANIEL

Department of Biological Sciences  
Arkansas State University  
State University, AR 72467

## ABSTRACT

Reported sex ratios in bobcat populations have suggested great variation ranging from strong male bias to strong female bias. Explanations offered for these observations have included factors of mobility, activity, behavior, inaccurate data collection, hunting pressure, and population density. Ratios are probably most representative during the winter, when females are no longer under constraints of parental care. Sex determination should be made by experienced observers and preferably through internal examination. The most productive direction for interpretation of validated ratios appears to be in terms of population density, hunting pressure, and the timing of harvest.

## INTRODUCTION

Most published sex ratios for bobcats (*Felis rufus*) are based on rather static data accumulated over 1-3 years. These sex ratios (and explanations offered to explain them) have varied considerably, and some explanations are contradictory. Reported ratios have ranged from 0.40 males/female (Foote, 1945) to 2.21/1 (Kohn, 1981a). Sex ratios may change dramatically between years: the male-dominated ratio of Kohn (1981a) dropped to 1.10/1 the next year (Kohn, 1981b). Alternatively, Erickson (1955) demonstrated a *gradual* change in sex ratios of 6496 bountied bobcats from 0.97/1 in 1941 to 1.90/1 in 1952.

Explanations offered for observed sex ratios in bobcats include: 1) greater mobility, thus vulnerability, of males; 2) lesser mobility, thus vulnerability, of females; 3) increased activity of either sex during the breeding season; 4) seasonal differences due to maternal care of young; 5) inaccurate sexing; 6) degree of hunting pressure; 7) density of the population; and 8) differential attractiveness to baits. The purposes of this paper are to consolidate thought on causes of observed sex ratios in bobcat populations and provide some insight into the applicability of these explanations.

## METHODS AND MATERIALS

When researchers feel that the sex ratio of a species is equal at birth, they look for causes when equality is not found in a sample. If the sample is of newborns, explanations usually invoke mechanisms for intrinsic population regulation such as sex-determining mechanisms and sex-specific intrauterine mortality. If the sample is from the general population, explanations often include differential mortality due to factors such as behavior or hunting pressure. The recent proliferation of data concerning sex ratios in bobcat populations has resulted in several explanations for ratios that deviated from equality. We examined literature reporting sex ratios in bobcat populations to evaluate the logic of explanations and to consolidate thought on the causes of unequal ratios, and to provide direction for future research. Most literature was located using publications of abstracting services and indexes for particular journals. In addition, letters were sent to several states to request information on bobcat research completed in those states.

## RESULTS AND DISCUSSION

Several researchers have suggested that male-dominated ratios are due to greater mobility of males, leading to increased vulnerability to trapping (Gashwiler *et al.*, 1961; Fritts and Sealander, 1978) or shooting (Knick *et al.*, 1985). This argument is based on home range and move-

ment studies that consistently indicate that males move farther and occupy larger ranges than do females (Robinson and Grand, 1958; Bailey, 1972; Hall, 1973; Guenther, 1980; Hamilton, 1982). If males are indeed more susceptible to trapping, then a female-dominated sex ratio in a sample reflects an even more female-dominated population in nature. McCord and Cardoza (1982), using the data of Donoho *et al.* (1979), argued that the sex ratio of specimens taken before and during the breeding season were similar, thus males were not more vulnerable due to reproductive activity. Interestingly, they stated that the seasonal differences found by Erickson (1955) showed no real variation, but examination of the original data indicated that males were collected in stronger disproportion during the summer (i.e., that females were more equally represented during the winter months).

Interpretations of proportions are often conceptually biased. Changing proportions may mean that one sex has become more susceptible, or that the other sex has become less so. Some literature deals with the question of why male vulnerability reflected in the ratio has changed, and doesn't question whether changes in female vulnerability are responsible for observed changes. Sex ratios are often expressed as the number of males per female, suggesting that we may conceive of females as constants and males as variables. In contrast, Parker and Smith (1983) did suggest that males become less prone to trapping than females that were hunting and caring for kittens during the winter. This supposes that changes in female activity may result in changing sex ratios, that is, that male bias occurred because females were *less* likely to be trapped rather than males *more* likely to be.

Many trappers search for bobcat sign when locating trap sites. Because male range is larger than that of females, a trapper would more likely search for sign within a male bobcat's range but would more likely find it in the more intensively utilized female's range (McCord and Cardoza, 1982). Therefore, one might expect females to dominate in sex ratios due to an assumed greater chance of being located (Fredrickson and Rice, 1979; Klepinger *et al.*, 1979). Most of the sex ratios in Table 1 suggest equality or male dominance, thus it is unlikely that females have a greater chance of being located by trappers.

Young (1958) described the success of a trapper who collected 321 bobcats in a 4-month period in Oregon. Females were not collected in substantial numbers until the latter part of October, when mothers and kittens began to travel. (Another interpretation may be that many of the males had been removed, leaving primarily females to trap.) Erickson (1955) and Gashwiler *et al.*, (1961) found that female bobcats were proportionately more often collected during the winter months. This period represents the breeding season when parous females with previous litters are dispersing their young as mating begins. Females, therefore, become more mobile and effectively more trap-susceptible than in other seasons. Sex ratios observed during winter probably best reflect the existing ratios in most populations.



Table 1. Literature data on sex ratios of bobcats in North America.

State or Region	N	Ratio (♂/♀)	Source
Vermont	351	0.40*	Foote, 1945
South Dakota	76	0.43*	Fredrickson & Rice, 1979
Wisconsin	1381	0.64*	Klepinger et al., 1979
Virginia	144	0.87	Progulski, 1952
Oklahoma	411	0.87	Rolley, 1983
California	60	0.94	Lembeck, 1978
Kansas	725	0.95	Johnson, 1979
Wyoming	161	1.01	Crowe, 1975
Alabama	213	1.01	Miller, 1980
Arkansas	471	1.01	Tumilson, 1983
Washington	1238	1.01	Knick et al., 1985
Northeastern U.S.	180	1.05	Pollack, 1950
Washington	176	1.07	Sweeney, 1978
New Mexico	150	1.08	Young, 1958
Nova Scotia	580	1.08	Parker & Smith, 1983
North Dakota	42	1.10	Kohn, 1981b
Utah	792	1.11 <sup>a</sup>	Gashwiler et al., 1961
Michigan	103	1.19	Erickson, 1955 (his study)
Texas	14256	1.20*	Blankenship & Swank, 1979
North Carolina	505	1.21*	King et al., 1983
Minnesota	169	1.22*	Berg, 1979
Arizona	8703	1.26*	Young, 1958
Utah	28432	1.29*	Gashwiler et al., 1961
Idaho	316	1.32*	Bailey, 1979
Colorado	2443	1.37*	Donoho et al., 1979
Texas	13737	1.40*	Roberson, 1981
Michigan	6496	1.54*	Erickson, 1955 (bountied)
Arkansas	180	1.69*	Fritts & Sealander, 1978
North Dakota	93	2.21*	Kohn, 1981a

\* indicates a significant difference from an even ratio, Chi-square ( $p < 0.05$ )

<sup>a</sup> the authors did not provide a reason for distinguishing a subgroup (N=792) of the total sample (N=28432)

Some researchers have compared sex ratios based on method of collection to gain insight on or to validate ratios. Erickson (1955) and Fritts and Sealander (1978) found no significant difference between sex ratios in trapped versus hunted specimens. However, Klepinger et al. (1979) suggested that hunters sometimes bias sex ratios by selecting only larger cats (males) due to trophy value. Britnell et al. (1979), Sweeney (1978), and Knick et al. (1985) noted that hound-hunted samples were male-biased while trapped samples had an even ratio. Therefore, comparisons of bobcat sex ratios calculated for hunted versus trapped specimens cannot be used for ratio validation. Still, distinction by method of collection does provide insight to the nature of bias in the samples.

Male-dominated sex ratios have been reported from Arizona, Arkansas, Colorado, Michigan, Minnesota, North Carolina, North Dakota, Texas, and Utah (Table 1). Because sexes are sometimes disproportionately collected during different seasons, the male dominance in some of these studies may be partially attributed to year-long collections (although Fritts and Sealander [1978] felt that this had not affected the Arkansas sex ratio). Bailey (1972) found sex ratios to vary among age groups: 1.0/1 (kittens), 3.0/1 (transients), 0.6/1 (adults). Parker and Smith (1983) found males dominated the first age class, the ratio was even in young adults, and females dominated in older adults. Thus, different sizes of classes may result in sex ratios biased in favor of males (males dominate in younger, much larger classes). Additionally, male dominance in Texas (Roberson, 1981) may be partly explained by inaccurate sexing because ratios were based on furbuyer reports. Arkansas bobcat sex ratios determined from buyer reports favor males (1.5:1; L. Johnston, pers. comm.) but the ratio determined from carcasses collected during the same period approximated a 1:1 distribution (Tumilson, 1983), possibly because bobcats are more difficult to sex than most furbearers. McCord and Cardoza (1982) reported bobcat sex ratios determined by wildlife personnel in Vermont heavily favored females until verification by internal examination revealed an almost equal sex ratio. A postscript in Fredrickson and Rice (1979) indicated that the female-biased ratio in South Dakota approached a 1:1 distribution based upon internal examination of carcasses collected during the succeeding year.

Females were strongly dominant in Vermont, Wisconsin, and South Dakota samples (Table 1). More harsh northern climates might require a female-dominated population for higher reproduction to offset higher mortality due to greater winter stress. Sex ratios from North Dakota and Washington do not support this interpretation. Further, McCord

and Cardoza (1982) alluded to Foote's (1945) female-dominated ratio when they provided information discounting the credibility of early sex ratios from Vermont.

Logically, a female-dominated population would optimally effect a population increase in a polygynous species. Mech (1975) found that sex ratios of wolf (*Canis lupus*) pups varied according to population density, with male domination significant in litters from high density populations. Conversely, an equal sex ratio or a preponderance of females was produced where the population had been exploited and had existed at a lower density. In a resource-limited environment, a preponderance of males would tend to stabilize the growth rate of the population by decreasing the percentage of breedable females and thereby prevent over-utilization of limited resources. Assuming bobcat reproduction is a density-dependent function, then, male-dominated sex ratios may indicate saturated or unexploited populations. Lembeck and Gould (1979) found a preponderance of males in high-density bobcat populations and females in low-density populations.

Recent estimates of the sex ratio for Arkansas bobcats (Tumilson, 1983) indicated a 1:1 distribution, although Fritts and Sealander (1978) determined a ratio of 1.69/1 in Arkansas a decade earlier. Their data represented an unexploited and probably high-density population, whereas the present population is exploited. If the findings of Mech (1975) for low-density versus high-density wolf populations are applicable to bobcats, exploitation may partially account for the disparity between previous and present bobcat sex ratios in Arkansas. Alternatively, hunting pressure itself may be responsible for the change in sex ratios from Arkansas. Gilbert (1979) suggested hunting pressure might be responsible for skewed ratios in bobcats based on similar research with black bears (*Ursus americanus*). As hunting pressure increases, the effect of different home range size decreases and sex ratios in the kill approach equality. Sex ratio, then, may reflect harvest pressure. Gilbert (1979) cited Lembeck and Gould (1979) as support, however Erickson (1955) found male-bias to increase with increasing harvests.

Gilbert (1979) tried to explain equal sex ratios as being the result of an excess of available females in older age classes. He cited Crowe and Strickland (1975) and Fritts and Sealander (1978) to support the concept of greater vulnerability of males, stating that young males had a greater chance of being caught, leaving more females available in older age classes. However, the number of "surplus" females in older age classes found by Fritts and Sealander (1978) is insufficient to balance the loss of males in younger age classes, thus the sex ratio was not equal (1.69/1). The sex ratio reported by Crowe and Strickland (1975) was equal, and males did dominate younger and females older age classes. However, almost one third of their total sample was not sexed, thus Gilbert (1979) assumed the sex ratio in that part of the total sample was proportionate to that of the sexed samples. If this assumption is false, the inferences made could also be false.

The timing of the harvest season is another important factor in the interpretation of sex ratios. With extended seasons, an increase in the proportion of kittens often occurs in exploited populations (Parker and Smith, 1983; Knick et al., 1985). Because sex ratios in younger age classes often favor males (Bailey, 1972; Parker and Smith, 1983; Knick et al., 1985), later or extended seasons will likely produce more males and earlier seasons relatively fewer females.

Other explanations for bias in observed sex ratios of bobcats are of interest but too few data are available to do more than note them here. Young (1958) thought differential attractiveness to baits may cause biases in trapping data. Fritts and Sealander (1978) suggested that higher postnatal mortality of female kittens might occur in the event of intralitter competition for food, and that smaller females might have lower survivorship after maternal care was withdrawn.

## CONCLUSION

It is evident that explanations given for observed sex ratios in bobcat populations are not always consistent or biologically defensible. Greater mobility of males as an explanation of male-dominated ratios versus lesser mobility of females as an explanation of female-dominated



## Sex Ratios in Bobcat Populations

ratios is obviously inconsistent. Females (but not males) probably become more susceptible to trapping during the breeding season. Ratios must be based on sex determined by internal examination. Perhaps future analyses of sex ratios should focus upon population density, hunting pressure, and timing of the harvest season because these hypothesized causes are biologically sound. At present, data are insufficient to determine their value as explanations.

## LITERATURE CITED

- BAILEY, T. N. 1972. Ecology of bobcats with special reference to social organization. Ph.D. dissert., Univ. Idaho, Moscow. 82 pp.
- BAILEY, T. N. 1979. Den ecology, population parameters and diet of eastern Idaho bobcats. Pp. 62-69, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- BERG, W. E. 1979. Ecology of bobcats in Minnesota. Pp. 55-61, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- BLANKENSHIP, T. L., and W. G. SWANK. 1979. Population dynamic aspects of the bobcat in Texas. Pp. 116-122, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- BRITTELL, J. D., S. J. SWEENEY, and S. T. KNICK. 1979. Washington bobcats: diet, population dynamics and movement. Pp. 107-110, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- CROWE, D. M. 1975. Aspects of aging, growth, and reproduction of bobcats from Wyoming. *J. Mammal.* 56:177-198.
- CROWE, D. M., and D. STRICKLAND. 1975. Population structures of some mammalian predators in southeastern Wyoming. *J. Wildl. Manage.* 39:449-450.
- DONOHU, H. S., H. D. RIFFEL, and R. J. TULLY. 1979. Colorado small game, furbearer and varmint harvest, 1978. Colorado Div. Wildl., Rep. Fed. Aid Wildl. Rest. Proj. W-121-R. 256 pp.
- ERICKSON, A. W. 1955. An ecological study of the bobcat in Michigan. M.S. thesis, Michigan State College, East Lansing. 133 pp.
- FOOTE, L. E. 1945. Sex ratio and weights of Vermont bobcats in autumn and winter. *J. Wildl. Manage.* 9:326-327.
- FREDRICKSON, L. F., and L. A. RICE. 1979. Bobcat management survey study in South Dakota, 1977-79. Pp. 32-36, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- FRITTS, S. H., and J. A. SEALANDER. 1978. Reproductive biology and population characteristics of bobcats (*Lynx rufus*) in Arkansas. *J. Mammal.* 59:347-353.
- GASHWILER, J. S., W. L. ROBINETTE, and O. W. MORRIS. 1961. Breeding habits of bobcats in Utah. *J. Mammal.* 42:76-84.
- GILBERT, J. R. 1979. Techniques and problems of population modeling and analysis of age distribution. Pp. 130-133, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- GUENTHER, D. D. 1980. Home range, social organization, and movement patterns of the bobcat, *Lynx rufus*, from spring to fall in south-central Florida. M.S. thesis, Univ. South Florida. 66 pp.
- HALL, H. T. JR. 1973. An ecological study of the bobcat in southern Louisiana. M.S. thesis, Louisiana State University, Baton Rouge. 131 pp.
- HAMILTON, D. A. 1982. Ecology of the bobcat in Missouri. M.S. thesis, Univ. Missouri, Columbia. 152 pp.
- JOHNSON, N. F. 1979. Efforts to understand Kansas' bobcat populations. Pp. 37-39, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- KING, A. M., R. A. LANCIA, S. D. MILLER, D. K. WOODWARD, and J. D. HAIR. 1983. Winter food habits of bobcats in North Carolina. *Brimleyana*, 9:111-122.
- KLEPINGER, K. E., W. A. CREED, and J. E. ASHBRENNER. 1979. Monitoring bobcat harvest and populations in Wisconsin. Pp. 23-26, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- KNICK, S. T., J. D. BRITTELL, and S. J. SWEENEY. 1985. Population characteristics of bobcats (*Felis rufus*) in Washington State. *J. Wildl. Manage.* 49:721-728.
- KOHN, S. C. 1981a. Bobcat population data. North Dakota Game Fish Dept., Rep. No. 1506. 7 pp.
- KOHN, S. C. 1981b. Bobcat population data. North Dakota Game Fish Dept., Rep. No. 1508. 10 pp.
- LEMBECK, M. 1978. Bobcat study, San Diego County, California. Calif. Dept. Fish Game, Progress Report, Proj. E-W-2, Job IV-1.7. 22 pp.
- LEMBECK, M., and G. I. GOULD, JR. 1979. Dynamics of harvested and unharvested bobcat populations in California. Pp. 53-54, *in Proc. Bobcat Res. Conf., Natl. Wildl. Fed. Sci. Tech. Ser. 6.* 137 pp.
- MCCORD, C. M., and J. E. CORDOZA. 1982. Bobcat and lynx (*Felis rufus* and *F. lynx*). Pp. 728-766, *in J. A. Chapman, and G. A. Feldhamer, (eds.). Wild mammals of North America.* Johns Hopkins Univ. Press. Baltimore. 1147 pp.
- MECH, L. D. 1975. Disproportionate sex ratios in wolf pups. *J. Wildl. Manage.* 39:737-740.
- MILLER, S. D. 1980. The ecology of the bobcat in south Alabama. Ph.D. dissert., Auburn Univ., Auburn, Alabama. 156 pp.
- PARKER, G. R., and G. E. J. SMITH. 1983. Sex- and age-specific reproductive and physical parameters of the bobcat (*Lynx rufus*) on Cape Breton Island, Nova Scotia. *Can. J. Zool.* 61:1771-1782.
- POLLACK, E. M. 1950. Breeding habits of the bobcat in the northeastern United States. *J. Mammal.* 31:327-330.
- PROGULSKE, D. R. 1952. The bobcat and its relation to prey species in Virginia. M.S. thesis, Virginia Poly. Inst., Blacksburg. 135 pp.
- ROBERSON, J. T. 1981. Bobcat status survey. Texas Parks Wildl. Dept., Prog. Rep., Proj. No. W-103-R-11. 22 pp.
- ROBINSON, W. B., and E. F. GRAND. 1958. Comparative movements of bobcats and coyotes as disclosed by tagging. *J. Wildl. Manage.* 22:117-122.
- ROLLEY, R. R. 1983. Behavior and population dynamics of bobcats in Oklahoma. Ph.D. dissert., Oklahoma State Univ., Stillwater. 98 pp.

SWEENEY, S. J. 1978. Diet, reproduction and population structure of the bobcat (*Lynx rufus fasciatus*) in western Washington. M.S. thesis, Univ. Washington, Seattle. 61 pp.

TUMLISON, C. R. 1983. Harvest trends, dietary ecology, reproduction, and population demographics of the bobcat (*Felis rufus*) in Arkansas. M.S. thesis, Arkansas State Univ., State Univ. Arkansas. 158 pp.

YOUNG, S. P. 1958. The bobcat of North America. Stackpole Co., Harrisburg, Pennsylvania, and Wildlife Management Institute, Washington, D.C. 193 pp.

# FOREST HABITAT USE BY WHITE-TAILED DEER IN THE ARKANSAS COASTAL PLAIN

T. B. WIGLEY and M. E. GARNER  
Department of Forest Resources  
University of Arkansas at Monticello  
Monticello, AR 71655

## ABSTRACT

Forest habitat use by five radio-equipped white-tailed deer (*Odocoileus virginianus*) was monitored in the Arkansas Coastal Plain during 1982-84. The deer were located 821 times. Use of forest types was compared to expected use as calculated from availability. The study area was also divided into 491 two-hectare cells for which timber characteristics and number of deer locations were determined. Pine sawtimber was the most heavily used forest type in all seasons and was used more often than expected during spring. Also used more than expected were brushy areas (clearcut but not site prepared) during spring, summer and fall and openings (grass fields and a site-prepared clearcut) during summer. Hardwood stands were used less often than expected during every season. Also used less than expected were pine pulpwood stands in summer and pine-hardwood stands during spring and summer. A significant ( $P < 0.001$ ) discriminant function correctly classified 74% of the two-hectare cells as used (1 + locations) or not used (0 locations). Used cells often had less hardwood pulpwood and sawtimber and more pine sawtimber than nonused cells. Use by deer of cells containing stand edges did not differ from use of cells without edges.

## INTRODUCTION

The white-tailed deer (*Odocoileus virginianus*) is an important natural resource in Arkansas. In Arkansas, an estimated 66,000 deer were harvested during the 1983-84 season by 217,600 hunters (Cartwright, 1984). Forty-eight percent of the 1983-84 Arkansas deer harvest was from the Coastal Plain region (Cartwright, 1984).

Forests provide most of the habitat for white-tailed deer and much of the area used for deer hunting. About one-half of Arkansas is forested. The Coastal Plain, the region of the state most heavily used for deer hunting, is 73% forested (USDA Forest Service, 1979).

In 1984, Arkansas produced about 4% of total United States wood products (Kluender *et al.*, 1988). To meet the needs of the Arkansas forest industry, large areas of Coastal Plain forest are intensively managed. Therefore, large areas of deer habitat in Arkansas are influenced by forest management. The objective of this study was to determine forest habitat use by white-tailed deer in the Arkansas Coastal Plain.

## METHODS

This study was conducted on the 285-ha University of Arkansas at Monticello Forest and about 190 ha of surrounding forest owned by Georgia-Pacific Corporation. The area is located about 5 km east of Monticello in Drew County, Arkansas, and is typical of the Coastal Plain physiographic region of the southeastern United States. Even-aged stands of loblolly (*Pinus taeda*) and shortleaf (*P. echinata*) pine (20 to 45 years old), and unevenaged pine, hardwood and mixed pine-hardwood stands dominate the area (Table 1). Also present are brushy areas (clearcut but not site-prepared) and openings such as a site-prepared, unplanted clearcut and grassy fields (Table 1). Dominant hardwood species are sweetgum (*Liquidambar styraciflua*), hickories (*Carya* spp.), southern red oak (*Quercus falcata*), water oak (*Q. nigra*) and willow oak (*Q. phellos*). Ground-level woody vegetation is characterized by American beauty-berry (*Callicarpa americana*), blueberry (*Vaccinium* spp.), greenbriar (*Simlax* spp.), Japanese honeysuckle (*Lonicera japonica*) and blackberry (*Rubus* spp.).

Timber inventory data routinely collected on the study area were used. Data available for hardwood and pine, and pulpwood and sawtimber included basal area (BA), diameter at breast height (dbh), volume and the number of stems per acre. Pine trees from 15.2 to 25.1 cm dbh and hardwood trees from 15.2 to 30.2 cm dbh were classed as pulpwood. Trees with larger dbhs were termed sawtimber. Stands were classed as pulpwood or sawtimber stands if the average dbh of all trees was within these specified ranges. Stands were categorized as pine if > 75% of the BA was in pine, as hardwood if > 75% of the

Table 1. White-tailed deer use of Arkansas Coastal Plain forest stands by forest type and season, 1982-84.

Forest Type	% of Study Area	% of Locations <sup>a,b</sup>				
		Spring	Summer	Fall	Winter	Total
	No. locations	103	113	372	233	821
Pine Sawtimber	28	53+	29	34	30	35+
Pine Pulpwood	10	5	1-	14	11	10
Hardwood	24	12-	14-	12-	12-	12-
Pine-Hdwd	22	9-	11-	21	24	19
Sweetgum Plantation	1	1	3	1	1	1
Brush	4	11+	19+	9+	7	10+
Open	11	9	23+	9	15	13

<sup>a</sup>Symbols indicate use significantly ( $P < 0.05$ ) more (+) or less (-) than expected, based on availability.

<sup>b</sup>Spring = Mar-May, Summer = Jun-Aug, Fall = Sep-Nov, Winter = Dec-Feb.

BA was in hardwood and as pine-hardwood if pine and hardwood each accounted for 25-75% of the BA. The term total, as used in this study, refers to timber characteristics of all trees.

Five white-tailed deer (three 1.5-year-old males and two 1.5-year-old females) were captured on the study area during 1982 to 1983 using box traps. Each deer was fitted with a collar-mounted radio transmitter operating in the 151 MHz range and released at the capture-site. The deer were located at randomly-selected times from 20 October 1982 to 15 October 1984. Locations were determined using two bearings that differed by 45-90 degrees and were taken less than 10 minutes apart and less than 0.40 km from the deer.

The number of locations in each habitat type on the study area was determined, and habitat use and availability were compared using the Bonferroni z-statistic (Neu *et al.*, 1974). All forest stands on the study area were assumed to be available to the deer. The expected number of locations in each forest type was calculated as the product of the total number of deer locations and the proportion of the study area in that forest type (Neu *et al.*, 1974). The terms preference, preferred, or greater than expected, as used in this study, indicate statistically

greater use of a forest type than the calculated expected value. The terms avoided or less than expected indicate use statistically less than the expected value.

A map of the study area was divided into 2-ha square cells, and timber inventory data were determined for each cell. For cells containing the edges of 2 or more stands, the timber inventory data for the predominant stand were used. The degree of contrast in each timber characteristic along stand edges occurring in the cells were also measured. For cells with no stand edges, values of 0 were assigned to the difference variables.

The number of deer locations was counted for each 2-ha cell and cells were classified as used (1 + deer location) or not used (0 location) for each season and for the entire study period. Timber characteristics of used and nonused cells were analyzed using discriminant analysis (Norusis, 1988). Two stepwise discriminant analyses were used to minimize multicollinearity (Sanathanan, 1975). Minimization of Wilks' lambda was the variable selection criteria. The average values of timber characteristics selected for the discriminant functions were compared between used and nonused cells using an F-test. Contingency table analysis was used to test for preferential use of 2-ha cells containing stand edges. Significance was accepted at the 0.05 probability level.

### RESULTS AND DISCUSSION

The deer were located 821 times over the study period. Pine sawtimber was the most heavily used forest type (Table 1) and was used more than expected during spring and over the entire study period. Brushy areas were preferred habitat during spring, summer and fall, and for the entire study period. Openings were used more than expected during summer.

Three forest types were used less than expected based on their availability. Although 12% of all locations were in hardwood stands, this habitat type was used less than expected during every season and over the entire study period (Table 1). Pine-hardwood stands were avoided during spring and summer, and pine pulpwood stands were used less than expected during summer (Table 1).

Seventeen stand characteristics were chosen for the function discriminating between used and nonused 2-ha cells (Table 2). The function correctly classified 74% of all cells and 82% of used cells. Two-hectare cells that were used by deer had more basal area and volume in pine pulpwood than cells that were not used. Used cells also had more pine sawtimber basal area, a greater pine sawtimber dbh, more sawtimber (pine and hardwood) stems and basal area and a greater total dbh than nonused cells. Used cells were located in stands with less perimeter (km of edge) length and more area than stands in which nonused cells were located.

Cells containing stand edges were not used at a rate different from cells without edges during any season or over the entire study period. Thirty-nine percent of all 2-ha cells contained edges of 2 or more stands. Of used cells, 42% contained stand edges. Cells containing high-contrast edges (a difference of > 25 sawtimber stems/ha), however, were used more often (56% vs. 41%) than cells with less contrast in number of sawtimber stems ( $\chi^2 = 8.86, 1 \text{ df}, P = 0.003$ ). Used cells had less contrast across edges in hardwood pulpwood basal area and volume (Table 2).

We feel that the preferential use of pine sawtimber stands, brushy areas and openings was related to the abundance of ground-level vegetation in these habitats. Although the diet of white-tailed deer in Coastal Plain forests is highly variable and changes seasonally (Newsome, 1984), forbs and the leaves and succulent twig tips of woody plants are preferred foods (Blair and Brunett, 1980). Thill (1984) found in Louisiana that about 90% of deer diet was woody browse, ranging from 85% in winter to 92% in fall. Forb usage varied from 6% in fall to 14% in winter. Hard and soft masts comprised less than 1% of deer diet in all seasons except in fall when they accounted for about 10%.

The production of these foods in southern forests has been related in other studies to overstory characteristics (Halls, 1970; Blair and Brunett, 1977; Wiggers *et al.*, 1978; Hurst *et al.*, 1979; Fenwood *et al.*, 1984). Browse, forb and grass production is inversely related to basal area and number of forest layers (Halls and Schuster, 1965; Blair, 1967;

Table 2. Standardized discriminant function coefficients and average values for forest characteristics of 2-ha cells used (1 + location) and not used (0 locations) by white-tailed deer in the Arkansas Coastal Plain, 1982-1984.

Stand Characteristic <sup>a</sup>	Standardized Discr. Func. Coefficients	Mean		P
		Used	Not Used	
No. of cells		224	267	
Stand Area	0.634	14.0	12.1	0.002
Stand Perimeter	-0.752	2.0	2.3	0.006
Pine Pulpwood BA	1.982	3.4	1.7	<0.001
Pine Pulpwood Volume	-1.361	23.7	12.6	<0.001
Pine Sawtimber BA	3.154	4.6	2.3	<0.001
Pine Sawtimber dbh	-0.316	19.1	14.9	0.014
Hdwd Sawtimber Volume	2.162	3.1	3.9	0.105
Sawtimber BA	-1.772	6.6	5.3	0.013
Sawtimber Stems	-0.904	62.2	51.6	0.046
Total dbh	-0.556	22.5	19.3	0.006
Contrast across stand edges within cells in:				
Pine Sawtimber dbh	0.300	9.2	6.8	0.082
Hdwd Pulpwood BA	1.641	1.1	2.1	0.010
Hdwd Pulpwood Volume	-1.888	6.6	14.5	0.005
Pulpwood dbh	-0.686	4.3	4.2	0.863
Sawtimber BA	-1.084	3.0	2.5	0.240
Sawtimber Stems	0.703	37.8	24.9	0.035
Total dbh	0.808	5.8	4.7	0.192

<sup>a</sup> Units of measure are: area (ha), perimeter (km), BA (m<sup>2</sup>/ha), pulpwood volume (m<sup>3</sup>/ha), sawtimber volume (m<sup>3</sup>/ha), stems (trees/ha), and dbh (cm).

Blair and Enghardt, 1976; Wiggers *et al.*, 1978; Hurst *et al.*, 1979). Soft and hard mast yields may also decrease as stand density increases (Blair, 1969).

In most southern forests, a dense multilayered midstory of hardwoods inhibits forage growth (Schuster and Halls, 1963; Blair, 1969; Blair and Enghardt, 1976; Blair and Feduccia, 1977). A dense hardwood midstory may also cause undesirable changes in forage production by decreasing total number of species, the number of palatable species and plant vigor (Schuster and Halls, 1963; Blair, 1967). In older stands with little hardwood midstory, more light reaches the forest floor than in stands with a midstory or in younger stands with low, dense canopies (Blair, 1969).

Used 2-ha cells and preferred forested habitats in this study usually had an open pine sawtimber overstory, little hardwood midstory and abundant browse available. Eighty-one percent of the locations in forested habitats were in stands with less than 25% of standing volume in hardwood pulpwood. Fifty-seven percent of locations in forested habitats were in stands in which hardwood comprised less than 25% of the pulpwood basal area. Brushy and open areas also had abundant deciduous browse such as Japanese honeysuckle, American beautyberry, blackberries, oaks and red maple (*Acer rubrum*) that remained available into late fall.

Conversely, habitats used less than expected often had a dense hardwood midstory that shaded forage. For example, 2-ha cells that were not used during spring had more stems, basal area and volume in hardwood sawtimber than cells that were used. Cells not used during spring and summer had more stems and basal area in hardwood pulpwood than used cells. The pine pulpwood stands used less than expected were without a hardwood midstory but typically had low, closed canopies and less forage than sawtimber stands.

### CONCLUSIONS

Habitat use by white-tailed deer in the Arkansas Coastal Plain is complex and explainable only by simultaneous consideration of many habitat characteristics. The results of this study, however, suggest that forest characteristics influence habitat use. Openings and pine sawtimber stands with little hardwood midstory were preferred, probably because these characteristics are usually associated with increased forage production.

Cultural practices that reduce overstory density and minimize hardwood midstory formation will ensure adequate light to the understory



Forest Habitat Use by White-Tailed Deer in the Arkansas Coastal Plain

and enhance habitat quality (Blair, 1969). Hardwood control should be used when making routine thinnings in managed stands to avoid development of a dense midstory (Blair and Feduccia, 1977). Preferential edge use by white-tailed deer has been reported (Williamson and Hirth, 1985). However, only edges offering high contrast in the number of sawtimber stems were preferentially used by deer in this study.

ACKNOWLEDGEMENTS

The authors thank the Arkansas Agricultural Experiment Station for financial support of this research and the Arkansas Game and Fish Commission for their assistance. A special debt is owed B. Cantrell, L. Caton, R. Crossett, L. Davis, K. Flenniken and D. Sharer.

LITERATURE CITED

- BLAIR, R. M. 1967. Deer forage is a loblolly pine plantation. *J. Wildl. Manage.* 24:401-405.
- BLAIR, R. M. 1969. Timber stand density influences food and cover. Pp. 74-76, *in Proc. white-tailed deer in the southern forest habitat.* USDA For. Serv. South. For. Exp. Stn., New Orleans, La. 130 pp.
- BLAIR, R. M., and L. E. BRUNETT. 1977. Deer habitat potential of pine-hardwood forests in Louisiana. *USDA For. Serv. Res. Pap. SO-136.* 13 pp.
- BLAIR, R. M., and L. E. BRUNETT. 1980. Seasonal browse selection by deer in a southern pine-hardwood habitat. *J. Wildl. Management.* 44:79-88.
- BLAIR, R. M., and H. C. ENGHARDT. 1976. Deer forage and overstory dynamics in a loblolly pine plantation. *J. Range Manage.* 29:104-108.
- BLAIR, R. M., and D. P. FEDUCCIA. 1977. Midstory hardwoods inhibit deer forage in loblolly pine plantations. *J. Wildl. Manage.* 41:677-684.
- CARTWRIGHT, M. E. 1984. 1983-84 deer harvest. *Ark. Game and Fish Comm., Wildl. Manage. Div. In-Serv. Rept.,* Little Rock, Ark. 21 pp.
- FENWOOD, J. D., D. F. URBSTON, and R. F. HARLOW. 1984. Deer habitat capability of pine stands in the Ouachita National Forest. *Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies* 38:13-22.
- HALLS, L. K. 1970. Growing deer food amidst southern timber. *J. Range Manage.* 23(3):213-215.)
- HALLS, L. K., and J. L. SCHUSTER. 1965. Tree-herbage relations in pine-hardwood forests of Texas. *J. For.* 63:282-283.
- HURST, G. A., D. C. GUYNN, and B. D. LEOPOLD. 1979. Correlation of forest characteristics with white-tailed deer forage. *Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies.* 33:48-55.
- KLUENDER, R. A., E. W. MCCOY, and J. L. EASTERLING. 1988. The Arkansas forest products industry: its status, health, and future. *Ark. Agri. Exp. Stn. Bull. No. 908.* 41 pp.
- NEU, C. W., C. R. BYERS, and J. M. PEEK. 1974. A technique for analysis of utilization-availability data. *J. Wildl. Manage.* 38:541-545.
- NEWSOME, J. D. 1984. Coastal Plain. Pp. 367-380, *in L. K. Halls, ed. White-tailed deer: ecology and management.* Stackpole Books, Harrisburg, Pa. 870 pp.
- NORUSIS, M. J. 1988. *SPSS/PC + advanced statistics V2.0.* SPSS, Inc. Chicago, Ill. 342 pp.
- SANATHANAN, L. 1975. Discriminant analysis. Pp. 236-256, *in D. J. Amick and H. J. Walberg, eds. Introductory multivariate analysis.* McCutchan Publ. Corp., Berkeley, Ca. 301 pp.
- SCHUSTER, J. L., and L. K. HALLS. 1963. Timber overstory determines deer forage in shortleaf-loblolly pine-hardwood forests. *Soc. Amer. For. Proc.* 1962:165-167.
- THILL, R. E. 1984. Deer and cattle diets on Louisiana pine-hardwood sites. *J. Wildl. Manage.* 48:788-798.
- USDA FOREST SERVICE. 1979. Forest statistics for Arkansas counties. *USDA For. Serv. Resour. Bull. SO-76.* 77 pp.
- WIGGERS, E. P., D. L. ROBINETTE, J. R. SWEENEY, R. F. HARLOW, and H. S. HILL, JR. 1978. Predictability of deer forages using overstory measurements. *Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies.* 32:187-194.
- WILLIAMSON, S. J., and D. H. HIRTH. 1985. An evaluation of edge use by white-tailed deer. *Wildl. Soc. Bull.* 13:252-257.

# SEEDLING GROWTH RESPONSE IN A GREENHOUSE TO FOUR RATES OF OLD AND NEW PAPER MILL SLUDGE

J. L. YEISER

Department of Forest Resources  
University of Arkansas at Monticello  
Monticello, AR 71655

## ABSTRACT

Four rates (0, 36, 75, and 112 DT/A) of both old and new pulp-mill sludges were tested in a greenhouse for impact on survival and growth of seedlings of loblolly pine (*Pinus taeda* L.). After one growing season no meaningful differences were detected for seedling survival and growth, number of flushes, and decomposition rate for old and new sludges regardless of rate. Seedling foliage showed increases in Mg and Ca and sludges exhibited high pH and increased salinity.

## INTRODUCTION

Dewatered sludge from pulp and paper mills is known to stimulate agronomic crop production and could potentially stimulate pine seedling growth. Concerns associated with sludge application to selected pine sites include (1) a high sludge pH and calcium carbonate equivalency, which could raise soil pH above a desirable level for loblolly pine and alter the species composition of the herbaceous community on the site, (2) the presence of salts that could kill pine seedlings, (3) the duration during which salts persist in the soil, (4) a high carbon to nitrogen ratio known to immobilize nitrogen and thereby detrimentally influence pine growth, (5) increased levels of nutrient availability, which in the absence of weed control could enhance the growth of herbs to the detriment of pine seedling survival and growth, (6) numerous water soluble nutrients that may enter the ground water, (7) low levels of heavy metals in the sludge that accumulate in the soil and could limit reapplication of sludge, and (8) the intricate relationships between seasonal patterns of rainfall and temperature, availability of nitrogen, quantity and quality of sludge and soil texture as they relate to sludge decomposition rate, nutrient release, soil penetration, ground water percolation and tree uptake.

Deposition of mill sludge is generally achieved through a chain of sediment ponds or placement in a pit. One pulp and paper company spends over \$125,000 annually on sludge deposition and pit maintenance. With seven pulp and paper mills in Arkansas, the annual cost to Arkansas' pulp and paper industry probably exceeds one million dollars annually. This large number is disturbing considering sludge deposition is totally a liability on the industry. A use for the mill sludge is needed.

The objectives of this study are: (1) to compare growth in height and groundline diameter, number of flushes, and nutrient constituents of needles from greenhouse-grown seedlings receiving postplant applications of 0, 36, 75 and 112 dry tons per acre (DT/A) of old or new sludge, (2) to contrast the nutrient constituents and electrical conductivity of sludge at the beginning and the end of the study, and (3) to examine rates of decomposition for sludge treatments.

## MATERIALS AND METHODS

### Seedling Care

One hundred and seventy bare-root seedlings were planted during the third week of February in 7-gallon pots and placed in a greenhouse. Pots contained five gallons of a 1:1 mixture of peat moss and vermiculite plus a 6-month, timed-release fertilizer containing nitrogen, phosphorus and potassium. Media were watered to saturation twice weekly. Care was taken to avoid flushing pots with excessive water.

Seedlings began breaking bud in mid-March, at which time they received the first of three weekly applications of selected nutrients (Table 1). Potting media were glazed with fertilizer and followed with sufficient water to move the nutrients throughout the root zone. It should be noted that only nitrogen, phosphorus, and potassium continued to be provided by the timed-release fertilizer. Some additional nutrients were released by the decomposing sludge.

Table 1. Fertilization regime for the first three weeks of the greenhouse study.

Element <sup>1</sup>	Concentration (ppm)
N	150.0
P	150.0
K	150.0
Ca	50.0
Mg	20.0
Cu	0.010
B	0.100
Mn	0.250
Zn	0.100
Mo	0.010
Fe	10.9
S	84.0
Cl	133.9
Na	111.1

<sup>1</sup> A 6-month, timed-release source of nitrogen, phosphorus, and potassium was used. All other elements were in three, weekly applications.

### Sludge Treatments

Seedlings were grown for approximately one month and then screened prior to the application of sludges. Those seedlings with an injury, brown needle-tips, or other signs of stress or abnormality were discarded. All seedlings were retained in the study once sludges were applied.

Both sludges used in this study originated from a Kraft pulp and paper mill near Ashdown, AR. The old sludge had been in a disposal pit for approximately one year. The new sludge was fresh from the mill. Samples of sludges were weighed, oven-dried, and reweighed to determine the percent content. Sufficient timed-release fertilizer was mixed with the sludges to bring the C:N to 20:1. During the second week in April, old and new sludges were applied to 84 seedlings at wet rates equivalent to 0, 36, 75, and 112 DT/A.

Seedling Growth Response in a Greenhouse to Four Rates of Old and New Paper Mill Sludge

Morphological Analysis

Seedlings were measured at the time of planting for height (HT) and groundline diameter (GLD). Incremental height and groundline diameter were determined as follows:

$$\begin{aligned} \text{Total HT} - \text{Initial HT} &= \text{Incremental HT} \\ \text{Total GLD} - \text{Initial GLD} &= \text{Incremental GLD} \end{aligned}$$

Nutrient Analysis

Initial nutrient levels were computed by averaging data from 12 sacrificed seedlings. In July four to six grams (green weight) of needles were collected from each seedling. Samples were collected from the south side of the upper one third of the crown according to the methods of White (1954) and Wells and Metz (1963).

As collected, samples were sealed in plastic bags and immediately placed in a refrigerator. In the laboratory, the needles were rinsed in distilled water, 1% HCL, and three distilled demineralized water baths. Needle samples were then dried at 65 °C in a forced-air oven. After drying, the tissue was ground in a Wiley mill using a 20-mesh stainless steel sieve and stored in airtight bottles.

At the initiation of the project and again in July, a sample of old and new sludges were collected from each pot for analysis. Sludges were not washed prior to analysis.

The concentration of phosphorus was determined by the colorimetric method (Trough and Meyer, 1929). Standard atomic absorption techniques (Issac and Kerber, 1971) were used to determine concentrations of calcium (Ca), magnesium (Mg), sodium (Na), and potassium (K). A conductivity meter was used to measure the electrical conductivity of aqueous sludge samples.

Statistical Analysis

The study was conducted as a randomized block design with three blocks. Analyses of variance and covariance were used to evaluate treatment differences. Duncan's Multiple Range test was used to contrast means. Dependent variables were growth in height (cm) and groundline diameter (mm), survival (%), number of flushes per tree, and DT/A of decomposed sludge. Initial height and initial groundline diameter were the covariates. All statistical tests were conducted at the 0.05 probability level.

Table 2. Seedling growth and decomposition of old and new sludge. Initial groundline diameter (GLD), initial height (HT) and rate of application were covariates.

Sludge Age	Survival	Initial		Incremental		No of Flushes	Sludge Decomposition <sup>2</sup>
		HT	GLD	HT	GLD		
	$\bar{x}$	cm	mm	cm	mm		DT/A
Check	92 B <sup>1</sup>	23	4	32 A	6 A	3 A	0 B
New	97 A	23	4	36 A	6 A	3 A	29 A
Old	89 B	24	5	39 A	6 A	3 A	32 A

<sup>1</sup> Means within a column sharing the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range test).

<sup>2</sup> Based on mid-April and mid-August dry weights of sludge.

RESULTS AND DISCUSSION

Sludge Age

Seedlings growing in new sludge exhibited higher survival than seedlings growing in old or no sludge (Table 2). Only six seedlings died: one in no sludge, one in new sludge and 4 in old sludge. Survival percentages are high enough that at normal planting rates mortality would not be of operational significance.

No significant differences were detected in height growth, groundline diameter growth or number of growth flushes per tree (Table 2). Seedlings receiving sludge treatments responded with at least similar growth in height or groundline diameter as untreated check seedlings regardless of the age of the sludge. No inhibition of growth was detected.

The proportion of applied sludge remaining in August was similar for old and new sludges. This suggests that allowing fresh sludge to

Table 3. Seedling responses to 0, 36, 75 and 112 dry tons per acre (DT/A) of sludge. Initial groundline diameter (GLD), initial height (HT) and rate of application were covariates.

Sludge Rate	Survival	Initial		Incremental		No of Flushes	Sludge Decomposition <sup>2</sup>
		HT	GLD	HT	GLD		
DT/A	$\bar{x}$	cm	mm	cm	mm		DT/A
0 (Check)	92 A <sup>1</sup>	23	4	32 A	6 A	3 A	0 B
36	96 A	23	5	43 A	7 A	3 A	31 A
75	92 A	24	5	33 A	5 A	3 A	29 A
112	92 A	24	5	38 A	5 A	3 A	32 A

<sup>1</sup> Means within a column sharing the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range test).

<sup>2</sup> Based on mid-April and mid-August dry weights of sludge.

Table 4. Seedling responses to four rates of old and new sludge. Initial groundline diameter (GLD), initial height (HT) and rate of application were covariates.

Sludge Age and Rate	Survival	Initial		Incremental		No of Flushes	Sludge Decomposition <sup>2</sup>
		HT	GLD	HT	GLD		
DT/A	$\bar{x}$	cm	mm	cm	mm		DT/A
Check 0	92 B <sup>1</sup>	23	4	32 A	6 A	3 A	0 A
New 36	92 B	21	4	42 A	7 A	3 A	30 A
New 75	100 A	26	4	31 A	5 A	3 A	29 A
New 112	100 A	23	5	36 A	6 A	3 A	28 A
Old 36	100 A	24	5	43 A	7 A	3 A	34 A
Old 75	84 C	22	5	35 A	5 A	3 A	29 A
Old 112	84 C	25	5	40 A	5 A	3 A	35 A

<sup>1</sup> Means within a column sharing the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range test).

<sup>2</sup> Based on mid-April and mid-August dry weights of sludge.

age for a year in the sludge pit had no effect on the subsequent rate of decomposition after it was spread in the field. It appears then that greater or additional applications are no more possible for old than new sludges.

Rate of Application

Analyses showed no differences in seedling survival, growth, number of growth flushes or sludge decomposition rate occurred as a result of application rate (Table 3). It is important to realize that sludge treated seedlings did not grow significantly more or less than untreated check seedlings. Therefore, stimulation or inhibition of seedling growth was not detected.

Sludge Age By Rate of Application Interaction

A statistically significant interaction between age of sludge and rate of application was detected for seedling survival (Table 4). Results show that survival was best for seedlings growing in new sludge or 36 DT/A of old sludge. However, the sample size was such that each dead seedling represents an 8% decrease in survival. Therefore, the two high rates of old sludge each had two dead trees while the check and the low rate of new sludge each had one dead tree. These differences are probably not meaningful. A significant interaction was not detected for the growth parameters or number of flushes per tree.

Nutrient Analysis

There were no major differences in sludge nutrient levels for P, Na, Mg, or Ca related to age or rate of application. Sludge salt levels, as measured by electrical conductivity, were observed to increase between March and July while sludge alkalinity and K decreased (Table 5). Changes in these values probably resulted from partial decomposition of sludges and/or the presence of fertilizer.

There were some differences in foliar nutrient levels. Needles of live seedlings treated with sludge contained higher levels of Mg and Ca but

Table 5. Analyses of needles from live seedlings and sludge from pots supporting live seedlings. Results are expressed in percent of dry weight. Control seedlings did not receive a treatment of sludge.

	P	K	Nutrient		Ca	pH	Con- duc- tivity <sup>1</sup>
			Na	Mg			
PREPLANT LEVELS <sup>2</sup>							
Needles	.11	.37	.07	.09	.31		
Old Sludge	.09	.20	.21	.11	.43	7.0	2.4
New Sludge	.09	.18	.22	.07	.57	7.4	2.7
Media	t	t	t	t	t	5.8	2.2
JULY							
Control needles	.12	.25	.09	.05	.29		
Old 36 needles	.15	.11	.11	.14	.57		
Old 36 sludge	.08	.09	.21	.17	.31	6.6	3.0
Old 75 needles	.16	.16	.06	.10	.52		
Old 75 sludge	.16	.11	.22	.18	.45	6.7	3.9
Old 112 needles	.15	.16	.06	.11	.53		
Old 112 sludge	.06	.06	.19	.12	.47	7.1	3.6
New 36 needles	.14	.19	.18	.15	.35		
New 36 sludge	.08	.10	.20	.16	.41	6.1	3.4
New 75 needles	.17	.17	.07	.08	.52		
New 75 sludge	.07	.06	.17	.11	.49	6.3	3.9
New 112 needles	.19	.11	.11	.14	.43		
New 112 sludge	.09	.10	.16	.12	.51	6.7	3.7

<sup>1</sup> Expressed in mmhos per cm.

<sup>2</sup> Initial levels are from 1 sample of sludge. July values are means from 1 sample taken from each of 12 pots.

lower levels of K than did the needles of untreated check seedlings (Table 5). Levels of P and Na varied little. Seedling growth was not highly correlated with nutrients levels (Ca:  $r = .21$ , Mg:  $r = .29$ , K:  $r = .37$ ). This suggests that while the sludge treated seedlings metabolized more Mg and Ca and less K than control seedlings, the difference did not translate into enhanced or reduced seedling growth. The levels of Mg, Ca, and K observed in pine needles of both sludge-treated and control seedlings is within the range observed by other researchers (White, 1954, Wells and Metz, 1963, van Buijtenen *et al.*, 1977) and considered acceptable for reasonable growth. Similarly, these same researchers have shown that the tendency of foliar levels of Mg and Ca to increase, and K to decrease is inherent to the seasonal trends characteristic of loblolly pine.

In general, nutrient levels in dead seedlings were similar to those in live seedlings, although 3 dead seedlings had Mg levels which were double that of their living counterparts (Table 6). The pH of sludges around dead seedlings was generally similar to those for live seedlings and for both was higher than the optimum for loblolly pine. At the time of analysis (July), salinity levels were higher for dead seedlings than for live seedlings and also higher than at the initiation of the study. This suggests that a salt problem may develop during the decomposition of the sludge which could lead to increased mortality.

### CONCLUSIONS

In conclusion, results showed both sludges have potential for field application and should be field tested. Neither sludge stimulated nor inhibited seedling survival or growth. Nutrients in seedling foliage were generally within accepted normal levels. Increases in Mg, Ca, pH and electrical conductivity suggest future studies should examine the potential

Table 6. Analyses of needles from dead seedlings and sludge from pots supporting dead seedlings. Samples were collection when death appeared imminent. Results are expressed in percent of dry weight. Seedlings in the control did not receive a sludge treatment.

Treatment	P	K	Nutrient		Ca	pH	Con- duc- tivity <sup>1</sup>
			Na	Mg			
Control foliage	.10	.47	.11	.10	.33		
New 36 foliage	.22	.18	.16	.33*	.41		
Old 36 sludge	.09	.11	.23	.41**	.66	6.9	4.9
Old 75 foliage	.19	.15	.09	.11	.61		
Old 75 sludge	.10	.13	.21	.18	.41	6.7	4.8
Old 75 foliage	.20	.19	.07	.25*	.66		
Old 75 sludge	.07	.13	.20	.33**	.50	6.6	4.7
Old 112 foliage	.22	.20	.11	.18	.63		
Old 112 sludge	.11	.10	.21	.31**	.48	6.9	4.1
Old 112 foliage	.22	.23	.10	.21*	.57		
Old 112 sludge	.11	.13	.18	.18	.47	6.7	3.9

<sup>1</sup> Expressed in mmhos per cm.

\* Dead seedlings whose Mg level is significantly greater than observed in live seedlings receiving the same sludge treatment.

\*\* Significantly greater Mg levels in the sludge of dead seedlings than live seedlings receiving the same sludge treatment.

impact of salts and lime on both seedling development and site quality. Mill sludge should be tested as a mulching agent to increase soil moisture by reducing competition from herbaceous plants. Incorporating sludge into the soil prior to planting should also be evaluated for its impact on seedlings and site quality.

### LITERATURE CITED

- ISSAC, R. R. and J. D. KERBER. 1971. Atomic absorption and flame photometry; techniques and uses in soil, plant and water analysis. *In* Walsh, L. M. (ed.) Instrumental methods for analysis of soils and plant tissue. Soil Sci. Soc. of America, Inc. Madison, Wis.
- TROUGH, E. and A. H. MEYER. 1929. Improvements in the Deniges colorimetric method for phosphorus and arsenic. *Ing. Eng. Chem. Anal. Ed.* 1:136-139.
- VAN BUIJTENEN, J. P., L. WILLETT, M. WENDEL, and P. LAYTON. 1977. Foliar nutrient levels in *Pinus taeda* L. seed orchards in East Texas. Texas Forest Service, Forest Genetics Laboratory, College Station, TX.
- WELLS, C. G. and L. J. METZ. 1963. Variation in the nitrogen, phosphorus, and potassium content of pine needles with season, crown position, and sample treatment. *Soil Sci. Soc. Am. Proc.* 27:90-93.
- WHITE, D. P. 1954. Variation in the nitrogen, phosphorus, and potassium content of pine needles with season, crown, position, and sample treatment. *Soil Sci. Soc. Am. Proc.* 18:326-330.



# SURVIVAL AND GROWTH TWO YEARS AFTER CONTROL OF HERBACEOUS COMPETITORS IN NEWLY PLANTED SEEDLINGS OF LOBLOLLY PINE

J. L. YEISER

Department of Forest Resources  
UA at Monticello  
Monticello, AR 71655

J. W. BOYD

UA Cooperative Extension Service  
Little Rock, AR 72203

## ABSTRACT

Early or late over-the-top applications of herbicides were used to control herbaceous competition in machine planted loblolly pine (*Pinus taeda* L.) seedlings at two locations in a pasture near Alleene and hand planted seedlings on a bedded site near Fouke. Sites were selected for diverse competitors. None of the treatments controlled weeds for the entire growing season. Only glyphosate + sulfometuron methyl produced seedling survival and growth below the check plots. The best over-the-top treatments were sulfometuron methyl alone or sulfometuron methyl + hexazinone.

## INTRODUCTION

Forest managers are beginning to realize the importance of controlling herbaceous competitors about newly planted pine seedlings. A recognition of the potential contribution of early weed control to total site productivity has stimulated investigations on the impact of specific herbicides on early pine seedling development.

Studies using potted seedlings and various watering regimes have demonstrated a strong positive correlation between soil moisture and growth of loblolly pine (Wenger, 1952; Zahner, 1962). Likewise, field studies by Stransky (1961) and Koshi and Stephenson (1962), showed a positive relationship between growth and soil moisture when weeds were controlled. In addition, growth of loblolly pine seedlings was inversely related to herbaceous weed cover or biomass following weed control treatments (Nelson *et al.*, 1981). Depending on the site, percentage of herbaceous cover seven weeks after herbicide treatment explained 43 to 81% of the variation in first-year height growth of loblolly pine. In another study of low, medium, or high levels of herbaceous control, first-year pine growth was most likely correlated to soil moisture level in late August, when soil moisture was lowest (Zutter *et al.*, 1986). From a summary of studies in herbaceous competition in 16 plantations largely in Alabama, researchers showed first, competition control had a significant positive effect on height and diameter at all 16 locations, and on survival or density when competition was intense. Second, a second year of herbaceous vegetation control led to significant additional gains in height and diameter at six and seven of 10 locations, respectively. And third, application technique did not significantly influence survival, or growth in height and groundline diameter (Creighton *et al.*, 1987). Increased growth in these studies was presumably due to increased soil moisture, nutrient availability and light availability as a result of removing competing herbs.

Much of the research in the South on herbaceous competitors has focused on traditional Coastal Plain sites and its competitors. Problem competitors often associated with poor soil drainage and non-timbered sites need to be examined and justifies the establishment of this study.

## OBJECTIVES

The objectives of this study were to compare (1) the efficacy of selected herbicides on herbaceous competitors found on newly planted pine sites and (2) the growth response of newly planted pine seedlings to release from these competitors.

## METHODS

Three sites were included in this study. Locations one and two were in a pasture near Alleene, AR. Location one supported mixed grasses (*Digitaria* spp., *Panicum* spp., *Croton* sp., *Carex* spp., and *Festuca* sp.) while location two had a dense bermudagrass (*Cynodon dactylon*) sod. These sites were machine planted in February 1986. Location three was near Fouke, AR. It was prepared by shearing, windrowing and bedding prior to hand planting in February 1986. The bedding was completed in November 1985.

Seedling buds and bermudagrass were evaluated for dormancy prior to the application of early (March 20) and late (April 22) treatments. On March 20, Fouke seedlings received early treatments of herbicides and were evaluated as 10% flushed, 20% swollen, and 70% dormant. At Alleene, locations one and two were given the same assessment: 10% flushed, 50% swollen, and 40% dormant. On July 2, Fouke seedlings were released with late treatments of herbicides and assessed as 100% flushed. At Alleene, late treatments were applied on April 22 and seedling buds assessed as 90% flushed, 5% swollen and 5% dormant. Bermudagrass was absent at Fouke and 10% green at Alleene.

Herbicides (Tables 1 and 2) were applied over-the-top in 1-meter bands centered over seedlings. No effort was made to protect seedlings from contact with herbicides. Herbaceous biomass was collected from a 1-meter square in each check plot at all sites. Samples were taken 30, 60, 90 and 120 days after treatment (DAT).

Percent reduction of herbaceous competition as compared to check plots was evaluated in 10% intervals for each plot. Evaluations were performed 30, 60, 90 and 120 DAT.

Table 1. Herbicides tested.

Trade Name	Common Name	Registered Trademark
Escort	metasulfuron methyl	E. I. du Pont de Nemours & Company
Fusilade	fluzifop	ICI Americas Inc.
Oust	sulfometuron methyl	E. I. du Pont de Nemours & Company
Poast	sethoxydim	BASF Wyandotte Corporation
Roundup	glyphosate	Monsanto Chemical Company
Velpar-L	hexazinone	E. I. du Pont de Nemours & Company

Table 2. Mean percent control of herbaceous competitors.

Time <sup>1</sup>	Treatment (kg/ha a.i.)	Days After Treatment			
		30	60	90	120
----(% herbaceous control)----					
Alleene (Mixed Grasses)					
E	0.15 Sulf <sup>2</sup>	93 B <sup>3</sup>	92AB	70 BCD	55 BC
E	0.28 Sulf	93 B	96A	86AB	77A
E	0.84 Hex+0.15 Sulf	99A	97A	87AB	75A
E	0.56 Hex+0.28 Sulf	99A	99A	95A	85A
E	0.56 Gly+0.15 Sulf	99A	95A	83ABC	68AB
E	0.43 Gly+0.28 Sulf	99A	99A	92A	83A
L	0.43 Flu+0.15 Sulf	93 B	68 C	58 D	50 C
L	0.43 Flu+0.28 Sulf	97A	80 BC	66 CD	50 C
L	0.56 Seth+0.28 Sulf	99A	95A	83ABC	78A
L	0.07 Met	30 C	23 D	15 E	10 D
Alleene (Bermudagrass)					
E	0.15 Sulf	97 B	85ABC	55 C	45 D
E	0.28 Sulf	99A	92AB	78AB	60 BC
E	0.84 Hex+0.15 Sulf	99A	90AB	82A	68ABC
E	0.56 Hex+0.28 Sulf	99A	90AB	85A	73AB
E	0.56 Gly+0.15 Sulf	99A	85ABC	63 BC	55 CD
E	0.43 Gly+0.28 Sulf	99A	90AB	80AB	68ABC
L	0.43 Flu+0.15 Sulf	90 C	83 BC	63 BC	63 BC
L	0.43 Flu+0.28 Sulf	90 C	95A	80AB	80A
L	0.56 Seth+0.15 Sulf	90 C	78 C	75AB	68ABC
L	0.56 Seth+0.28 Sulf	90 C	93A	75AB	75AB
Fouke (Wet Site Grasses)					
E	0.15 Sulf <sup>2</sup>	99A <sup>3</sup>	99A	99A	99A
E	0.28 Sulf	99A	99A	99A	99A
E	0.56 Gly+0.15 Sulf	99A	99A	99A	99A
E	0.43 Gly+0.28 Sulf	99A	99A	99A	99A
E	0.56 Hex+0.28 Sulf	99A	100A	99A	99A
E	0.84 Hex+0.15 Sulf	99A	98A	90A	74 B
L	0.84 Hex+0.15 Sulf	99A	99A	90A	90A
L	0.56 Hex+0.15 Sulf	97A	92A	99A	99A
L	1.00 Hex+0.15 Sulf	97A	99A	99A	90A
L	1.00 Hex+0.07 Met	50 B	50 B	50 B	30 C

<sup>1</sup> E=early; L=late;

<sup>2</sup> Sulf=sulfometuron methyl; Met=metsulfuron methyl; Gly=glyphosate; Hex=hexazinone;

<sup>3</sup> Treatment means having the same letter within the column are not significantly different at the 0.05 level (Duncan's Multiple Range test).

Heights and groundline diameters were recorded immediately after planting and in late October 1986 and December 1987. Seedling survival was expressed in percent, height in centimeters, and groundline diameter in millimeters.

The study layout was a randomized complete block design with four blocks. Each block contained 11 one-row plots with 10 seedlings per row.

Data were evaluated using analyses of covariance with initial seedling size as the covariate. Duncan's Multiple Range test was used to separate means. All statistical tests were conducted at the 0.05 level of confidence.

## RESULTS AND DISCUSSION

### Efficacy

Overall control of herbaceous competitors was good at all sites (Table 2). Treatments with 0.15 kg/ha of sulfometuron methyl alone or in mixture generally exhibited less control than the 0.28 kg/ha rate approximately 90 DAT. This suggests that the low rate of sulfometuron methyl was possibly too light and that an intermediate rate may provide grass control similar to the high rate at a lower cost. Mixtures containing sulfometuron methyl showed little additional control above that observed for sulfometuron methyl alone. On mixed grasses, metsulfuron methyl gave narrow spectrum weed control. At Fouke, hexazinone + metsulfuron methyl proved the least effective.

At 60 to 90 DAT, bermudagrass had invaded plots from the sides regardless of timing, rate, or herbicide. Future tests on bermudagrass should include fall applications prior to spring planting, over-the-top

Table 3. Mean percent control of herbaceous competitors.

Time	Days After Treatment	Days After Treatment			
		30	60	90	120
----(% herbaceous control)----					
Alleene (Mixed Grasses)					
Early		97A <sup>1</sup>	96A	86A	74A
Late		80 B	67 B	56 B	47 B
Alleene (Bermudagrass)					
Early		99A	89A	74A	62 B
Late		90 B	87A	73A	72A
Fouke (Wet Site Grasses)					
Early		99A	99A	99A	95A
Late		86 B	85 B	85 B	77 B

<sup>1</sup> Treatment means having the same letter within the column are not significantly different at the 0.05 level (Duncan's Multiple Range test).

<sup>2</sup> Without metsulfuron methyl 30, 60, 90, and 120 day means are: 96%, 81%, 69%, and 59%, respectively.

Table 4. Trends in herbaceous biomass (kg/ha) on untreated plots.

Location	May	June	July	August	September
Mixed Grasses	209	901	1181	1721	1841
Bermuda-grass	177	708	1214	2345	2856
Wet Site Grasses	71	131	289	791	741

applications with a wider band (1.7 meters), or multiple applications of herbicide. At 120 DAT herbs were re-established in all plots at all sites.

Early applications were more effective than late ones (Table 3). This may be related to differences in competitor biomass levels at application (Zutter *et al.*, 1986) in which case lower rates may be used if herbicides are applied early (Table 4).

### Seedling Response

First- and second-year survival and growth were greater at Alleene than Fouke (Table 5). This probably occurred for two reasons. First, levels of herbaceous biomass were higher at Alleene than Fouke, and thus the release was greater (Table 4). Land managers should consider site conditions, the density of herbaceous competitors and the type and timing of site preparation before recommending additional competitor control. Avoid blanket recommendations. Second, Fouke was poorly drained with water standing between beds through June. During this same period, Alleene was well drained. Excessive moisture is known to inhibit seedling development (Patrick, 1977; Stone, 1977).

Based on survival, height and groundline diameter, treatment of mixed grasses with sulfometuron methyl, hexazinone + sulfometuron methyl and sethoxydim + sulfometuron methyl were the most effective treatments (Table 5). These treatments provided first-year responses averaging 17% more survival, 59% more height, and 235% more groundline diameter. Glyphosate treatments resulted in 17% less survival, 49% less height and 6% more groundline diameter than check seedlings.

For bermudagrass control, similar and best survival and growth in height and groundline diameter were recorded on sulfometuron methyl and sethoxydim + sulfometuron methyl treated plots (Table 5). These treatments provided first-year responses averaging 6% more survival, 61% more height growth, and 210% more groundline diameter than check seedlings. During this same period, glyphosate + sulfometuron

## Survival and Growth Two Years After Control of Herbaceous Competitors in Newly Planted Seedlings of Loblolly Pine

Table 5. Mean survival (SUR), total height (HT) and groundline diameter (GLD) after one (86) and two (87) growing seasons.

Time <sup>1</sup>	Herbicide (kg/ha)	SUR (%)		HT (CM)		GLD (MM)	
		86	87	86	87	86	87
-----Alleene (Mixed Grasses)-----							
L	0.43 Flu+0.15 Sulf <sup>2</sup>	98A <sup>3</sup>	93A	36AB	83 BC	7 B	17 C
L	0.43 Flu+0.28 Sulf	95A	93A	39AB	105A	7AB	21ABC
L	0.56 Seth+0.28 Sulf	95A	88A	42A	109A	8A	22AB
L	0.07 Met	93AB	85AB	32 BC	95AB	5 C	19 BC
E	0.15 Sulf	98A	98A	41A	116A	7AB	24AB
E	0.28 Sulf	97A	95A	42A	116A	8A	25A
E	0.84 Hex+0.15 Sulf	95A	88A	40A	113A	8AB	22ABC
E	0.56 Hex+0.28 Sulf	90AB	90A	36AB	95AB	7AB	22ABC
	Check	78 BC	70 BC	26 C	67 C	4 D	12 D
E	0.56 Gly+0.15 Sulf	68 C	57 C	12 D	45 D	3 D	9 D
E	0.43 Gly+0.28 Sulf	63 D	57 C	12 D	42 D	4 D	8 D
-----Alleene (Bermudagrass)-----							
L	0.56 Seth+0.28 Sulf	100A	100A	47ABC	139A	9A	28AB
L	0.56 Seth+0.15 Sulf	97A	95A	42 CD	121 BC	8 BC	25 C
L	0.43 Flu+0.15 Sulf	100A	100A	43 BCD	131AB	9 BC	28AB
L	0.43 Flu+0.28 Sulf	100A	100A	44 BCD	121 BC	8 BC	25 BC
E	0.15 Sulf	98A	97A	49AB	137AB	9AB	28AB
E	0.28 Sulf	97A	97A	51A	144A	10A	30A
E	0.56 Hex+0.28 Sulf	98A	98A	37 D	111 C	8 C	22 C
E	0.84 Hex+0.15 Sulf	95A	98A	41 CD	133AB	8 BC	28AB
	Check	92A	89A	30 E	94 D	5 D	17 D
E	0.43 Gly+0.28 Sulf	53 B	50 B	11	G 42	E 4 D	7 E
E	0.56 Gly+0.15 Sulf	49 B	21 C	19	F 22	F 3	E 4 E
-----Fouke (Wet Site Grasses)-----							
E	0.15 Sulf	98A	97A	37AB	82AB	10ABC	22AB
E	0.28 Sulf	87A	90A	30 BC	57 C	8 BCDE	14 D
E	0.56 Gly+0.15 Sulf	98A	97A	36AB	84AB	9ABCD	19 BCD
E	0.43 Gly+0.28 Sulf	97A	97A	37AB	84AB	10AB	21ABC
E	0.56 Hex+0.28 Sulf	93A	90A	34ABC	71ABC	10ABC	20 BCD
E	0.84 Hex+0.15 Sulf	90A	90A	39A	68ABC	10ABC	20ABC
L	0.84 Hex+0.15 Sulf	93A	93A	39A	88A	11A	25A
L	1.00 Hex+0.07 Met	90A	88A	35ABC	74ABC	8 CDE	17 BCD
L	0.56 Hex+0.15 Sulf	88A	85AB	35ABC	85A	9 BCDE	21ABC
	Check	87A	87AB	32ABC	71ABC	7 DE	13 D
L	1.00 Hex+0.15 Sulf	70 B	70 B	27 C	62 BC	7 E	16 CD

<sup>1</sup> E=early; L=late;

<sup>2</sup> Sulf=sulfometuron methyl; Met=metsulfuron methyl; Gly=glyphosate;

<sup>3</sup> Hex=hexazinone;

<sup>4</sup> Treatment means within a column sharing the same letter are not significantly different at the 0.05 level (Duncan's Multiple Range test).

methyl treatments exhibited 41% less survival, 22% less height, and 34% less groundline diameter than untreated checks.

At Fouke, similar and best survival and growth occurred with sulfometuron methyl, hexazinone + sulfometuron methyl, and glyphosate + sulfometuron methyl (Table 5). These treatments provided first-year responses over that of check seedlings by 5% for survival, 29% for height, and 68% for groundline diameter.

Second-year mortality was less than 2% for check and non-glyphosate plots at all locations. In glyphosate treated plots, second-year mortality averaged 9%, 16% and 0% in the studies of mixed, bermuda-grass and wet site grasses, respectively. Data showed a two-year growth response to herbaceous control. The magnitude of the first-year response was greater than for the second year. Reduced growth was apparent on glyphosate treated plots after two growing seasons.

Treatment time was contrasted for effect on survival and growth (Table 6). Differences were detected but when mixtures of glyphosate + sulfometuron methyl were not considered, early and late applications provided similar responses with differences among treated and untreated plots. Similar seedling survival and growth on plots receiving early (March 20) and late (April 20) treatments indicates that (1) practitioners can integrate herbaceous control with tree planting and controlled burning as weather and other duties permit, and (2) applicators can locate and release seedlings prior to and during emergence of herbs while seedlings are easy to see. Thus, land managers can capitalize on the pre-emergence and postemergence attributes of herbicides for safe and reliable control.

These results show that complete weed control does not always correlate with seedling performance. The low rate of sulfometuron methyl provided intermediate competitor control but was among treatments with the best seedling survival and growth. Metsulfuron methyl provided the worst control of mixed grasses and above average seedling survival and growth. This suggests that total control may not be needed for optimal seedling growth. Additional work is needed to determine the level of control needed for optimal seedling performance and cost effective treatments. Second, physiologically active seedlings should not be treated with mixtures of glyphosate. That is, pine tolerance can not be sacrificed to gain additional control for subsequent growth. Third, several mixtures and rates of herbicides are available for control of selected herbaceous competitors. Therefore, land managers can select herbicides based on availability, cost and the specific competitors to be controlled. Fourth, sulfometuron methyl alone or mixed with hexazinone provided best seedling response at all three sites. Fifth, a two-year increase in survival and growth can be used to justify treatment cost. Sixth, March through April applications provided similar seedling responses giving land managers an opportunity to integrate herbaceous vegetation control with other land management practices.

## ACKNOWLEDGEMENTS

The contributions of Nekoosa Papers Inc., plus E. I. du Pont de Nemours & Co. and Monsanto Company, made this study possible.

## LITERATURE CITED

- CREIGHTON, J. L., G. R. GLOVER, and B. R. ZUTTER. 1986. Loblolly pine growth response to herbaceous weed control — a summary of 15 studies. Proc. South. Weed Sci. Soc. 39:193.
- KOSHI, P. T. and G. K. STEPHENSON. 1962. Shade and mulch as influences on loblolly pine seedlings and their immediate environment. For. Sci. 8:191-204.
- NELSON, L. R., R. C. PEDERSEN, L. L. AUTRY, S. DUDLEY and J. D. WALSTAD. 1981. Impacts of herbaceous weeds in loblolly pine plantations. South. J. Appl. For. 5(3):153-158.
- PATRICK, W. H. 1977. Chemistry of flooded soil and effects on mineral nutrition. Pp. 40-48, in: W. E. Balmer, ed. Proc. Soil Moisture...Site Productivity Symposium. 400 pp.
- STONE, E. L. 1977. A critique of soil moisture-site productivity relationships. Pp. 377-387, in: W. E. Balmer, ed. Proc. Soil Moisture...Site Productivity Symposium. 400 pp.
- STRANSKY, J. J. 1961. Weed control, soil moisture, and loblolly pine seedling behavior. J. For. 59:282-284, 289-290.
- WENGER, K. F. 1952. Effect of moisture supply and soil texture on the growth of sweetgum and pine seedlings. J. For. 50:862-864.
- ZAHNER, R. 1962. Terminal growth and wood formation by juvenile loblolly pine under two soil moisture regimes. For. Sci. 8:345-352.
- ZUTTER, B. R., G. R. GLOVER and D. H. GJERSTAD. 1986. Effects of herbaceous weed control using herbicides on a young loblolly pine plantation. For. Sci. 32:(4)882-899.



# CONTROL OF HERBACEOUS COMPETITORS IN PROGENY TESTS USING CONTAINER-GROWN SEEDLINGS

J. L. YEISER

Department of Forest Resources  
University of Arkansas at Monticello  
Monticello, AR 71655

J. W. BOYD

Arkansas Cooperative Extension Service  
Little Rock, AR 72203

D. J. REED

Department of Forest Resources  
University of Arkansas at Monticello  
Monticello, AR 71655

## ABSTRACT

Container-grown and May-planted seedlings of loblolly and shortleaf pines were treated with herbicides for control of herbaceous competitors. Weed control and seedling growth were evaluated. Competitor control was good for all treatments. Survival and growth of pines differed by species and herbicide treatment. The best treatment for both species included covering seedlings and spraying competitors with glyphosate. Both species showed decreased survival and growth when treated with medium and high rates of hexazinone + sulfometuron methyl.

## INTRODUCTION

Studies have reported herbicide tolerance and performance of loblolly pine (*Pinus taeda* L.) seedlings released from herbaceous competition with various herbicides including sulfometuron methyl, glyphosate, hexazinone, atrazine and imazapyr. Zutter (1984) showed that weed control resulted in greater height and diameter growth of loblolly pine, with trees receiving weed control for two years showing the most improvement. Barber *et al.* (1984) reported that imazapyr and sulfometuron methyl may cause stunting of loblolly pine. Sulfometuron methyl was found to be the most consistently effective herbicide in another study (Nelson and Metcalfe, 1983). Hexazinone caused greater pine mortality on sites with coarser soil texture when used for pine release (Minogue *et al.*, 1984). Increases in early height growth were attributed to herbaceous weed control. Similar information on the performance of seedlings of shortleaf pine (*P. echinata* Mill.) is lacking. All of the above herbicides are labeled for use in herbaceous weed control in forestry in the South (Anonymous 1988).

Most studies of herbaceous competition control have addressed operational plantings of bare-root seedlings. Many of the companies expected to apply this information also participate in tree breeding programs and need similar information for container-grown seedlings used in progeny tests. Progeny tests are used to determine the efficacy of selected matings in a tree breeding program, and are maintained in a relatively artificial environment compared to operational plantings (van Buijtenen and Lowe, 1982). Such plots usually receive broadcast weed control. Progeny tests represent a substantial investment of time and money to the company, and are usually maintained at all costs.

Container-grown seedlings differ from bare-root seedlings in that they may be less than six months old, and no dormant period is experienced prior to outplanting. Seedlings are vigorous, often with little woody tissue, and are actively growing when planted in late spring after danger of frost is past. Bare-root seedlings are nearly one year old and are dormant when lifted from the nursery bed prior to planting during the winter months.

Planting methods also differ between bare-root and container-grown stock. Ordinarily, bare-root seedlings are planted by hand using a dibble with a 10 inch long spade, which often places the root collar of these seedlings several inches below ground. Container-grown seedlings have more uniform root development, and are planted using tools designed for such seedlings. While this places the tree at the appropriate position in the substrate, it also places its roots in a more vulnerable location when soil-active herbicides are applied.

The limited information on the response of shortleaf pine and container-grown seedlings to herbicide treatments and control of herbaceous competitors justifies the establishment of this study. The study objectives are: 1) to contrast the efficacy of herbicides, and 2) to compare the survival and growth of container-grown seedlings of loblolly and shortleaf pines when released from herbaceous competitors using herbicides.

## MATERIALS AND METHODS

The study is near Batesville in Independence County, which is physiographically in the Ozark Highlands of northern Arkansas. The soil is a sandy loam with 62 percent sand, 34.5 percent silt, 2 percent clay and 1.5 percent organic matter.

Christmas trees were removed from the site in 1985 leaving a dense sod supporting major proportions of broomsedge (*Andropogon* spp.), sedges (*Carex* spp.), and panicgrass (*Panicum* spp.), with lesser proportions of crabgrass (*Digitaria* spp.), bermudagrass (*Cynodon* spp.), blackberry (*Rubus* spp.), greenbriar (*Smilax* spp.), and sumac (*Rhus* spp.).

In mid-September, 1986, 3.2 kg/ha glyphosate was broadcast over the entire study. In November, seeds from loblolly and shortleaf pines were sown in styroblocks® (No. 8) and the seedlings were grown in a greenhouse. Two weeks before outplanting, seedlings moved outside to become acclimated. Actively growing seedlings were outplanted on May 6, 1987 on a 1.2 x 2.4 M spacing. The fall application of glyphosate plus droughty conditions over the previous year contributed to minimal early May herbaceous competition. Approximately 1.9 cm of precipitation fell shortly before and on the day of planting.

Treatments were applied in 0.9 m bands centered on seedlings. Each herbicidal treatment was mixed with water until the total volume was 93.5 l/ha. Treatments were applied in late May following 2.54 cm of postplanting precipitation. Seedlings were visible and herbaceous competitors abundant at treatment. The glyphosate treatment was scheduled as a preplant application, but lack of herbaceous vegetation resulted in delaying application until late May with the other treatments. Treatments tested are presented in Table 1.

Reduction of herbaceous competition was expressed to the nearest 5% class by visual estimation at 30 and 60 days after treatment. Following the 60-day evaluation, seedlings were covered and glyphosate (3.2 kg/ha) applied to all non-check plots in a 0.9 m band to control the regrowth of *Rhus* and *Cynodon* spp.



Control of Herbaceous Competitors in Progeny Tests Using Container-Grown Seedlings

Seedling heights (cm) and groundline diameters (mm) were recorded on planting day and again in November 1987. Seedlings were also assessed in July for mortality.

The study was a randomized block design with three blocks. Each block contained 20 one-row plots with 20 seedlings per plot. Data were evaluated using analyses of covariance (P=0.05) with initial height or initial groundline diameter as covariates. Duncan's Multiple Range test was used to contrast means (P=0.05).

RESULTS AND DISCUSSION

The fall application of glyphosate was effective. The composition of September 1986 and May 1987 herbaceous competitors was similar, although many May competitors were new germinants. This probably contributed to the very effective and similar efficacy observed at the 30- and 60-day evaluations (Table 1). New germinants of *Andropogon* spp. were controlled by imazapyr and mixtures of hexazinone. The

Table 1. Herbicide treatments and efficacy.

Treatment	kg ai/ha	Days After Treatment	
		30	60
glyphosate <sup>1</sup>	2.52	100 A <sup>3</sup>	97 AB
H <sup>2</sup> -hexazinone+sulfometuron methyl	0.84+0.16	98 AB	98 A
M-hexazinone+sulfometuron methyl	0.56+0.16	96 ABC	95 ABC
L-hexazinone+sulfometuron methyl	0.28+0.16	95 ABC	93 ABCD
H-imazapyr	0.34	93 BCD	93 ABCD
L-imazapyr	0.17	89 CD	87 CD
sulfometuron methyl	0.16	89 CD	87 CD
H-atrazine+sulfometuron methyl	2.24+0.10	93 BCD	85 D
L-atrazine+sulfometuron methyl	1.12+0.10	92 BCD	88 BCD
Check		-	-

<sup>1</sup> Only treatment with seedlings covered during the application of herbicide.  
<sup>2</sup> L=low; M=medium; H=high.  
<sup>3</sup> Means within a column sharing the same letter are not significantly different (Duncan's Multiple Range test).

Table 2. Mean seedling response to herbicide treatment.

Treatment	Height	Groundline Diameter	Survival
	cm	mm	%
glyphosate <sup>1</sup>	14.5 AB <sup>2</sup>	2.8 A	70.0 A
H <sup>3</sup> -hexazinone+sulfometuron methyl	6.2 D	1.2 D	28.3 C
M-hexazinone+sulfometuron methyl	6.1 D	1.2 D	30.0 C
L-hexazinone+sulfometuron methyl	12.4 ABC	2.6 AB	55.8 B
H-imazapyr	11.0 C	2.6 AB	68.3 A
L-imazapyr	12.3 ABC	2.4 AB	73.3 A
sulfometuron methyl	13.6 ABC	2.8 A	69.2 A
H-atrazine+sulfometuron methyl	11.7 BC	2.0 C	53.3 B
L-atrazine+sulfometuron methyl	15.2 A	3.0 A	70.8 A
Check	13.5 ABC	1.8 C	65.0 A

<sup>1</sup> Only treatment with seedlings covered during the application of herbicide.  
<sup>2</sup> Means within a column sharing the same letter are not significantly different (Duncan's Multiple Range test).  
<sup>3</sup> L=low; M=medium; H=high.

Table 3. Response of container-grown, loblolly (Lob) and shortleaf (Shlf) pine seedlings to treatments of herbicides for herbaceous control.

Treatment	Height		Groundline Diameter		Survival	
	Lob	Shlf	Lob	Shlf	Lob	Shlf
L <sup>1</sup> -atrazine+sulfometuron methyl	18.1 A <sup>3</sup>	12.2 AB*	3.8 A	2.2 A*	80.0 A	61.7 B*
sulfometuron methyl	16.6 A	10.7 B*	3.6 A	2.0 A*	80.0 A	58.3 B*
H <sup>1</sup> -imazapyr	15.3 AB	6.8 CD*	3.1 AB	2.1 A	75.0 AB	61.7 B
Check	14.9 AB	12.0 AB	2.1 CD	1.6 A	70.0 AB	60.0 B
L-imazapyr <sup>2</sup>	14.7 AB	10.0 BC*	2.6 BCD	2.1 A	75.0 AB	71.7 AB
glyphosate	14.0 ABC	15.1 A	3.2 AB	2.4 A	58.3 BC	81.7 A*
L-hexazinone+sulfometuron methyl	14.0 ABC	10.8 B	2.8 ABC	2.3 A	56.7 BC	55.0 B
H-atrazine+sulfometuron methyl	11.6 BCD	11.9 AB	2.0 CD	2.0 A	50.0 C	56.7 B
H-hexazinone+sulfometuron methyl	9.8 CD	2.7 E*	1.9 CD	0.6 B*	41.3 C	13.3 C*
M-hexazinone+sulfometuron methyl	8.7 D	3.6 DE*	1.8 D	0.5 B*	41.7 C	18.3 C*
Species Mean	13.7A <sup>4</sup>	9.6 B	2.7 A	1.8 B	63.0 A	53.8 B

<sup>1</sup> L=Low; M=Medium; H=High.  
<sup>2</sup> Only treatment with seedlings covered during the application of herbicide.  
<sup>3</sup> Means within a column sharing the same letter are not significantly different (Duncan's Multiple Range test).  
<sup>4</sup> Species means within a row sharing the same letter are not significantly different (Duncan's Multiple Range test).  
 \* The loblolly versus shortleaf contrast is significant (Duncan's Multiple Range test).

July reapplication of glyphosate to treatment plots resulted in nearly total control of herbaceous competitors throughout the summer.

Seedling mortality in late July was not significantly different from that recorded in November; thus November values are presented (Table 2). Greatest survival was observed on imazapyr, check, sulfometuron methyl, glyphosate, and atrazine (low) plus sulfometuron methyl treated plots. Mixtures of hexazinone (low) or atrazine (high) with sulfometuron methyl were similar with intermediate survival while medium and high levels of hexazinone plus sulfometuron methyl were similar with the least survival. Mortality on atrazine (high) or hexazinone plus sulfometuron methyl treated plots was greater than for untreated check plots and was unacceptable.

For treatments with acceptable survival, similar and best growth was observed on plots treated with imazapyr (low), sulfometuron methyl, glyphosate (covered seedlings), and atrazine (low) mixed with sulfometuron methyl (Table 1).

Survival and growth of loblolly and shortleaf pine seedlings varied by herbicide treatment (Table 3). Seedlings of loblolly pine exhibited better survival and growth than those of shortleaf pine (Table 3). Acceptable shortleaf pine survival occurred on plots treated with imazapyr (low) and glyphosate (covered seedlings). Seedlings of shortleaf pine showed lower survival and growth than loblolly pine seedlings when plots were treated with medium and high hexazinone mixtures with sulfometuron methyl, sulfometuron methyl (alone), and atrazine (low) mixed with sulfometuron methyl. Shortleaf pine height growth was also less than loblolly on imazapyr treated plots. Data suggest seedlings of shortleaf pine may be more sensitive to herbicides than seedlings of loblolly pine.

Greatest survival and growth of loblolly pine seedlings occurred on plots treated with atrazine (low) + sulfometuron methyl, sulfometuron methyl (alone), and imazapyr (high). The best treatment for both species was covering seedlings and spraying plots with glyphosate. Worst growth and survival for loblolly and shortleaf seedlings occurred with treatments containing medium to high rates of hexazinone.

#### ACKNOWLEDGEMENTS

The contributions of the Arkansas Forestry Commission, plus E. I. du Pont de Nemours & Co., Monsanto Company, and American Cyanamid Company made this study possible.

#### LITERATURE CITED

- ANONYMOUS. 1988. Auburn University Silvicultural Herbicide Cooperative 1987 Annual Report. Alabama Agricultural Experiment Station, School of Forestry. 42 pp.
- BARBER, B., L. R. NELSON, and C. S. METCALFE. 1984. Herbaceous weed control in newly planted loblolly pine plantations using Oust and Arsenal: 1983 results. Auburn Univ. Silvicultural Herbicide Cooperative Research Note No. 84-2. 4 pp.
- MINOGUE, P. J., B. R. ZUTTER and D. H. GJERSTAD. 1984. Comparison of liquid and solid hexazinone formulations for pine release. Auburn Univ. Silvicultural Herbicide Cooperative Research Note No. 84-18. 9 pp.
- NELSON, L. R. and C. S. METCALFE. 1983. Herbaceous weed control in young pine plantations: 1982 herbicide trials. Auburn Univ. Silvicultural Herbicide Cooperative Research Note No. 83-5. 11 pp.
- VAN BUIJTENEN, J. P. and W. J. LOWE. 1982. Use of containerized seedlings for progeny testing. Pages 145-148 *In* R. W. Guldin and J. P. Barnett, eds, Proc. Southern Containerized Forest Tree Seedling Conference USDA Gen. Tech. Report SO-37.
- ZUTTER, B. R. 1984. 1984 herbaceous weed control growth response studies — first-year results. Auburn Univ. Silvicultural Herbicide Cooperative Research Note No. 85-11. 7 pp.

# GENERAL NOTES

## SPAWNING FREQUENCY AND FECUNDITY OF BLUE TILAPIA

Blue tilapia, *Tilapia aurea*, are becoming increasingly popular as commercial culture fish in Arkansas. Tilapia have a variety of aquaculture applications. They can be used to control rooted aquatic vegetation and filamentous algae, raised for sale as baitfish or to provide forage for channel catfish brood stock, largemouth bass or striped bass. In addition, polyculture of blue tilapia and channel catfish may result in a reduced incidence of off-flavor in channel catfish (Torrans and Lowell, Proc. Ark. Acad. Sci. 41:82-86, 1987).

Blue tilapia are also excellent food fish, however, the growing season in central Arkansas may be too short to grow them to market size in a single season (Torrans and Lowell, Proc. Annu. Conf. Southeast Assoc. Fish and Wildl. Agencies, 40:187-193, 1986). Early spawning of tilapia in a heated indoor hatchery may extend the growing season long enough to solve this problem. The purpose of this study was to determine the spawning frequency and fecundity of blue tilapia spawned in indoor facilities.

Twenty sexually mature pair of blue tilapia were placed in individual 36"-diameter circular tanks on July 15, 1982. The females ranged in weight from 22 g to 138 g and the males from 50 g to 178 g. The upper lip (maxillary and premaxillary bones) was surgically removed from the males prior to the study to reduce aggressive behavior toward the females. The fish were fed daily to satiation with a 32% protein floating feed.

The tanks were continuously supplied with outdoor pond water at ambient temperature, and the water temperature was monitored beginning the third week of the study with a recording thermometer. A 6" piece of 4" diameter PVC pipe was placed on the bottom of each tank to provide a refuge for the female. Spawning substrates, such as sand or gravel, were not added to the tanks.

The fish were examined at weekly intervals for 15 weeks. Females that had spawned and were mouthbrooding eggs were removed with a fine mesh dip net and weighed to the nearest gram. The eggs were removed from the buccal cavity for later counting, and the females were immediately returned to their respective tanks.

The 20 pair of tilapia spawned a total of 48 times during the study. Five females did not spawn, three spawned once, three spawned twice, three spawned three times, one spawned four times, four spawned five times, and one spawned six times. Twenty-three of the 33 repeat spawns came within two weeks of the previous spawn. There was not a significant correlation between female weight and spawning frequency ( $r = -0.25$ ,  $N = 20$ ), nor between the male/female weight ratios and spawning frequency ( $r = 0.15$ ,  $N = 20$ ).

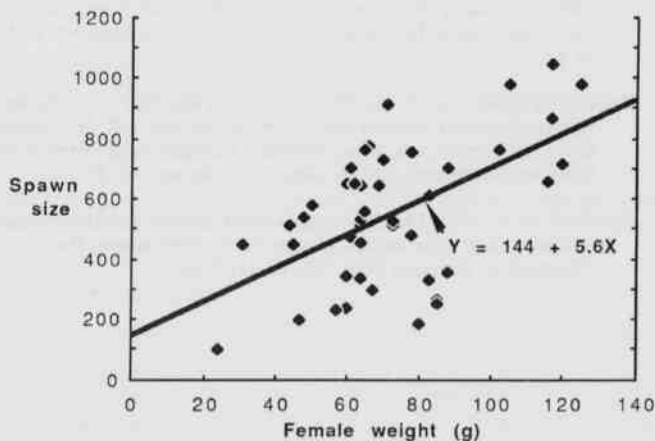


Figure 1. Spawn size (number of eggs) of female blue tilapia. The calculated regression line is shown.

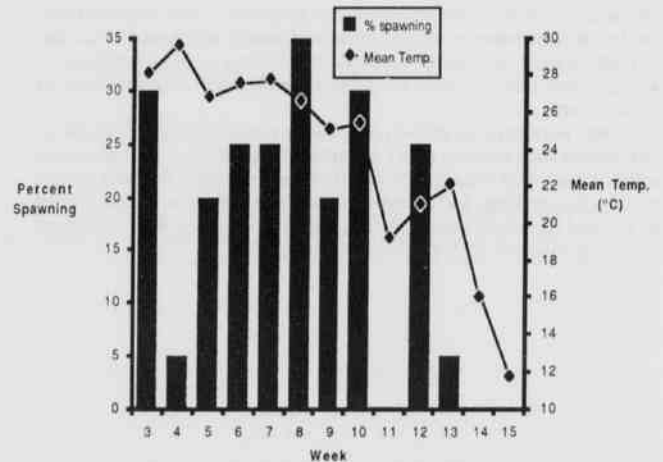


Figure 2. Percentage of 20 female tilapia spawning each week (solid bars) and the mean weekly water temperature (line). Data are not shown for weeks 1-2, since the temperature was not recorded during this period.

The spawns ranged in size from 97 eggs from a 24 g female, to 1042 eggs from a 117 g female (Figure 1). While there was a highly significant positive correlation between female weight and spawn size ( $r = 0.55$ ,  $P < 0.01$ ,  $N = 48$ ), there was considerable variation in the size of the spawns produced by individual females. One female, for example, produced consecutive spawns of 178 and 479 eggs. The reason for this variation is unknown. There was no clear tendency for successive spawns to be larger, nor was there a significant correlation between the spawn size and the time period since the last spawn.

Only one fish spawned during week 4 (Figure 2), when the highest temperature of the study was recorded (29.6°C). This may indicate an upper temperature threshold for spawning. Within the temperature range of 25°C to 28°C, 20% to 35% of the females spawned each week. Spawning ceased in late September and early October (weeks 11, 14 and 15) when the weekly water temperature averaged 19.4°C or less. The lowest weekly water temperature at which fish spawned during this study was 21.1°C. This was one degree lower than the lower temperature threshold previously determined for pond spawning in the spring, when the water temperature was rising (Torrans and Lowell, Ark. Farm Research, 34[1]:3, 1985).

Indoor production of tilapia fry is possible. Tilapia will spawn readily in confinement within the optimum temperature range of 25°C to 28°C. Female tilapia can spawn in intervals as short as two weeks if they are not allowed to incubate the eggs. Eleven kg (twenty-five pounds) of female tilapia could produce over 20,000 fry per week on a continuing basis, assuming a 25% weekly spawning rate. The spawning rate, and thus total weekly egg production, could be increased if non-spawning females were identified and replaced.

This research was supported by USDA CSRS Project ARX 1108, and is published with the approval of the Director, Arkansas Agricultural Experiment Station.

THOMAS J. AURELI, Arkansas Power and Light Company, 9005 Penrose Lane, Little Rock, AR 72205, and LES TORRANS, Department of Agriculture, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

## General Notes

## EQUATIONS OF VARIATION FOR ORDINARY DIFFERENTIAL EQUATIONS ON MANIFOLDS

For systems of ordinary differential equations in  $R^n$  (real Euclidean space of dimension  $n$ ), it is well known that derivatives of solutions with respect to the initial time, initial position and parameters satisfy certain variational equations. However, for systems of ordinary differential equations on manifolds, only the variational equations for the derivatives of solutions with respect to the initial position seem to have appeared in print (Sternberg, Lectures on Differential Geometry, p. 184, 1964). In this paper, we will derive equations of variation for systems on manifolds. Our methods are different from those employed in the above reference and since no extra effort is involved, all three types will be deduced.

For definitions and properties concerning differentiable manifolds, we refer the reader to (Brickell and Clark, Differentiable Manifolds, 1970). If  $f: E_1 \rightarrow E_2$  and  $g: H_1 \rightarrow H_2$  are maps, then  $f \times g$  will denote the mapping from  $E_1 \times H_1$  into  $E_2 \times H_2$  defined by

$$f \times g(x, y) = (f(x), g(y)).$$

Let  $M$  and  $N$  be  $C^\infty$  manifolds of dimensions  $m$  and  $n$  respectively and denote the real numbers by  $R$ . We suppose that  $X$  is a map with domain (denoted by  $\text{dom}(X)$ ) an open subset of  $R \times M \times N$  and range a subset of the tangent bundle of  $M$ . We assume further that  $X$  is  $C^\infty$  and that if  $(t, p, q)$  is in  $\text{dom}(X)$ , then  $X(t, p, q)$  is an element of the tangent space to  $M$  at  $p$ . Stated in a different manner,  $X$  is a time dependent vector field that also depends on parameters  $q$  in  $N$ .

We consider the initial value problem

$$(IV) \quad \dot{c}(t) = X(t, c(t), q), \quad c(t_0) = p.$$

For each  $(t_0, p, q)$  in  $\text{dom}(X)$ , it is known (Brickell and Clark, Differentiable Manifolds, p. 136, 1970) that the unique solution of (IV) corresponding to  $(t_0, p, q)$  is defined in an open interval of  $R$ . We will denote the value of this solution at  $t$  by  $c(t; t_0, p, q)$ . It follows that a function may be defined with domain an open subset of  $R \times R \times M \times N$  by  $C(t, t_0, p, q) = c(t; t_0, p, q)$ .

Let  $(t_0, p, q)$  be in  $\text{dom}(X)$  and suppose  $u: U \rightarrow R^m$  and  $v: V \rightarrow R^n$  are charts at  $p$  and  $q$  respectively. Denote identity maps by  $\text{id}$ . In each case, the domain of a particular  $\text{id}$  will be clear from the context in which it is used. We note that  $\text{id} \times u \times v: R \times U \times V \rightarrow R \times R^m \times R^n$  is a chart for the product manifold  $R \times M \times N$ .

Assume that  $c: I \rightarrow M$  is a solution of (IV) defined on an open interval  $I$  of  $R$ . Let  $J$  be the largest open interval such that  $t_0$  is in  $J$  and  $J$  is contained in  $I \cap c^{-1}(U)$ . Then  $t$  in  $J$  implies  $(t, c(t), q)$  is in  $\text{dom}(X)$  ( $J \times U \times V$ ).

For each  $j = 1, \dots, m$ , let  $u_j$  be the  $j$ th coordinate function of  $u$  and let  $X(u_j)$  be the value of the vector field,  $X$ , at  $u_j$ . Also, define  $f_j$  by

$$(1) \quad f_j = X(u_j) \circ (\text{id} \times u^{-1} \times v^{-1}) = X(u_j) \circ (\text{id} \times u \times v)^{-1}$$

and set  $f = (f_1, \dots, f_m)$ .

Arguments similar to those given in (Brickell and Clark, Differentiable Manifolds, p. 131, 1970) establish that  $c: I \rightarrow M$  is a solution of (IV) if and only if  $u \circ c$ , restricted to  $J$ , is a solution of

$$IV') \quad x'(t) = f(t, z(t), v(q)), \quad z(t_0) = u(p).$$

Denote the value of this solution at  $t$  by  $z(t; t_0, u(p), v(q))$ . Also, for elements  $(t_0, u(p), v(q))$  in  $\text{dom}(f)$ , one may define a function  $Z$  on an open subset of  $R \times R \times u(U) \times v(V) \subset R \times R \times R^m \times R^n$  by  $Z(t, t_0, u(p), v(q)) = z(t; t_0, u(p), v(q))$ . It follows from the preceding discussion that

$$(2) \quad \begin{aligned} Z(t, t_0, u(p), v(q)) &= z(t; t_0, u(p), v(q)) \\ &= u(c(t); t_0, p, q) \\ &= u(C(t, t_0, p, q)) \\ &= [u \circ C \circ (\text{id} \times \text{id} \times u^{-1} \times v^{-1})](t, t_0, u(p), v(q)). \end{aligned}$$

Thus,  $Z = u \circ C \circ (\text{id} \times \text{id} \times u^{-1} \times v^{-1})$ , and it follows that  $Z$  is  $C^\infty$ . Also,  $f$  is  $C^\infty$  because we assumed that  $X$  is  $C^\infty$ .

For the purpose of writing partial derivatives, we will denote the arguments of  $Z$  by  $(t, t_0, \xi, \eta)$  where  $\xi = (\xi_1, \dots, \xi_m)$  and  $\eta = (\eta_1, \dots, \eta_n)$ . It is well known (Reid, Ordinary Differential Equations, p. 70, 1971) that the first partial derivatives of  $Z$  with respect to  $t_0$ ,  $\xi_i$  and  $\eta_j$  satisfy certain variational equations. In the equations that follow, it is understood that the arguments of derivatives of the  $Z_i$  are  $(t, t_0, u(p), v(q))$  and the arguments of derivatives of the  $f_i$  are  $(t, Z(t, t_0, u(p), v(q)), v(q))$ . Also,  $\delta_{ik}$  denotes the Kronecker delta. The variational equations are

$$(V1) \quad \frac{\partial}{\partial t} \left( \frac{\partial Z_i}{\partial t_0} \right) = \sum_{j=1}^m \frac{\partial f_i}{\partial \xi_j} \frac{\partial Z_j}{\partial t_0}, \quad \frac{\partial Z_i}{\partial t_0}(t_0, t_0, u(p), v(q)) = -f_i(t_0, u(p), v(q));$$

$$(V2) \quad \frac{\partial}{\partial t} \left( \frac{\partial Z_i}{\partial \xi_k} \right) = \sum_{j=1}^m \frac{\partial f_i}{\partial \xi_j} \frac{\partial Z_j}{\partial \xi_k}, \quad \frac{\partial Z_i}{\partial \xi_k}(t_0, t_0, u(p), v(q)) = \delta_{ik};$$

$$(V3) \quad \frac{\partial}{\partial t} \left( \frac{\partial Z_i}{\partial \eta_k} \right) = \sum_{j=1}^m \frac{\partial f_i}{\partial \xi_j} \frac{\partial Z_j}{\partial \eta_k} + \frac{\partial f_i}{\partial \eta_k}, \quad \frac{\partial Z_i}{\partial \eta_k}(t_0, t_0, u(p), v(q)) = 0$$

It follows from (1) and (2) that  $\frac{\partial Z_i}{\partial t_0}$ ,  $\frac{\partial Z_i}{\partial \xi_j}$  and  $\frac{\partial Z_i}{\partial \eta_k}$  are the respective coordinate expressions for  $\frac{\partial C_i}{\partial t_0}$ ,  $\frac{\partial C_i}{\partial u_j}$  and  $\frac{\partial C_i}{\partial v_k}$ . The derivatives of the

$Z_i$ 's are evaluated at  $(t, t_0, u(p), v(q))$  and the derivatives of the  $C_i$ 's are evaluated at  $(t, t_0, p, q)$ . Also,  $\frac{\partial f_i}{\partial \xi_j}$  and  $\frac{\partial f_i}{\partial \eta_k}$  are coordinate expressions for

$$\frac{\partial X(u_j)}{\partial u_j} \quad \frac{\partial X(u_j)}{\partial v_k}$$

respectively. The derivatives of the  $f_i$ 's are evaluated at  $(t, Z(t, t_0, u(p), v(q)), v(q))$  and the derivatives of the  $X(u_j)$ 's are evaluated at  $(t, C(t, t_0, p, q), q)$ . Consequently, the variational equations for  $C$  may be found by substituting in (V1), (V2) and (V3). In the equations that follow,



Arkansas Academy of Science

it is understood that the arguments of derivatives of the  $C_i$ 's are  $(t, t_0, p, q)$  and the arguments for the derivatives of the  $X(u_j)$ 's are  $(t, C(t, t_0, p, q), q)$ . The variational equations for the system on the manifold are

$$(VM1) \quad \frac{\partial}{\partial t} \left( \frac{\partial C_i}{\partial t_0} \right) = \sum_{j=1}^m \frac{\partial X(u_j)}{\partial u_j} \frac{\partial C_i}{\partial t_0}, \quad \frac{\partial C_i}{\partial t_0} (t_0, t_0, p, q) = X(u_j)(t_0, p, q);$$

$$(VM2) \quad \frac{\partial}{\partial t} \left( \frac{\partial C_i}{\partial u_k} \right) = \sum_{j=1}^m \frac{\partial X(u_j)}{\partial u_j} \frac{\partial C_i}{\partial u_k}, \quad \frac{\partial C_i}{\partial u_k} (t_0, t_0, p, q) = \delta_{ik}$$

$$(VM3) \quad \frac{\partial}{\partial t} \left( \frac{\partial C_i}{\partial v_k} \right) = \sum_{j=1}^m \frac{\partial X(u_j)}{\partial u_j} \frac{\partial C_i}{\partial v_k} + \frac{\partial X(u_j)}{\partial v_k}, \quad \frac{\partial C_i}{\partial v_k} (t_0, t_0, p, q) = 0.$$

J. B. BENNETT, Department of Computer Science, Mathematics and Physics, Arkansas State University, State University, AR 72467.

NOTES ON THE BIOLOGY OF *THYANTA CALCEATA* (HEMIPTERA: PENTATOMIDAE)  
ON *TEPHROSIA VIRGINIANA* (LEGUMINOSAE), A NEW HOST PLANT

*Thyanta calceata* (Say) is distributed over the eastern United States from New England to Florida and west to Michigan, Illinois and Missouri (McPherson, The Pentatomoidea [Hemiptera] of northeastern North America with emphasis on the fauna of Illinois. S. Ill. Univ. Pr., Carbondale, 1982). The nymphal instars of this pentatomid have been previously described (Paskewitz and McPherson, Great Lakes Entomol. 15(4):231-255, 1982). *Tephrosia virginiana* (L.) ranges from Massachusetts south to Georgia, and west to Minnesota, Texas and Oklahoma (Steyermark, Flora of Missouri, Iowa St. Univ. Pr., Ames, 1975). This study presents additional information on the biology of this insect as it relates to *T. virginiana*, a previously unreported host plant.

McPherson (1982) reported *T. calceata* having been collected from soybean, red clover, blue-grass, cheat, wheat, timothy, winter cress, milkweed, horse-weed, buckbrush, *Lespedeza*, bean, pea, tomato, allegheny blackberry, common bromegrass, mullein, wild raspberry, goldenrod, and evening primrose. We have observed *T. calceata* commonly associated with *T. virginiana* in northeastern Arkansas on Crowley's Ridge and in northern Arkansas and southern Missouri on the Ozark Plateau.

Table 1. Occurrence of *Thyanta calceata* on *Tephrosia virginiana*, 28 April - 7 August 1987.

	PREBLOOM			FLOWERING				POSTBLOOM						
	April		May		June		July			August				
	28	1	8	15	22	28	19	26	3	10	16	24	31	7
Adult (N=23)			1	3		6		3	2	1	1	4		2
1st Instar (N=0)														
2nd Instar (N=7)			1	1			1	1				1		2
3rd Instar								2	1					
4th Instar (N=7)						1		2	1			2		1
5th Instar (N=1)								1						

## General Notes

From 8 April to 7 August 1987, the study area was visited a total of 14 times for one hour each trip between 1040 - 1645 hrs. Collections were made by sweeping the plants with a sweep net. Specimens were transferred to a chloroform kill jar, then pinned, pointed, or preserved in 70% EtOH. Voucher specimens are located in the Arkansas State University Insect Collection, State University, AR 72467.

During this study, *T. calceata* was collected from and observed on a population of *T. virginiana* from 8 May - 7 August 1987 on Crowley's Ridge, in northeastern Arkansas. Adult and second through fifth nymphal instars were collected from this host plant throughout the study (Table 1). The absence of first nymphal instars in our collections was probably due to their small size and short stadial length.

No specimens of *T. calceata* were collected from this host plant during the prebloom stage (Table 1). Adults and second through fifth nymphal instars were collected throughout the flowering and postbloom stages of the host plant.

We thank Dr. E. Leon Richards, Arkansas State University for help in identification of *T. virginiana*.

PHOEBE A. HARP and HARVEY E. BARTON, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

REPRODUCTIVE CHARACTERISTICS OF SOUTH FLORIDA *STERNOTHERUS ODORATUS* AND  
*KINOSTERNON BAURII* (TESTUDINES: KINOSTERNIDAE)

The reproductive characteristics of south Florida kinosternids are poorly known; however, populations of the stinkpot, *Sternotherus odoratus*, in central (Gross, 1982) and north Florida (Iverson, 1977), and the striped mud turtle, *Kinosternon baurii*, in central (Einam, 1956; Lardie, 1975) and in north Florida (Iverson, 1977, 1979) have been studied. A comparative study of northern and southern United States populations of *S. odoratus* by Tinkle (1961) concluded that clutch size increases with increasing body size of the female. In addition, southern populations should produce multiple clutches and exhibit both early maturity and sexual dimorphism in size. These findings were later supported by Gibbons (1970) in central Florida. The objectives of this study are to provide information on the reproductive characteristics of *S. odoratus* and *Kinosternon baurii* from south Florida and to test Tinkle's (1961) summary of southern populations of *S. odoratus* from a region further south than his north Florida sample.

Fifty-four turtles were collected along 1 km of Snapper Creek canal between SW 87 Ave and US Hwy 1, and along 0.3 km of C-100A canal near 104th Str. and SW 82 Ave in Miami, Dade County, Florida, from June through August 1982. Specimens were captured by dipnet or wire mesh funnel traps (1.8 × 0.8 m and 0.8 × 0.5 m) baited with bread, fish and beef scraps. Carapace length (CL) and plastron length (PL) were measured to the nearest 0.1 mm. Females were considered mature if they possessed ovarian follicles exceeding 7 mm diameter or if oviductal eggs or corpora lutea were present (Iverson, 1979). Clutch size was estimated by counts of oviductal eggs, corpora lutea, or enlarged follicles over 11 mm for *S. odoratus* (Iverson, 1977) and 10 mm for *K. baurii* (Iverson, 1979). The presence of sperm in testes was used to determine maturity in males. All turtles were deposited in the National Museum of Natural History, Washington, DC. Means are followed by ± one standard deviation. All measurements are in mm.

*Sternotherus odoratus* — Average carapace lengths for eighteen sexually mature females (77 ± 5.69; range = 52-80) and ten sexually mature males (68 ± 8.79; range = 62-86) support Tinkle's (1961) findings of sexual dimorphism in southern populations. This, however, was not observed by Tinkle (1961) in northern specimens. The small size at maturity in both males and females from south Florida is similar to those findings reported by Tinkle (1961) and Gibbons (1970) of 54, 61 and 52, 65, respectively. These data reveal an almost continuous north to south decrease in minimum size at maturity in Florida stinkpots. Mean clutch size was not significantly different ( $p > 0.05$ ) whether by counts of enlarged follicles (2.22 ± 0.441 N = 9), oviductal eggs (2.38 ± 0.51; N = 8), or corpora lutea (2.34 ± 0.76; N = 18). Based on oviductal eggs, clutch size was significantly larger ( $t = 2.13$ ;  $p < 0.05$ ) than the mean (1.74) reported by Gross (1982) in central Florida and significantly smaller ( $t = 2.87$ ;  $p < 0.05$ ) than the mean (3.2) in north Florida (Iverson, 1977). Clutch size, based on either corpora lutea ( $r = 0.198$ ) or oviductal eggs ( $r = 0.178$ ) showed no significant positive correlation with female plastron size at 0.05 level. Multiple sets of corpora lutea (largest first) followed by oviductal eggs found in nine female *S. odoratus* were 2,2 and 2 eggs (71 mmPL), 2,2,2 and 2 eggs (76 mmPL), 2,2,2 and 2 eggs (75 mmPL), 2,2 and 2 eggs (80 mmPL), 3,1 and 0 eggs (76 mmPL), 3,2 and 0 eggs (71 mmPL), 3,2 and 0 eggs (80 mmPL), 2,3 and 2 eggs (81 mmPL), and 2,3 and 2 eggs (85 mmPL). Pre-ovulatory follicles greater than 10 mm were found in all but the last three turtles. Three clutches are clearly produced by some turtles, however, production of four clutches by one female indicates that at least nine eggs are produced annually by south Florida stinkpots. Mean egg size for 19 oviductal eggs from eight females examined was 22.59 ± 2.10 (longest diameter; range = 20.0-29.0) by 13.63 ± 0.8 (shortest diameter; range = 12.2-15.0) and was not significantly correlated with female plastron size ( $r = 0.142$ ;  $p > 0.05$ ). It is unclear whether the absence of any significant positive correlation between clutch size and female plastron size of south Florida stinkpots reflects an artifact of a small sample, a geographic trend, or even local habitat differences. Although this sample was collected from a region further south than Tinkle's (1961), the presence of sexual dimorphism, early maturity, and multiple clutches from south Florida specimens corroborates Tinkle's (1961) summary of southern populations.

*Kinosternon baurii* — Average carapace lengths of fourteen sexually mature females (105 ± 10.0; range = 85-125) and twelve sexually mature males (91 ± 4.97; range = 90-98) indicates sexual dimorphism in size. Difference in mean clutch size for this sample was not significant whether estimated by counts of enlarged follicles (2.91 ± 1.75; N = 12), oviductal eggs (3.14 ± 1.67; N = 7), or corpora lutea (2.70 ± 1.43; N = 13). No significant difference in clutch size was found when compared to the 2.6 average in north Florida (Iverson, 1979). Multiple sets of corpora lutea (largest first) and oviductal eggs found in three turtles were 5,3 and 5 eggs (102 mmPL), 3,5 and 3 eggs (104 mmPL), and 3,2 and 3 eggs (95 mmPL). Pre-ovulatory follicles greater than 10 mm were found in all three specimens. Egg retention is suspected in one turtle (109 mmPL) that contained two corpora lutea (5.7 and 5.3 mm) and one oviductal egg. Clutch size, based either on corpora lutea ( $r = 0.253$ ;  $p > 0.05$ ) or oviductal eggs ( $r = -0.321$ ;  $p > 0.05$ ) was not significantly correlated with plastron size. These data suggest that at least nine eggs are produced from at least three clutches. Mean egg size for 22 oviductal eggs from seven females examined was 27.57 ± 1.63 (longest diameter; range = 25.0-31.0) by 15.30 ± 1.40 (shortest diameter; range = 11.7-17.3) and egg length was significantly correlated with female plastron size ( $r = 0.816$ ;  $p < 0.05$ ). No such correlation was found in north Florida (Iverson, 1979) using a larger sample.

The influence of tropical conditions is known to play a role in multiple clutching and aseasonal reproduction in turtles (Moll and Legler, 1971); however, the scarcity of available information concerning south Florida populations as well as the diversity of suitable habitats stresses the need of further studies before possible trends in the reproductive biology of south Florida kinosternids can be established.

Roy McDiarmid and J. Steve Godley supported this research both in supplies and in their encouragement. I especially thank G. E. Woolfenden for the use of his lab and to S. E. Trauth for his help in histological examination and in reviewing this manuscript.

## Arkansas Academy of Science

## LITERATURE CITED

- EINAM, G. E. 1956. Certain aspects of the natural history of the mud turtle, *Kinosternon baurii*. *Copeia* 1956:186-188.
- GIBBONS, J. W. 1970. Reproductive characteristics of a Florida populations of musk turtles (*Sternotherus odoratus*). *Herpetologica* 26:268-270.
- GROSS, D. 1982. Reproduction in a central Florida population of *Sternotherus odoratus*. M.S. thesis, University of South Florida, Tampa.
- IVERSON, J. B. 1977. Reproduction in freshwater and terrestrial turtles of north Florida. *Herpetologica* 33:205-212.
- IVERSON, J. B. 1979. The female reproductive cycle in north Florida *Kinosternon Baurii*. *Brimleyana* 1:37-46.
- MOLL, E. O., and J. M. LEGLER. 1971. The life history of a neotropical slider turtle, *Pseudemys scripta* (Schopff) in Panama. *Bull. Los. Ang. Co. Mus. Nat. Hist. Sci.* 11:1-102.
- TINKLE, D. W. 1961. Geographical variation in reproduction, size, sex, ratio, and maturity of *Sternotherus odoratus*. *Ecology* 42:68-76.
- WALTER E. MESHAKA, Department of Biological Sciences, Arkansas State University, State University, Arkansas 72467.

## MEASUREMENTS OF THE DRAG ON SPHERES FALLING THROUGH THE AIR

A problem often investigated in undergraduate labs on classical mechanics is the effect of air resistance on falling objects. One of the most interesting of these involves the drag force on spheres falling through the air. Frequently in these experiments the time of fall of the sphere is measured; this time is then used in a drag equation to calculate the distance fallen, for comparison with the measured distance. This distance measurement is a critical one and, for distances on the order of a few meters or less, must be accurate to within 0.5 mm. Measurements to this precision are difficult with the equipment and techniques available to the average undergraduate laboratory and, when several distances are involved, can present a large source of error. The experiment to be described eliminates the need for this distance measurement by using a phototransistor timing circuit to obtain the velocities at various times of flight. These measured velocities are then compared to the velocities calculated from a drag equation.

For many problems in fluid mechanics it is useful to define the dimensionless drag coefficient  $C_d$  in terms of the drag force  $F_d$  by the equation  $C_d = (F_d/A)/(\frac{1}{2}\rho V^2)$ , where  $A$  is the cross sectional area of the body normal to the direction of motion,  $\rho$  is the density of the medium, and  $V$  is the speed of the body. Thus, for a sphere falling through the air,  $F_d = \frac{1}{2}C_d\pi r^2\rho_a V^2$ , where  $\rho_a$  is the density of air and  $r$  is the radius of the sphere. Another dimensionless quantity which relates the inertial forces on a body to the viscous forces is the Reynolds number  $R$  which is defined by  $R = 2rV/\nu$ , where  $\nu$  is the kinematic viscosity of the medium. For spheres, the relationship between  $C_d$  and  $R$  is well known from experiment; a value of  $C_d \approx \frac{1}{2}$  for  $R$  between  $10^3$  and  $10^5$  is commonly accepted (H. Rouse, *Elementary Mechanics of Fluids*, Dover Publishing, 1978, p. 249). For air at room temperature,  $\nu = 0.15$  cm<sup>2</sup>/s, and for a sphere of radius  $r = 2$  cm, this range corresponds to velocities between 38 cm/s and 3800 cm/s. Since all velocity measurements in this experiment are made in this range, the drag force may be approximated by:

$$F_d = \frac{1}{4} \pi r^2 \rho_a V^2 . \quad [1]$$

From Newton's 2nd Law,

$$M \frac{dv}{dt} = Mg - F_d = Mg - \frac{1}{4} \pi r^2 \rho_a V^2 , \quad [2]$$

and

$$\frac{dv}{dt} = g - \left( \frac{1}{4} \pi r^2 \rho_a V^2 \right) / \left( \frac{4}{3} \pi r^3 \rho_s \right) , \quad [3]$$

with  $\rho_s$  = the density of the sphere, so that

$$\frac{dv}{dt} = g \left( 1 - \frac{3\rho_a V^2}{16\rho_s g r} \right) = g \left( 1 - V^2/V_0^2 \right) \quad [4]$$

where  $V_0^2 = (16\rho_s g r)/(3\rho_a)$ . From this we find

$$\frac{dv}{V_0^2 - V^2} = g \frac{dt}{V_0^2} . \quad [5]$$

Integrating both sides and setting  $V = 0$  at  $t = 0$ , we have

$$(1/V_0) \tanh^{-1}(V/V_0) = gt/V_0^2 , \quad [6]$$

and

$$\tanh^{-1}(V/V_0) = gt/V_0 . \quad [7]$$

With this approximation the velocity of a sphere falling through air is given by

$$V = V_0 \{ \tanh(gt/V_0) \} . \quad [8]$$

The device used for dropping the spheres was constructed by modifying the apparatus used in a typical undergraduate falling body lab. An electromagnet is mounted on a stand approximately 1.7 meters tall. Positioned in front of the magnet is a bracket designed to hold the ball before it drops without influencing its motion when it is released. The ball is held against the bracket by a metal bar which is hinged to the stand under tension by a spring, and held in place by the electromagnet. Timing was done with a Merlan Micro Series Computimer #30M100 controlled by a Commodore CBM Model 8032 Computer. A double pole-single throw switch is used to control the electromagnet as well as the timer. When

## General Notes

Table 1. Velocities of falling spheres at various fall times.

Time of fall (msec)	Ideal Velocity (cm/s)	Calculated Velocity (cm/s)	Measured Velocity (cm/s)
146	142.97	142.89	142.95
236	231.46	231.13	230.73
278	272.21	271.67	271.98
324	317.17	316.33	316.50
370	362.41	361.15	360.80
406	398.14	396.47	396.23
455	445.58	443.24	443.58
484	473.72	470.91	470.57
515	504.80	501.40	501.06
551	539.80	535.65	535.77

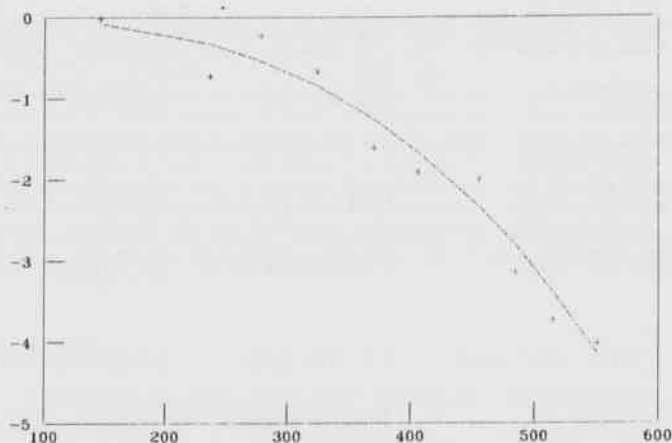


Figure 1. Differences from the ideal falling body case (dashed line - calculated values; pluses - measured values).

the switch is thrown, the power to the magnet is cut off, allowing the bar to fall and release the ball. At the same time, the timer cycle begins. Located in the path of the ball is a photogate consisting of a laser beam directed onto a phototransistor connected to the timing system. When the ball breaks the beam, the phototransistor is turned off and the timer stops. In addition, the computer can be set to measure the time the phototransistor is obstructed by the sphere. In this mode, a microsecond timer begins when the leading edge of the sphere breaks the beam and ends when the phototransistor is no longer darkened.

The experiment was conducted using a plastic sphere of diameter  $d = 4.379$  cm and mass  $M = 57.80$  g. Since a photogate may not be obstructed by all of an object which passes through it, a preliminary test was made and the effective diameter of the sphere was found to be 4.27 cm. The main timing procedure involved first setting the timer to the microsecond time-through-gate mode and determining the time taken for the ball to travel through the photogate. Great care was taken through numerous horizontal adjustments of the photogate system to insure that the sphere passed through the beam along its diameter, since this path will give the longest possible time measurement for the pass through the gate. When this time was achieved consistently, it was recorded as the gate time and the timer was reset to the (millisecond) time-of-flight mode. The ball was then dropped to determine the time taken to fall from rest to the photogate. This entire procedure was followed for 10 different heights at approximately 15 cm increments.

The average velocity of an object travelling a distance  $d$  in a time  $t$  can be written as  $V_{av} = d/t$ . If the velocity increases linearly with time, then the average velocity is equal to the velocity at  $t/2$ . For the time interval during which the sphere passes through the gate, the acceleration is very nearly constant, so these approximations are valid for calculating the velocity at a particular time. Thus, the experimental velocity, which is just the average velocity of the sphere through the photogate, may be calculated from  $4.27$  cm/(gate time) and corresponds to a total travel time equal to the time of flight plus one half the gate time. Using this travel time, the theoretical velocity was calculated from the drag equation (Eq. 8). A value for  $g$  for the local latitude and elevation equal to  $979.7$  cm/s<sup>2</sup> and an air density of  $\rho_a = 1.2 \times 10^{-3}$  g/cm<sup>3</sup> were used. A computer program was written to determine the lag time between the start of the timer and the actual dropping of the sphere to obtain the best agreement between the theoretical and calculated velocities; the lag was found to be 3 msec. The velocity if there were no air resistance is referred to as the ideal velocity and can be calculated from  $V = gt$ . Figure 1 shows the differences from the ideal case for the measured velocities and the velocities calculated from Eq. 8 for various times of flight. It is seen from the figure that the experimental velocities correspond very well with the calculated velocities.

We have shown that this timing technique can be used to provide measurements of the effects of drag forces on falling bodies to relatively high precision. This can be useful in the undergraduate laboratory to supplement the usual free-fall measurement of the gravitational acceleration and to introduce the concept of drag forces in viscous media.

J. G. ROSS, S. R. ADDISON, and N. O. GAISER, Physics Department, University of Central Arkansas, Conway, Arkansas 72032.

## EXTRALIMITAL HUMMINGBIRDS IN ARKANSAS

The Ruby-throated Hummingbird (*Archilochus colubris*) is the only species of hummingbird known to nest in Arkansas or anywhere else in eastern North America (James and Neal, 1986; A.O.U., 1983). Until 1985 it was the only hummingbird species ever identified in Arkansas, where it is a common summer resident and migrant in all parts of the state (James and Neal, 1986).

Before 1985 there were several well documented Arkansas reports (notably at Little Rock in December of 1978 and January of 1979 and at North Little Rock in October of 1984) of unidentified hummingbirds that clearly belonged to other species (Arkansas Audubon Society files). All these were identified as members of the genus *Selasphorus*, most likely Rufous Hummingbirds (*S. rufus*), a western species that normally winters in Mexico, though small numbers of Rufous Hummingbirds regularly overwinter along the Gulf Coast of the U.S. (A.O.U., 1983). Positive identification of the Arkansas birds could not be made on the basis of field observations or photographs. Only in the plumage of the adult male (with an all-rufous back) is *S. rufus* distinguishable in the field from the very similar Allen's Hummingbird (*S. sasin*). In female and immature plumages,



## Arkansas Academy of Science

Table 1. Additional vagrant and out-of-season hummingbirds 1987-88 (from Arkansas Audubon Society files).

DATE	LOCATION	RECORD	OBSERVERS
25-26 Aug.	Columbia Co.	Rufous (adult male)	Charline Aubrey
26-30 Aug.	Fayetteville	<u>Selasphorus</u> sp.	Tess Grasswitz, James, Neal, & others
7 Nov.-27 Jan.	El Dorado	Black-chinned	L. & H. Shugart & others
26 Nov.	Fort Smith	Rufous (adult male)	William Brazelton
Dec.-Jan.	Little Rock	<u>Archilochus</u> sp.	Marge & Ben Dunn, Shepherd, & others
21 Jan.-11 Feb.	El Dorado	Rufous (specimen)	L. & H. Shugart & others

the two species can be distinguished only by capturing the birds and measuring retrices (Stiles, 1972; N.L. Newfield, pers. com.). None of these early Arkansas vagrants were in adult male plumage (AAS files).

On 23 January 1985, a dead hummingbird was found frozen on its perch at Pine Bluff. Foti sent the specimen to Louisiana State University at Baton Rouge (James and Neal, 1986), where J. Van Remsen identified it as a Rufous Hummingbird and retained it in the collection (Louisiana State University Museum of Zoology, Cat. No. 121495). Other female and immature hummingbirds of the brown-and-green *Selasphorus* type continue to appear in Arkansas (Table 1) but have not been captured and thus, unless found dead, cannot be identified to species with certainty.

The second species of stray hummingbird identified in Arkansas was the most surprising to date: the Green Violet-ear (*Colibri thalassinus*). Unlike the Rufous Hummingbird and other hummingbird species (see below) that have strayed into Arkansas, the Green Violet-ear does not occur north of Mexico except as an extremely rare vagrant. All previous verified U.S. records of the Green Violet-ear came from south-central and southern Texas (A.O.U., 1983). (Two reports from California [including the one cited in A.O.U., 1983] were rejected by the California Bird Records Committee [Roberson, 1986].) The Arkansas record for Green Violet-ear is based on a photograph taken at Fort Smith by William Brazelton on 7 October 1984. The bird itself was positively identified from photographs by the method described in James and Neal (1986).

The late summer, fall, and winter of 1987-88 yielded several hummingbirds from the West, including two species previously unrecorded from Arkansas. A hummingbird observed and photographed (Helen and Max Parker, *et al.*) at North Little Rock in December and January proved to be an immature male Black-chinned Hummingbird (*Archilochus alexandri*), a species new to the state (report accepted by the Arkansas Bird Records Committee on the basis of written documentation and photographs submitted). More surprisingly, a bird observed and photographed (also by the Parkers and others) at Gillett in January and February of 1988 was an Anna's Hummingbird (*Calypte anna*) (identification verified from photographic slides in a letter from J. Van Remsen and Peter E. Scott to Max Parker, dated 11 February 1988). Anna's Hummingbird is a species of the West Coast and Arizona reported only a few times from southern Louisiana in winter, whereas the Black-chinned, breeding as close to Arkansas as central Texas (A.O.U., 1983), having summered and possibly nested near Oklahoma City, Oklahoma (Vacin, 1969), and wintering with some regularity in southern Louisiana (N.L. Newfield, pers. com.), was almost to be expected.

Other vagrant and out-of-season hummingbirds reported in the 1987-88 season are listed in Table 1. Worth comparing with these records are Newfield's report of "numbers of Black-chinned Hummingbirds ... higher than normal in [southern] Louisiana" during the fall of 1987 and Mississippi's first record of this species 26 November 1987 (Purrrington, 1988).

All vagrant hummingbirds observed in Arkansas to date have been observed in the months of August through February. This seasonal pattern is consistent with the dates of vagrant Rufous Hummingbirds elsewhere in eastern North America (Conway and Drennan, 1979).

Although few hummingbirds have been banded in Arkansas, if any, the experience of Marguerite Baumgartner south of Jay, in northeastern Oklahoma (on City, 17 km. west of the Arkansas State line), provides a basis for speculating on the abundance in Arkansas of extralimital hummingbirds relative to the abundance of Ruby-throated Hummingbirds. In 11 years Baumgartner banded 2,290 Ruby-throated Hummingbirds, two Rufous, and one Black-chinned (Baumgartner, pers. com.). Thus she banded between 700 and 800 Ruby-throated Hummingbirds for every individual of a vagrant species. Since all the vagrants originate farther west, they may be relatively even scarcer in Arkansas. Conversely, more hummingbirds may attempt to winter in central and southern Arkansas than in the vicinity of Jay, Oklahoma, because vagrant hummingbirds in Texas and Louisiana concentrate near the Gulf Coast and Baumgartner's site in Oklahoma lies only 13 km. south of the latitude of the northern border of Arkansas.

Why have so many vagrant hummingbirds been observed in Arkansas in recent years when none had been recorded in Arkansas only 10 years ago? Part of the answer may be that more people are watching birds now than in the past. It may be also that the reporting network has enlarged or otherwise improved, though both this and the preceding tentative explanation would be difficult, if not impossible, to prove. Perhaps both a growing corps of informed observers and better reporting are contributing to larger numbers of records for extralimital birds in all taxonomic groups.

We suggest that an additional factor in the case of hummingbirds is the greatly increased popularity of hummingbird feeders. We do not claim to demonstrate that this is a factor, but want to set out the hypothesis for others to test if they wish. Neither can the increase in artificial feeding of hummingbirds be demonstrated statistically; but Shepherd's personal experience illustrates how much more common such feeding has

## General Notes

become. Forty years ago Shepherd had been feeding hummingbirds from tiny glass medicine vials painted red with fingernail polish. Then he talked his father into mail-ordering from Massachusetts some hand-blown glass feeders that held about 12 cc. of sugar water each. Everybody who knew him then remembers this, because at the time, they knew no one else in Pine Bluff, Arkansas, who fed hummingbirds.

In January of this year Shepherd bought a plastic hummingbird feeder from a Little Rock florist. In mid-winter that one shop had in stock at least four models of hummingbird feeders of various designs and capacities. It is no longer unusual to see a hummingbird feeder in an Arkansas garden. There must be thousands of them! Significantly, every one of the hummingbirds seen in Arkansas during the winter months and every one identified as something other than a Ruby-throated Hummingbird was frequenting a feeder (AAS files). Not only are hummingbirds easier to see well (and thus to identify to species) when they drink repeatedly from a feeder placed near a window, but, more important for the bird, a well stocked feeder represents the only chance for a belated hummingbird to survive more than a day or two. A hard freeze kills the last nectar-producing flowers and, along with them, any flying insects and flower-dwelling arthropods that may have been supplementing the diet of nectar.

This paper has benefited greatly from thoughtful comments offered by A. Marguerite Baumgartner, Nancy L. Newfield, and Charles R. Preston, who reviewed earlier versions of it. We thank them sincerely.

## LITERATURE CITED

- AMERICAN ORNITHOLOGISTS' UNION. 1983. Check-list of North American birds, 6th ed. Amer. Ornith. Union, xxix + 877 pp.
- CONWAY, A. E., and S. R. DRENNAN. 1979. Rufous hummingbirds in eastern North America. Amer. Birds 33:130-132.
- JAMES, D. A., and J. C. NEAL. 1986. Arkansas birds. Univ. Arkansas Press, Fayetteville, xii + 402 pp.
- PURRINGTON, R. D. 1988. The autumn migration: Central Southern Region. Amer. Birds 42:85-92.
- ROBERSON, D. 1986. Ninth report of the California bird records committee. Western Birds 17:49-77.
- STILES, F. G. 1972. Age and sex determination in Rufous and Allen Hummingbirds. Condor 74:25-32.
- VACIN, V. J. 1969. Black-chinned Hummingbird at Silver Lake, near Oklahoma City. Bull. Okla. Ornithol. Soc. 2:14-15.

WILLIAM SHEPHERD<sup>1</sup>, JOSEPH NEAL<sup>2</sup>, THOMAS FOTT<sup>1</sup>, and DOUGLAS JAMES<sup>3</sup>; <sup>1</sup>Arkansas Natural Heritage Commission, Suite 200, The Heritage Center, 225 East Markham, Little Rock, AR 72201; <sup>2</sup>Department of Zoology, University of Arkansas, Fayetteville, Arkansas 72701.

MAMMALIAN SPECIES RECOVERED FROM A STUDY OF BARN OWL, *TYTO ALBA*, PELLETS FROM SOUTHWESTERN ARKANSAS

The barn owl, *Tyto alba*, has been historically a common raptor in Arkansas and one might expect a wealth of data available on the food habits of this owl. While studies have been conducted in other areas of the country (Banks, R. C., Auk 82:506, 1965; Jemison, E. S. and R. S. Chabreck, Wilson Bull. 74(1):95-96, 1962; and Parmalee, P. W., Auk 71:469-470, 1954), in Arkansas only one other study has been reported (Paige, K. N., C. T. McAllister, and C. R. Tumison, Proc. Ark. Acad. Sci. 33:88-89, 1979).

A. C. Bent (1937), in his book *Life Histories of North American Birds Of Prey*, relates that the barn owl is a very beneficial predator in that it consumes large numbers of harmful rodents. He also indicates that its choice of prey is dependent upon those items available in its forage range.

Our study began in April 1987, when an owl roost was discovered in an abandoned cotton gin in Ozan, Hempstead County. The roost is located on the edge of a small community in an area composed mostly of farm land with scattered stands of hardwood trees.

Table 1. Frequency of occurrence (Percentage of occurrence) of prey items recovered from barn owl pellets.

Species	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
<i>Microtus pinetorum</i>	6(33.3)	37(54.4)	36(53.0)	6(19.4)	2(20.0)	1(11.1)	2(10.0)	2(9.1)	5(18.5)	16(32.0)	49(60.5)	162(40.1)
<i>Sigmodon hispidus</i>	8(44.4)	19(27.9)	16(23.5)	16(51.6)	5(50.0)	8(88.9)	15(75.0)	16(72.7)	17(63.0)	14(28.0)	11(13.6)	145(35.9)
<i>Rattus rattus</i>	-	5(7.4)	10(14.7)	5(16.1)	1(10.0)	-	1(5.0)	1(4.5)	1(3.7)	-	2(2.5)	26(6.4)
<i>Oryzomys palustris</i>	3(16.7)	1(1.5)	1(1.4)	4(12.9)	1(10.0)	-	-	2(9.1)	4(14.8)	4(8.0)	4(4.9)	24(5.9)
<i>Reithrodontomys fulvescens</i>	-	-	2(2.9)	-	-	-	-	1(4.5)	-	6(12.0)	8(9.9)	17(4.2)
<i>Reithrodontomys humulis</i>	1(5.6)	-	-	-	-	-	-	-	-	2(4.0)	1(1.2)	4(1.0)
<i>Reithrodontomys sp.</i>	-	-	-	-	-	-	-	-	-	2(4.0)	-	2(0.5)
<i>Blarina carolinensis</i>	-	4(5.9)	1(1.4)	-	-	-	-	-	-	1(2.0)	4(4.9)	10(2.8)
<i>Cryptotis parva</i>	-	1(1.5)	-	-	-	-	-	-	-	1(2.0)	2(2.5)	4(1.0)
<i>Notiosorex crawfordi</i>	-	-	1(1.4)	-	1(10.0)	-	-	-	-	-	-	2(0.5)
<i>Ochrotomys nuttalli</i>	-	-	-	-	-	-	-	-	-	2(4.0)	-	2(0.5)
<i>Mus musculus</i>	-	-	-	-	-	-	1(5.0)	-	-	-	-	1(0.2)
Unknowns	-	1(1.5)	1(1.4)	-	-	-	1(5.0)	-	-	2(4.0)	-	5(1.2)
Total	18	68	68	31	10	9	20	22	27	50	81	404

Arkansas Academy of Science

---

Initially, an area of concrete floor approximately 72 sq m was cleared of all soil, litter and remains. The process involved removing and transporting to the laboratory approximately 1500 lbs (680 kg) of material for a later study (not reported here). This bulk material constituted an initial qualitative sample of prey items. From this cleared area, during the first week of each month, quantitative samples were collected. All pellets and other remains deposited in the cleared area were collected and shipped to Arkansas State University. Once at ASU, the pellets were dried and carefully dissected and the contents identified using cranial and dental morphology. Specimens were then tagged, cataloged and permanently deposited in the Museum of Recent Mammals at ASU.

Eleven months of quantitative samples were available for this study. Analysis of these samples yielded 404 specimens comprising eleven species of mammals (9 additional specimens identified as avian were not considered in this report). The results are presented in Table 1.

Interestingly, for every month *Microtus pinetorum* and *Sigmodon hispidus* were the most numerous prey items taken. *M. pinetorum* was taken in greatest numbers during the months of June, July, February and March. The dominance of these two species in the pellets indicates (as do the *Reithrodontomys* taken) that the owl(s) at this site forage(s) extensively over the prairie-like fields north and east of the cotton gin. It appears that the owl(s) forage(s) little, if at all, within the town of Ozan.

Another interesting feature of the data is the marked increase in the number of specimens taken during June, July, February and March. The large number of items, as well as the greater diversity of prey items, taken during summer months is attributable to the fact that young were present in the roost increasing the need for food during this period. The increased number and diversity of prey taken during the month of March likely is attributable to greater activity of the prey in response to the improved weather of early spring. February's increase is likely attributable to the documented unseasonably warm weather this particular year which probably increased the nocturnal activity and therefore the availability of these prey species.

This study has resulted in the collection of eleven mammalian county records, one of which (*Notiosorex crawfordi*) represents a significant extension of the presently reported range. With the exception of the range extension, all of the species collected during this study have reported ranges which include this county; however, *Reithrodontomys fulvescens* is the only species encountered that does not represent a new documented species for Hempstead County. *Notiosorex crawfordi* was collected from the roost on two different occasions, indicating that this species is not simply a spurious report for Hempstead County. Previously the only known specimens of *Notiosorex crawfordi* were from extreme northwest Arkansas (Sealander, J. A., A Guide to Arkansas Mammals, p. 48, 1969). Our records place this species a considerable distance south and/or east of its previously acknowledged range.

We would like to express our appreciation to the Southern Arkansas University Research Committee for providing funds to aid in this study.

T. W. STEWARD<sup>1</sup>, J. D. WILHIDE<sup>1</sup>, V. RICK McDANIEL<sup>1</sup>, and DANIEL R. ENGLAND<sup>2</sup>, <sup>1</sup>Department of Biological Science, Arkansas State University, State University, AR 72467; <sup>2</sup>Department of Biology, Southern Arkansas University, Magnolia, AR 71753.

## PUBLICATION POLICIES AND SUGGESTIONS FOR AUTHORS

The PROCEEDINGS OF THE ARKANSAS ACADEMY OF SCIENCE appears annually. It is the policy of the Arkansas Academy of Science that 1) at least one of the authors of a paper submitted for publication in the PROCEEDINGS must be a member of the Arkansas Academy of Science, 2) that only papers presented at the annual meeting are eligible for publication, and 3) that the manuscript is due at the time of presentation. In accordance with this policy, manuscripts submitted for publication should be given to the section chairman at the time the paper is being presented. Correspondence after this time should be directed to Dr. James H. Peck, Editor-PAAS, Dept. Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

**Each submitted paper** should contain results of original research, embody sound principles of scientific investigation, and present data in a concise yet clear manner. The COUNCIL OF BIOLOGY EDITORS STYLE MANUAL, published by the American Institute of Biological Sciences, is an example of a convenient and widely consulted guide for scientific writers. Authors should strive for directness and lucidity, achieved by use of the active voice. Special attention should be given to consistency in tense, unambiguous reference of pronouns, and to logically placed modifiers. It is strongly recommended that all authors 1) inspect the existing format for feature articles and general notes in the PROCEEDINGS OF THE ARKANSAS ACADEMY OF SCIENCE and follow that format while drafting their submission, and 2) submit their manuscript to another qualified person for a friendly review to appraise it for clarity, brevity, grammar, and typographical errors.

### Preparation of Manuscript

The author should submit two copies of the manuscript, tables, and figures. Manuscripts must be double spaced (preferably typed with a carbon ribboned typewriter) on 8½ x 11 inch bond paper with at least one inch margins on all sides. Do not staple pages together. Do not hyphenate words on the right-hand margin; do not submit word processed copy printed with justified right-hand margins. Do not submit copy in italics; underline words to be set in italics. If co-authored, designate which author is to receive correspondence and at what address.

**An abstract** summarizing in concrete terms the methods, findings and implications discussed in the body of the paper must accompany a feature article. The abstract should be completely self-explanatory.

**A feature article** comprises approximately six or more typewritten pages. A PROCEEDINGS printed page is equal to approximately three and one-half typewritten pages and the author is assessed a PAGE CHARGE (see Procedure section). A separate title page, including the title in capital letters, the authors names and addresses should be included with the manuscript. Feature articles are often divided into the following sections: abstract, introduction, materials and methods, results, discussion, acknowledgments, and literature cited. These sections should be centered and capitalized. Subheadings should begin at the left-hand margin, but more than one subheading should be avoided.

**A general note** is usually one to five typewritten pages and rarely utilizes subheadings. A note should have the title (capitalized) at the top of the first page with the body of the paper following. Abstracts are not used for general notes. The authors name and address should appear at the end of the manuscript.

**Abbreviations:** Use of abbreviations and symbols can be ascertained by inspection of recent issues of the PROCEEDINGS. Suggestions for uniformity include the use of numerals before units of measurements (5 millimeters), but nine animals (10 or numbers above, such as 13 animals). Abbreviations must be defined the first time they are used. The metric system of measurements and weights must be employed.

**The literature cited** section should include six or more references; entries should take the following form:

DAVIS, D. H. S. 1933. Rhythmic activity in the short-tailed vole, *Microtus*. J. Anim. Eco. 2:232-238.

HUDSON, J. W. and J. A. RUMMELL. 1966....

FLEMING, T. H. 1969. Population ecology of three species of Neotropical rodents. Unpublished Ph.D. dissertation. Univ. Michigan, Ann Arbor, 231 pp.

JONES, I. C. 1957. The adrenal cortex. Cambridge Univ. Press, London, 316 pp.

WRIGHT, P. L. 1966. Observations on the reproductive cycle of the American badger (*Taxidea taxus*). Pp. 27-45, in Comparative biology of reproduction in mammals (I. W. Rowlands, ed.) Academic Press, London, xxi + 559 pp.

If fewer than six references are cited they should be inserted in text and take these forms: (Jones, The adrenal cortex, p. 210, 1957); (Davis, J. Anim. Ecol., 2:232-238, 1933).

**Tables and Illustrations:** Tables and figures (line drawings, graphs, or black and white photographs) should not repeat data contained in the text. The author must provide numbers and short legends for illustrations and tables and place reference to each of them in the text. Legends for figures should be typed on a separate piece of paper at the end of the manuscript. Do not run tables in the text. Illustrations must be of sufficient size and clarity to permit reduction to standard page size; ordinarily they should be no larger than twice the size of intended reduction and whenever possible no larger than a manuscript page for ease of handling. Photographs must be printed on glossy paper; sharp focus and high contrast are essential for good reproduction. Figures and labeling must be of professional quality. Notations identifying author, figure number, and top of print must be made on the back of each illustration. All illustrations must be submitted in duplicate. Tables should be typed with a carbon-ribboned typewriter and in the exact format that the author wishes them to appear in the text. Tables will be printed using the offset process and thus must be of professional quality when submitted. Note preferred placement of figures and tables in the margins of the manuscript.

### Review Procedure

**Evaluation of a paper** submitted to the PROCEEDINGS begins with a critical reading by the Editor. The paper is then submitted to referees for checking of scientific content, originality, and clarity of presentation. Attention to the preceding paragraphs will greatly speed up this process. Judgments as to the acceptability of the paper and suggestions for strengthening it are sent to the author. If the paper is tentatively accepted the author will rework it, where necessary, and return two copies of the revised manuscript together with the original to the Editor. Usually a time limit for this revision will be requested. If the time limit is not met, the paper may be considered to be withdrawn by the author and rejected for publication. All final decisions concerning the acceptance or rejection of a manuscript are made by the Editor.

When a copy of the proof, original manuscript, and reprint order blanks reach the author, they should be carefully read for errors and omissions. The author should mark corrections on the proof and return both the proof and manuscript to the Editor within 48 hours or the proof will be judged correct. Printing charges accruing from excessive additions to or changes in the proofs must be assumed by the author. Reprint orders are placed with the printer, not the Editor. Page charges are \$25/printed page or portion thereof. These charges and excessive printing charges will be billed to the author by the Academy of Science.

### ABSTRACT COVERAGE

Each issue of the PROCEEDINGS is sent to several abstracting and review services. The following is a partial list of this coverage:

- Abstracts in Anthropology
- Abstracts of North American Geology
- Biological Abstracts
- Chemical Abstracts
- Mathematical Reviews
- Recent Literature of the Journal of Mammalogy
- Science Citation Index
- Sport Fishery Abstracts
- Wildlife Review
- Zoological Record
- Review Journal of the Commonwealth Agricultural Bureau

### BUSINESS AND SUBSCRIPTION INFORMATION

Remittances and orders for subscriptions and for single copies and changes of address should be sent to Dr. Walter Godwin, Secretary, Arkansas Academy of Science, Dept. of Natural Sciences, University of Arkansas at Monticello, Monticello, AR 71655.

Members receive one copy with their undergraduate membership of \$5.00, regular membership of \$15.00, sustaining membership of \$20.00, sponsoring membership of \$30.00 or life membership of \$200.00. Institutional members and industrial members receive two copies with their membership of \$100.00. Library subscription rates for 1989 are \$25.00. Copies of most back issues are available. The Secretary should be contacted for prices.



## TABLE OF CONTENTS

Secretary's Report and Financial Statement	1
Program	7
<b>FEATURE ARTICLES</b>	
LEO J. PAULISSEN: In Memoriam: Lowell F. Bailey 1911-1988	14
GARY E. TUCKER: In Memoriam: Maxine Clark 1905-1988	15
GARY E. TUCKER: In Memoriam: Delzie Demaree 1889-1987	16
ROBERT T. ALLEN: Additions to the known endemic flora and fauna of Arkansas	18
ROBERT T. ALLEN: A new species of <i>Occasjapyx</i> from the Interior Highlands (Insecta: Diplura: Japygidae)	22
RICHARD A. ATWILL and STANLEY E. TRAUTH: Mandibular dentition in six species of salamanders, genus <i>Plethodon</i> (Caudata: Plethodontidae), from Arkansas using scanning electron microscopy	24
R. H. DILDAY: Effect of nitrogen fertilizer on milling quality of rice ( <i>Oryza sativa</i> )	26
DANNY J. EBERT and STEPHEN P. FILIPEK: Response of fish communities to habitat alteration in a small Ozark stream	28
JAMES M. GULDIN, TIMOTHY T. KU, and R. SCOTT BEASLEY: Forestry on the Island of Taiwan, ROC - the state of the art	33
C. KAY HOLTMAN, TAMMY K. EBSEN, JUDITH A. BEAN, J. SCOTT BRYLES, and THOMAS J. LYNCH: Comparison of cyclic nucleotide phosphodiesterase in <i>Physarum flavicomum</i>	37
R. A. KLUENDER, L. C. THOMPSON, and G. W. CALLAHAN: Analysis of wildfire occurrence in southeastern Arkansas, 1984-1987	41
R. A. KLUENDER, T. B. WIGLEY, and M. E. CARTWRIGHT: Factors affecting annual deer harvest in Arkansas	45
R. A. KLUENDER and R. L. WILLETT: Arkansas' timber resource: yesterday, today, and tomorrow	48
M. A. MGONJA, R. H. DILDAY, S. L. SKINNER, and F. C. COLLINS: Association of mesocotyl and coleoptile elongation with seedling vigor in rice	52
THOMAS A. NELSON, LUKE EGGERING, and DANNY ADAMS: Autumn foods of white-tailed deer in Arkansas	56
JAMES H. PECK and CAROL J. PECK: A bibliographic summary of Arkansas field botany	58
JAMES H. PECK and CAROL J. PECK: Distribution, abundance, status, and phytogeography of Log Ferns ( <i>Dryopteris</i> : Woodsiaceae) in Arkansas	74
DAVID A. SAUGEY, GARY A. HEIDT, DARRELL R. HEATH, TIM W. STEWARD, DANIEL R. ENGLAND, and V. R. McDANIEL: Distribution and status of the Brazilian Free-tailed Bat ( <i>Tadarida brasiliensis cynocephala</i> ) in Arkansas	79
DAVID SAUGEY, DIANNE G. SAUGEY, GARY A. HEIDT, and DARRELL R. HEATH: The bats of Hot Springs National Park, Arkansas	81
STANLEY E. TRAUTH: Eggtooth development and morphology in the six-lined racerunner, <i>Cnemidophorus sexlineatus</i> (Sauria: Teiidae), using scanning electron microscopy	84
STANLEY E. TRAUTH and J. D. WILHIDE: Toe tip surface morphology in six species of salamanders, genus <i>Ambystoma</i> (Caudata: Ambystomatidae), from Arkansas using scanning electron microscopy	86
RENN TUMLISON and V. RICK McDANIEL: Comments on estimating population rate of increase from age frequency data	89
RENN TUMLISON and V. RICK McDANIEL: Sex ratios in bobcat populations	92
T. B. WIGLEY and M. E. GARNER: Forest habitat use by white-tailed deer in the Arkansas coastal plain	96
J. L. YEISER: Seedling response in a greenhouse to four rates of old and new paper mill sludge	99
J. L. YEISER and J. W. BOYD: Survival and growth two years after control of herbaceous competitors in newly planted seedlings of loblolly pine	102
J. L. YEISER, J. W. BOYD, and D. J. REED: Control of herbaceous competitors in progeny tests using container-grown seedlings	105
<b>GENERAL NOTES</b>	
THOMAS J. AURELI and LES TORRANS: Spawning frequency and fecundity of Blue Tilapia	108
J. B. BENNETT: Equations of variation for ordinary differential equations on manifolds	109
PHOEBE A. HARP and HARVEY E. BARTON: Notes on the biology of <i>Thyanta calceata</i> (Hemiptera: Pentatomidae) on <i>Tephrosia virginiana</i> (Leguminosae), a new host plant	110
WALTER E. MESHAKA: Reproductive characteristics of South Florida <i>Sternotherus odoratus</i> and <i>Kinosternon baurii</i> (Testudines: Kinosternidae)	111
J. G. ROSS, S. R. ADDISON, N. O. GAISER: Measurements of the drag on spheres falling through the air	112
WILLIAM SHEPHERD, JOSEPH NEAL, THOMAS FOTI, and DOUGLAS JAMES: Extralimital hummingbirds in Arkansas	113
T. W. STEWARD, J. D. WILHIDE, V. RICK McDANIEL, and DANIEL R. ENGLAND: Mammalian species recovered from a study of Barn Owl, <i>Tyto alba</i> , pellets from southwestern Arkansas	115