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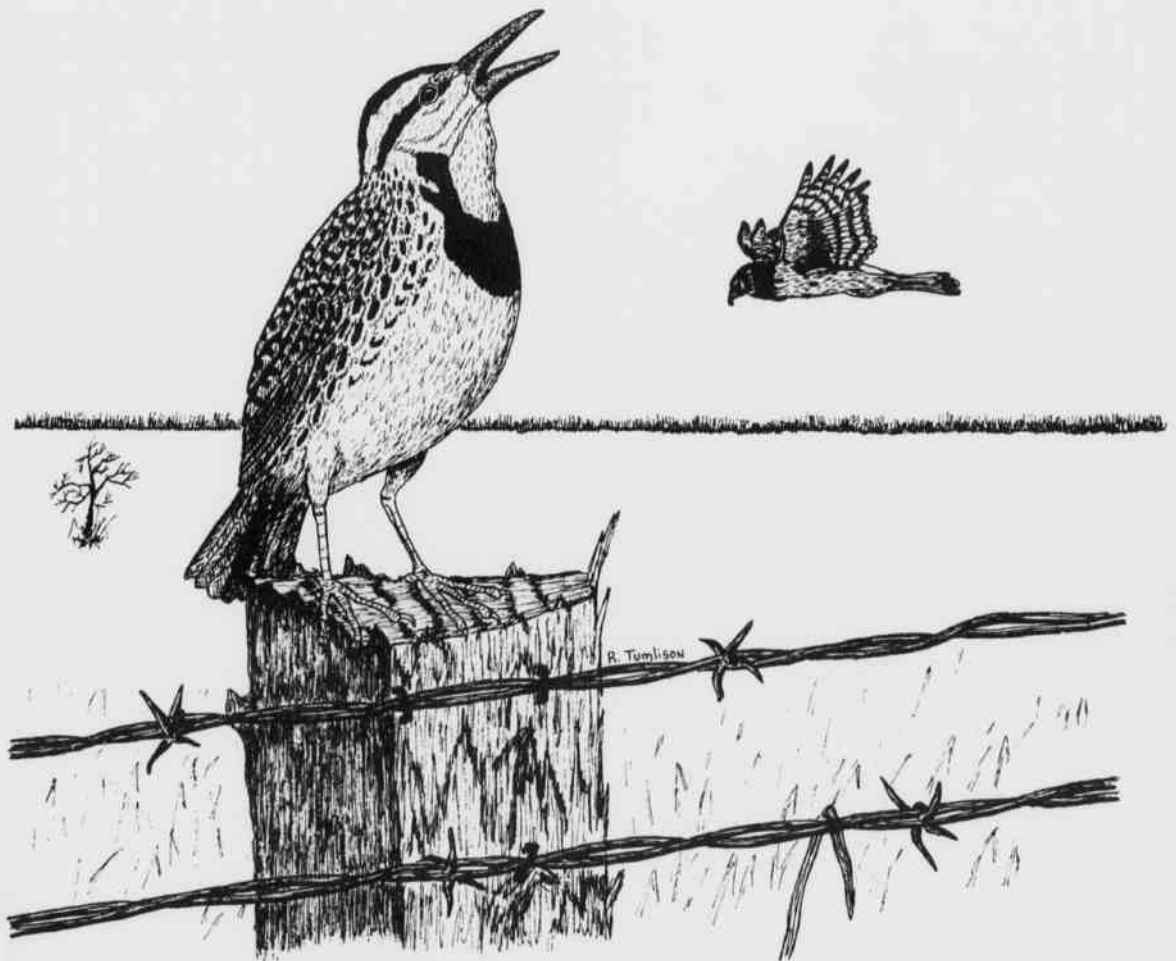
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Proceedings of the

ARKANSAS ACADEMY OF SCIENCE

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VOLUME 40
1986



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

Library Rate

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. Whitlake, 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	

INSTITUTIONAL MEMBERS

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

ARKANSAS COLLEGE, Batesville	OUACHITA BAPTIST UNIVERSITY, Arkadelphia
ARKANSAS STATE UNIVERSITY, State University	PHILLIPS COUNTY COMMUNITY COLLEGE, Helena
ARKANSAS TECH UNIVERSITY, Russellville	SOUTHERN ARKANSAS UNIVERSITY, Magnolia
COLLEGE OF THE OZARKS, Clarksville	UNIVERSITY OF ARKANSAS AT FAYETTEVILLE
HARDING COLLEGE, Searcy	UNIVERSITY OF ARKANSAS AT LITTLE ROCK
HENDERSON STATE UNIVERSITY, Arkadelphia	UNIVERSITY OF ARKANSAS FOR MEDICAL
HENDRIX COLLEGE, Conway	SCIENCES, Little Rock
JOHN BROWN UNIVERSITY, Siloam Springs	UNIVERSITY OF ARKANSAS AT MONTICELLO
MISSISSIPPI COUNTY COMMUNITY COLLEGE,	UNIVERSITY OF ARKANSAS AT PINE BLUFF
Blytheville	UNIVERSITY OF CENTRAL ARKANSAS, Conway

EDITORIAL STAFF

EDITOR: V. RICK McDANIEL, Dept. of Biological Science, Arkansas State University, State University, Arkansas 72467.

EDITOR FOR NEWSLETTER: JOHN D. RICKETT, Dept. of Biology, University of Arkansas at Little Rock, Little Rock, Arkansas 72204.

ASSOCIATE EDITORS:

John K. Beadles
Aquatic Environment

Robert Steinmeier
Chemistry

Kenneth Steele
Geology

PROCEEDINGS ARKANSAS ACADEMY OF SCIENCE

Volume XXXX

1986

Gary Heidt
President

Edmond Bacon
President-Elect

Gary Tucker
Vice-President

Walter Godwin
Secretary

Arthur Johnson
Treasurer

UNIVERSITY OF ARKANSAS
Henry Robison
Historian

FEB 8 1989

Secretary's Report

MINUTES OF THE SEVENTYTH ANNUAL MEETING, 4-5 APRIL 1986, FAYETTEVILLE, ARKANSAS

FIRST BUSINESS MEETING

Gary Heidt, President, called the meeting to order.

Joe Jeffers, Local Arrangements Chairman, introduced Dr. Daniel Grant, President of Ouachita Baptist University, who welcomed the Academy to campus. He summarized meeting events and indicated that a group picture would be made after the Second Business Meeting.

Walter Godwin, Secretary, presented the minutes of the Sixty-Ninth Annual Meeting and asked for any corrections to be presented in writing before the Second Business Meeting.

Art Johnson, Treasurer, presented the Financial Report. An Audit Committee consisting of Jim Fribrough (Chairman), Art Fry, and Hugh Johnson will examine the report. A copy of the report follows.

ANNUAL FINANCIAL STATEMENT

MARCH 12, 1986

Statement Approved by Audit April 6, 1985

First State Bank and Trust Co., Conway, AR:

TOTAL Account	4,988.38
Certificates of Deposit(71-0361781)	2,052.89
Security Savings and Loan Association of Conway	
Certificate of Deposit(48490.1)	1,023.91
Total Funds, April 6, 1985	\$ 8,065.18

SUMMARY

(March 12, 1985 to March 12, 1986)

Balance Approved by Audit on April 6, 1985	\$ 8,065.18
Total Income(Page 2)	9,550.35
Total Expenses(Page 3)	8,979.49
Balance for the Year	\$ 570.86
Funds on Hand as of March 12, 1986	\$ 8,636.04

DISTRIBUTION OF ACCOUNTS

TOTAL Account	\$ 5,254.93
Certificates of Deposit	
First State Bank and Trust Co., Conway(0007-769-4)	2,266.01
Security Savings and Loan Assn., Conway(C 01-70048490)	1,115.10
	\$ 8,636.04

INCOME: March 12, 1985 to March 12, 1986

1. ANNUAL MEETING: UAM APRIL 5-6, 1985	\$ 3,185.00
2. INDIVIDUAL MEMBERSHIPS	
a. Regular(107)	\$ 1,070.00
b. Sustaining(8)	120.00
c. Sponsoring(11)	725.00
d. Associate(3)	15.00
Total	1,930.00
3. INSTITUTIONAL MEMBERSHIPS(8)	400.00
4. PROCEEDINGS, Subscriptions, Misc. Sales	1,132.62
5. PROCEEDINGS, Page Charges	1,620.00
6. BIOTA RECEIPTS	12.00
7. INTEREST	620.73
a. First State Bank and Trust Co.(Conway)	
1) TOTAL Account	316.42
2) CD(0007-769-4)	213.12
b. Security Savings and Loan Assn.(Conway)	
CD(C-01-70048490)	91.19
8. ENDOWMENT	650.00

TOTAL INCOME

\$ 9,550.35

EXPENSES: March 12, 1985 to March 12, 1986

1. PROCEEDINGS: Publication and Distribution	
a. Phillips Litho Co., Inc.(#189)	\$5,562.97
b. V. Rick McDaniel(#186)	104.75
c. Mary Ann McDaniel(#188)	500.00
Total	6,167.72
2. AWARDS	
a. Mark S. Ross(#173)	50.00
b. Terry Gilton(#172)	50.00
c. Eugene Sargent(#174)	35.00
d. Douglas J. Thacker(#175)	30.00
e. Arkansas State Science Fair(#176)	100.00
Total	265.00
3. MEETING EXPENSES(UAM Statement)	
a. Prof. Food Service Management(#182)	1,088.25
b. Geographics(#183)	80.00
c. James Quick Print(#184)	241.51
d. Robert W. Wiley(#185)	138.97
Total	1,548.73
4. OPERATING COSTS	
a. President's Office	
1) UAF Cashier's Office(#180)	9.68
2) McRoy & McNair, Inc.(#181)	3.18
3) Arthur A. Johnson(#191)	9.17
4) U. S. Postal Service(#192)	28.60
b. Secretary's Office-Postage(#187,190)	250.00
c. Treasurer's Office-Postage(179,195)	44.00
Total	344.63

Arkansas Academy of Science

5. NEWSLETTER

a. Copy Cat(#193,198)	428.40	
b. UALR Biology Department(#194,197)	122.96	
Total	551.36	551.36


6. MISCELLANEOUS

a. Biota Printing(#178)	31.35	
b. EBSCO(#196)	45.00	
c. Check--Insufficient Funds	5.00	
d. National Assn. Acad. Sciences(#199)	20.70	
Total	102.05	102.05

TOTAL EXPENSES

\$ 8,979.49

Respectfully Submitted


 Arthur A. Johnson, Treasurer

Meeting: April 4-5, 1986
 Ouachita Baptist University
 Arkadelphia, Arkansas

Rick McDaniel, Editor of the *Proceedings*, presented a report on this year's edition indicating that the *Proceedings* will be ready in a few weeks. A total of 52 papers were submitted of which 21 will be published in full and 24 will be published as notes. There will be a total of 150 pages. Due to the size, the *Proceedings* must be bound specially creating the delay in distribution. He stated that the page charges will be increased from \$20 to \$25 per page with the next *Proceedings*. He reminded section chairs be sure to collect papers at the sessions and to turn those papers in. 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 40 of the *Proceedings*.

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

John Rickett, Editor of the Newsletter, requested that any comments on the Newsletter be given to him. He moved that the Academy appropriate \$580 for the cost of the Newsletter for next year. 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 and the Junior Academy. Over 200 students participated in the State Fair and Junior Academy meeting had about 75 papers. He thanked the Academy for the good response to the call for judges. Three students went to the International Fair and won a first and fourth in engineering and a first in physics plus having the overall winner. He moved that the Academy continue to support the Science Fair in the amount of \$200 (\$25 for each Regional Fair and \$25 for the State Fair) and to continue to support the Junior Academy in the amount of \$200. 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 35th Annual Arkansas Science Talent Search 1985-86, held in conjunction with the 45th Westinghouse Science Talent Search.

	First Place
Todd Harrison Rider	School: Ole Main High School
501 West A Street	Teacher: Bonnie Moody
North Little Rock, AR 72116	Project: How Can Rocketry Staging Be Improved

	Second Place
Charles Eldon King	School: Springdale High School
Rt. 3, Box 173,	Teacher: David A. Young
King's Rd.	Project: Evidence of Benzo(a)pyrene in the Saliva of Cigarette Smokers
Springdale, AR 72764	

He also reported that one student attending the national talent search placed in the top 10 while another received an honors award. He moved that the Academy provide \$35 for first place and \$30 for second place winners. The motion was seconded and will be voted on at the Second Business Meeting. He stated that a mailout to schools had produced increased participation and should be continued. To allow this, he moved that support for postage in the amount of \$28.60 be provided by the Academy. The motion was seconded and will be voted on at the Second Business Meeting.

President Heidt reported for Tom Palko, Director of the Arkansas Junior Science and Humanities Symposium that the symposium is doing well and is quite successful this year.

Ed Bacon, Chairman of the Constitution Committee, reported on recommended changes to the constitution. The report of this committee follows:

The members of the Constitution Committee of the Arkansas Academy of Science were E. J. Bacon (Chairman), Bill Evans, and Paul Sharrah. The Committee recommends the following changes in the Constitution and By-Laws of AAS:

I. CONSTITUTION CHANGES RECOMMENDED:

1. CHANGE ARTICLE II which now reads:

ARTICLE II: OBJECTS

The objects of this organization shall be the promotion and diffusion of knowledge of the fields of Science and unification of these interests in the State.

TO READ:

ARTICLE II: OBJECTIVES

The objectives of this organization shall be the promotion and diffusion of knowledge of the fields of science and unification of these interests in the State.

2. CHANGE ARTICLE III SECTION I which now reads:

SECTION 1. Persons and organizations interested in the objects of this academy may join on the recommendation of the membership committee and payment of dues.

TO READ:

SECTION 1. Persons and organizations interested in the objectives of this academy may join by the payment of dues.

II. BY-LAWS CHANGES RECOMMENDED:

1. CHANGE SECTION 2 OF THE BY-LAWS which now reads:

The following committees shall be set up whenever necessary: Program, Membership, Publications, Auditing, Nominations, Local, Publicity, and Awards.

TO READ:

The following standing committees shall be established: Auditing, Awards, Biota, Constitution,

Secretary's Report

Development, Local, Nominations, Publications, Publicity, Resolutions, and Science Education. AD HOC committees may be appointed by the President. The make-up, duties, and duration of service for members of each standing committee shall be determined by the Executive Committee with members for vacancies to be appointed by the President.

2. CHANGE SENTENCE 2 OF SECTION 5 OF THE BY-LAWS which now reads:

Such ex-members may regain their membership by the regular process of election and paying of dues.

TO READ:

Such ex-members may regain their membership by the payment of dues.

3. CHANGE SECTION 9 OF THE BY-LAWS which now reads:

A person elected to membership within a year holds paid-up membership for the remainder of the remainder of the fiscal year.

TO READ:

A person joining the Academy during the year is entitled to membership privileges for the remainder of the fiscal year.

Dr. Bacon moved that the Academy accept the report of the Constitution Committee. The motion was seconded and will be voted on at the Second Business Meeting.

Dave Saugey, Chairman of the Nominating Committee, presented the nominees for Vice President. The nominees were Glyn Turnipseed, Arkansas Tech University, and Horace Marvin, University of Arkansas for Medical Sciences, and Ken Smith, Arkansas Natural History Commission. It was moved and seconded to close nominations and the motion passed. He also indicated that the committee nominated Jim Peck, University of Arkansas at Little Rock, for Editor to begin in 1987 but to allow one year overlap.

The Resolutions Committee will consist of Dan England and Mike Plummer.

President Heidt introduced Pat Troth of the Arkansas Science and Technology Authority.

President Heidt encouraged section chairs to keep their sections on time and to not start presentations early.

President Heidt announced the Sigma Xi breakfast at Palmeara's Restaurant on Saturday morning.

Steve Fillipek announced that there would be a short discussion of stream studies immediately after the meeting.

Leo Paulissen reported that new Biota Surveys and a checklist on birds are ready and will be available at the Second Business Meeting.

President Heidt adjourned the First Business Meeting.

SECOND BUSINESS MEETING

Gary Heidt, President, called the meeting to order with approximately 65 members present.

Walter Godwin, Secretary, moved the approval of the minutes of the Sixty-Ninth Annual Meeting as distributed. The motion was seconded and passed.

Art Johnson, Treasurer, moved that the Treasurer's Report be approved. The motion was seconded. Jim Fribourgh presented the following report from the Audit Committee.

The Audit Committee reviewed the attached 1985-86 Annual Financial Statement of the Academy and examined the various documentation submitted to us. We found the receipts and expenditures to be in order and the financial records to be in balance.

We also ask the Academy to join us in expressing our thanks and appreciation to Dr. Arthur A. Johnson for his services and dedication as Treasurer.

Respectfully submitted,
Arthur Fry
Hugh Johnson
James H. Fribourgh, Chairman

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 by Rick McDaniel at the First Business Meeting, to allocate \$620 for editorial assistance and travel for next year was passed.

The motion, presented by John Rickett at the First Business Meeting, to allocate \$580 for the Newsletter for next year was passed.

The motion, presented by Mike Rapp at the First Business Meeting, to allocate \$200 for support of the Science Fair and \$200 for support of the Junior Academy for next year was passed.

The motion, presented by John Peck at the First Business Meeting, to allocate \$94 for the Arkansas Science Talent Search for next year was passed.

President Heidt asked for nominations from the floor for Vice President. There were no nominations so nominations were closed and ballots distributed. A count of the ballots as reported later showed that Horace Marvin had been elected Vice President. President Heidt also asked for nominations from the floor for Editor. It was moved and seconded to accept Jim Peck by acclamation. The motion passed.

The motion, presented by Ed Bacon at the First Business Meeting, to accept the report of the Constitution Committee was passed by well over the necessary three-fourths margin.

Henry Robinson, Historian, reported that this is the Seventieth Annual Meeting and the second to be held in Ouachita. The first meeting was a joint meeting with Henderson State. He repeated his call for any old pictures of past activities, officers, and other items of historical interest.

Robbin Anderson, Chairman of the Science Education Committee, reported that there has been increased activity and increased cooperation in the area of science education.

Leo Paulissen reported on the Biota Survey. Several more lists have been added bringing the total to 45. The checklists should be bound by next year. He mentioned that Doug James has a new checklist of spiders. He also reported that some progress has been made on the Endowment Fund.

Arkansas Academy of Science

John Rickett reported on the 1987 meeting site. His report follows:

The 71st Annual Meeting of the Arkansas Academy of Science will be held at the Riverfront Hilton in North Little Rock, AR on 5 and 6 April 1987.

Due to construction and very limited parking it would be very difficult to hold the meeting on the UALR campus. The Riverfront Hilton has all needed facilities, and the convenience should be of primary interest to out-of-town guests. We will encourage as many persons as can take overnight rooms at the Riverfront Hilton because the more rooms are occupied the more accessory facilities will be made available for our use without charge. If we occupy 100 room-nights, the charge for the various section rooms and banquet facilities will be \$500, which will be covered by a much-appreciated donation from Dean Bob Franke and fees from exhibitors.

President Heidt stated that an invitation for the 1988 meeting had been extended by Arkansas Tech University. It was moved and seconded to accept the invitation. The motion passed.

Joe Jeffers, Local Arrangements Chairman reported on the Undergraduate Awards. He reported that the Undergraduate Awards had been won by:

Life Sciences: Keith R. Smith - UALR

Cyclic AMP and Cyclic GMP Phosphodiesterase Activity During Sclerotization of the Myxomycete *Physarum flavicomum*

Physical Sciences: Monica L. Wooley - UAPB

Development of a Sensitive Method to Measure Aflatoxin B1, B2, G1, and G2 Using Electrochemistry

Jeffers also indicated that a group picture would be taken after the meeting and that copies of the picture would be available.

Dan England, Chairman of the Resolutions Committee, moved the adoption of the following resolution.

It was resolved:

The members of the Arkansas Academy of Science express their gratitude to Ouachita Baptist University at Arkadelphia for hosting the 1986 meeting of the Arkansas Academy of Science. The Academy congratulates the University in attaining its one-hundredth year of service, and is particularly appreciative of the opportunity to meet on its campus during this centennial year. In particular, thanks is given to members of the local arrangements committee: Joe Jeffers, Chairman; Mary Bolton; Richard Brown; Alton Crawley; Wayne Everett; Glenn Good; Brian Harmon; Steve Hennigin; Alex Nisbet; Joe Nix; Victor Oliver; Judee Royston; Kenneth Sandifer; and to numerous OBU students. Appreciation is expressed to all concerned who helped provide the pleasant spacious facilities and excellent banquet. Also, thanks is given to Martin Rosenberg of Smith, Kline and French Labora-

tories for his presentation on using recombinant DNA.

The Academy appreciates the efforts of the various section chairpersons and recognizes that they play an important role in the conduct of the meeting. To be noted are: John Guise and Henry Robinson (Aquatic and Environmental Biology), Dee Palmer and Warfield Teague (Chemistry), Peggy Doris and Perry Max Johnson (Vertebrate Zoology), Paul Raines (Botany), Jimmy Bragg (Microbiology), George Harp (Invertebrate Zoology), David Straub (Biomedical), Dick Hansen (Science Education), and Clark McCarty (General).

The Academy expresses gratitude to the various directors of the science youth activities which are supported by the Academy: Robin Anderson (Science Education Committee), Mike Rapp (Director of the Arkansas State Science Fair), Tom Palko (Director of the Junior Science and Humanities Symposium), John Peck (Science Talent Search), and Norman Hoover and Paul Krause (Arkansas Junior Academy of Science).

The Academy is only as successful as its leadership in planning, working and directing the various activities. To Gary Heidt (President), Edmond Bacon (President-Elect), Gary Tucker (Vice-President), Walter Godwin (Secretary), Art Johnson (Treasurer), William Evans (Past-President), Rick McDaniel (*Proceedings* Editor), John Rickett (Newsletter Editor), and Henry Robinson (Historian), the Academy expresses gratitude and thanks for an excellent year.

The Academy expresses thanks and encouragement to continue to Delta Optical Instruments Company, Fisher Scientific, and Advanced Scientific, Inc. for their exhibition booths at the meeting.

The Academy recognizes the dedicated and thorough work of Ed Bacon, Chairman; William Evans and Paul Sharrah in reviewing the Constitution and Bylaws of the Academy. Also appreciation is tendered to Leo Paulissen for his work on the Endowment Fund. Joe Jeffers, Chairman; Walt Godwin; Leo Bowman; Rick McDaniel; Stan Trauth and Mike Rapp are thanked for their efforts on the Student Awards Committee as well as Collis Geren, Chairman; David Saughey and Jim Daly for their work on the Nominating Committee.

The motion was seconded and passed.

President Heidt asked for any other business and David Saughey stated that the Arkansas Herpetological Society invites all interested persons.

President Heidt expressed his pleasure at serving as President. He also emphasized the need for more Life Members. Finally he mentioned the Endowment Fund and the need for continuing support for it.

President Heidt passed the gavel to President-Elect Ed Bacon. President Bacon presented Past-President Heidt with a plaque in appreciation for his year of service.

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

Respectfully submitted,

Walter E. Godwin
Secretary

REGULAR MEMBERS

Robert T. Allen	University of Arkansas
John T. Annulis	University of Arkansas at Monticello
Michael L. Armstrong	Arkansas Game & Fish Commission
Lanny Asklock	University of Arkansas Cooperative Extension Service
Dennis A. Baeyens	University of Arkansas at Little Rock
Claudia F. Bailey	University of Arkansas
Gary A. Bannon	University of Arkansas for Medical Sciences
Adelphia M. Basford	Henderson State University (Retired)
Ralva Bass	University of Central Arkansas
John K. Beadles	Arkansas State University

Laurence J. Boucher	Arkansas State University
William R. Bowen	University of Arkansas at Little Rock
Robert E. Bowling	University of Arkansas for Medical Sciences
Leo H. Bowman	Arkansas Tech University
Jimmy D. Bragg	Henderson State University
John F. Bridgman	University of the Ozarks
Arthur V. Brown	University of Arkansas
Kristine B. Brown	West Fork High School
Richard H. Brown	Ouachita Baptist University
Charles T. Bryant	U. S. Geological Survey

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Neal D. Buffaloe	University of Central Arkansas	Frank Meriwether	University of Arkansas at Pine Bluff
Bruce L. Carr	University of Arkansas	Lawrence A. Wink	Arkansas State University
Stanley L. Chapman	University of Arkansas Cooperative Extension Service	Richard S. Mitchell	Arkansas State University
Joseph M. Clark		David L. Monts	University of Arkansas
Maxine B. Clark		Luis Morales	Arkansas State University
Frances E. Clayton	University of Arkansas	Stephen R. Moulton II	Quachita Baptist University
Richard A. Collins	University of Central Arkansas	Joe Mix	University of Arkansas for Medical Sciences
David R. Cross	University of Arkansas at Little Rock	Timothy J. O'Brien	Arkansas Tech University
Donald Culwell	University of Central Arkansas	Tom Palke	Henderson State University
Fred Dalske	University of Central Arkansas	Bryan D. Palmer	University of Arkansas
James J. Daly	University of Arkansas for Medical Sciences	Leo J. Paulissen	University of Oklahoma
James T. Daniels	SAU - Tech	Mark A. Paulissen	University of Arkansas for Medical Sciences
Stanley N. David	Arkansas State University	John E. Pauly	University of Arkansas at Pine Bluff
David L. Davies	University of Arkansas for Medical Sciences	Carol J. Peck	University of Arkansas for Medical Sciences
Leo Carson Davis	Southern Arkansas University	Ernest J. Peck	University of Arkansas at Little Rock
Don C. De Luca	University of Arkansas for Medical Sciences	James H. Peck	University of Central Arkansas
Larry W. Dorman	University of Arkansas	John D. Peck	U. S. Geological Survey
Peggy Rea Dorris	Henderson State University	James C. Peterson	University of Arkansas Cooperative Extension Service
Lee Doyle	University of Arkansas for Medical Sciences	Robert A. Pierce	Harding University
Benjamin T. Duhart	University of Arkansas at Pine Bluff	Michael V. Plummer	University of Arkansas
Danny J. Ebert	U. S. Forest Service	Paul J. Polechla, Jr.	University of Arkansas
Rudolph J. Eichenberger	University of Central Arkansas	Thonlot T. Prabhakaran	University of Arkansas at Little Rock
Hudson B. Eldridge	Southern Arkansas University	Charles R. Preston	Arkansas Department of Pollution Control & Ecology
Daniel R. England	Southern Arkansas University	Alan D. Price	University of Central Arkansas
Claude E. Epperson	University of Arkansas for Medical Sciences	Denver L. Prince	Arkansas State University
Wilbur W. Everett	Quachita Baptist University	Paul L. Raines	Jacksonville Wastewater Utility
Dale Ferguson	University of Arkansas at Little Rock	Diane Randall	University of Central Arkansas
Steve Filipek	Arkansas Game & Fish Commission	Michael W. Rapp	University of the Ozarks
Sheldon Fitzpatrick	University of Arkansas at Pine Bluff	Ruby S. Reynolds	Arkansas State University
E. P. Floyd	U. S. Public Health Service (Retired)	Edward L. Richards	University of Arkansas
Thomas L. Foti	Arkansas Natural History Commission	Rex Roberg	Harding University
Walter E. Godwin	Arkansas Department of Pollution Control & Ecology	Bryce Roberson	Southern Arkansas University
Glynn Good	University of Arkansas at Monticello	Peggy Root	University of Arkansas for Medical Sciences
Rachel Goss	Quachita Baptist University	David A. Saughey	U. S. Forest Service
D. Leroy Gray	University of Arkansas at Little Rock	S. Jeffery Scott	University of Arkansas
Gaston Griggs	Cooperative Extension Service	John A. Sealander	University of Arkansas
William C. Guest	John Brown University	Larry Seward	John Brown University
Bruce Hagard	University of Arkansas	Alli U. Shaikh	University of Arkansas at Little Rock
Earl L. Hanebrink	Hendrix College	Bill Shepard	Arkansas Natural History Commission
Richard H. Hanson	Arkansas State University	Samuel Siegel	University of Arkansas
George L. Harp	University of Arkansas at Little Rock	Dewey H. Sifford	Arkansas State University
Jarvis Harper	Arkansas State University	Farli Simpson	University of Central Arkansas
John L. Harris	Alcoa	Kenneth L. Smith	Arkansas Natural History Commission
Calvin J. Haskins	Arkansas Highway & Transportation Department	Robin M. Smith	Arkansas State University
Darrell Heath	Arkansas Game & Fish Commission	Roy J. Smith, Jr.	U. S. Department of Agriculture
Gary Heldt	University of Arkansas at Little Rock	Clifford S. Snyder	University of Arkansas Cooperative Extension Service
Mustafa Hemmati	University of Arkansas at Little Rock	Bernard Soloff	J. L. M. Memorial Veterans Hospital
Craig Hilburn	Arkansas Game & Fish Commission	Frederick W. Spiegel	University of Arkansas
Larry Hinck	Arkansas State University	Carl R. Stapleton	University of Arkansas at Little Rock
Kathleen L. Hornberger	University of Arkansas	Marcus L. Steele	Henderson State University
Jim Huey	University of Arkansas at Monticello	Karl David Straub	University of Arkansas for Medical Sciences
Joe Jeffers	Quachita Baptist University	Joseph Sylvester	U. S. Fish & Wildlife Service
Donn T. Johnson	University of Arkansas	Sandy Tedder	University of Arkansas
Hugh A. Johnson	Southern Arkansas University	Lyell Thompson	University of Arkansas
Michael I. Johnson	Nettleton High School	Dan Timmermann	Arkansas State University
Jay Justice	Arkansas Department of Pollution Control & Ecology	Les Torrains	University of Arkansas at Pine Bluff
Aliyan A. Karlin	University of Arkansas at Little Rock	Gary Tucker	Arkansas Tech University
Mark Karnes	University of Arkansas at Little Rock	Denzil L. Tullis	University of Arkansas at Little Rock
Phillip L. Kehler	The Ross Foundation	Renn Tumilson	Arkansas State University
Raj V. Kilambi	University of Arkansas	Glyn Turnipseed	University of Arkansas at Little Rock
Scott Kirkconnell	Arkansas Tech University	Tito Viswanathan	Arkansas State University
Maurice G. Klee	University of Arkansas at Little Rock	David L. Vosburg	University of Arkansas at Pine Bluff
Richard Klunder	University of Arkansas at Monticello	Richard B. Walker	University of Arkansas at Little Rock
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PROGRAM

Arkansas Academy of Science

Seventyth Annual Meeting
OUACHITA BAPTIST UNIVERSITY
Arkadelphia, Arkansas

Meeting concurrently with sessions of
The Collegiate Academy of Science

Friday, 4 April

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SENIOR ACADEMY -- Executive Board Meeting

SENIOR ACADEMY -- First General Business Meeting

SENIOR AND COLLEGIATE ACADEMIES: Papers [Concurrent Sessions]:

Aquatic and Environment I
Botany
Vertebrate Zoology I
Chemistry I
Biomedical
Microbiology

SCIENCE EDUCATION COMMITTEE

SENIOR AND COLLEGIATE ACADEMIES -- Banquet

POST BANQUET SPEAKER -- Dr. Martin Rosenberg
Smith Kline and French Laboratories

Saturday, 5 April

SENIOR AND COLLEGIATE ACADEMIES -- Registration

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

Aquatic and Environment II
Vertebrate Zoology II
Chemistry II
General
Invertebrate Zoology
Science Education

SENIOR ACADEMY -- Second General Business Meeting

SECTION PROGRAMS

[Papers marked with * are presentations by Collegiate Academy members]

AQUATIC AND ENVIRONMENTAL I

Session Chairperson: John Geise

SURVEY OF PERIODICAL CICADA EMERGENCE SITES IN WASHINGTON COUNTY, ARKANSAS, AND POSSIBLE ECOLOGICAL IMPLICATIONS.

Douglas A. James, Kimberly G. Smith and Kathy S. Williams, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

POPULATION STRUCTURE OF CREOLE (*Etheostoma collettei*) AND REDFIN (*E. whipplei*) DARTERS IN THE UPPER SALINE RIVER, SALINE COUNTY, ARKANSAS.

John D. Rickett, Biology Department, University of Arkansas at Little Rock, Little Rock, AR 72204.

TWO ATYPICAL PRECIPITATION SAMPLES AND THE ASSOCIATED AIRQUALITY AND METEOROLOGICAL CONDITIONS.

James C. Petersen, U.S. Geological Survey, 2301 Federal Building, Little Rock, AR 72201.

RELATIONSHIP BETWEEN DIAMETER BREAST HIGH AND DIAMETER NEAR GROUND LINE FOR HARDWOOD SPECIES IN ARKANSAS.

Richard A. Kluender and Jimmy L. Yeiser, Arkansas Agricultural Experiment Station, Forest Resources Department, University of Arkansas, Monticello, AR 71655.

EFFECTS OF JUGLONE (5-HYDROXY-1,4-NAPHTHOQUINONE) ON THE ALGAE *Anabaena flos-aquae*, *Nostoc commune* and *Scenedesmus acuminatus*.

V. Diane Randall, Jacksonville Wastewater Utility, P.O. Box 623, Jacksonville, AR 72076, and J. D. Bragg, Biology Department, Henderson State University, Arkadelphia, AR 71923.

A FOREST DATA BASE FOR ARKANSAS.

Richard A. Kluender and E. Wesley McCoy, Forest Resources Department, University of Arkansas at Monticello, Monticello, AR 71655.

TAGGING AND MARKING CRAWFISH (*Procambarus clarkii*) IN A POPULATION ESTIMATION STUDY.

Frank Meriwether, Agricultural Experiment Station, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

EFFECT OF STUNTING ON THE GROWTH OF BLUE TILAPIA (*Oreochromis aureus*, CICHLIDAE).

Les Torrains and Fran Lowell, Department of Agriculture, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

EVALUATION OF A FIN-RAY SCARRING TECHNIQUE FOR INDIVIDUALLY MARKING FISH.

Les Torrains, Fran Lowell, Department of Agriculture, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601 and Howard Clemens, Department of Zoology, University of Oklahoma, Norman, OK 73069.

A NEW RECORD OF PARASITISM IN THE FINTAIL DARTER, *Etheostoma flabellare* (PERCIDAE: ETHEOSTOMATINI).

Stephen R. Moulton II, Lawrence W. Hinck, and George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

BOTANY

Session Chairperson: Paul Raines

REPRODUCTIVE BIOLOGY OF ISOLATED FERN GAMETO-

PHYTES.

Carol Jacobs Peck, Department of Natural Sciences, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

ECOLOGICAL ANALYSIS OF DISJUNCT POPULATIONS OF THE RARE SHRUB *Neviusia alabamensis*.

Robert D. Wright and Alice A. Long, University of Central Arkansas, Conway, AR 72032.

THE MORPHOLOGY OF *Acremonium coenophialum* SAMUELS, THE SYMBIOTIC FUNGAL ENDOPHYTE OF TALL FESCUE.

Maurice G. Kleve, Thomas J. Lynch and Alvan A. Karlin, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

*PRELIMINARY ISOZYME STUDIES IN TALL FESCUE.

Alvan A. Karlin, Elizabeth A. Rush, Thomas J. Lynch and Maurice Kleve, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

PROPOSED CONSORTIUM EFFORT TOWARD CONTINUANCE OF ARKANSAS FLORA PROJECT.

James H. Peck, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204, Steve L. Orzell, Arkansas Natural Heritage Commission, Little Rock, AR 72201, and Edwin L. Bridges, Arkansas Nature Conservancy, Little Rock, AR 72201.

BLUE-EYED GRASS (*Sisyrinchium*: Iridaceae) OF ARKANSAS.

Kathleen L. Hornberger, Department of Botany and Microbiology, SE-401, University of Arkansas, Fayetteville, AR 72701.

VASCULAR PLANTS OF CROWLEY'S RIDGE IN NORTH-EASTERN ARKANSAS.

Edward L. Richards, Department of Biological Science, Arkansas State University, State University, AR 72467.

SECOND LOCALITY FOR *Dryopteris carthusiana* IN ARKANSAS.

James H. Peck, University of Arkansas at Little Rock, Little Rock, AR 72204.

WOODY VEGETATION OF THE CRYSTAL MOUNTAIN REGION.

Durwood Mayo and P. L. Raines, Amity High School, Amity, AR, and Arkansas State University, State University, 72467.

THE ROLE OF FLAGELLAR ANCHORAGE IN CELL SWIMMING IN THE AMOEBO-FLAGELLATE CELL OF *Protozoarium articulatum*.

Frederick W. Spiegel, Department of Botany and Microbiology, University of Arkansas, Fayetteville, AR 72701.

AUTOTRIPLOIDY IN *ERYTHRONIUM ROSTRATUM* (LILIACEAE): REPRODUCTION, DISTRIBUTION AND ORIGIN.

Bruce L. Carr, Department of Botany and Microbiology, University of Arkansas, Fayetteville, AR 72701.

VERTEBRATE ZOOLOGY I

Session Chairperson: Peggy Dorris

A SURVEY OF THE INTERIOR LEAST TERN ON THE ARKANSAS AND WHITE RIVERS.

Kenneth Lee Smith and William M. Shepherd, Arkansas Natural Heritage Commission, The Heritage Center, Suite 200, 225 East Markham, Little Rock, AR 72201.

Program

*THE EFFECTS OF LOW pH ON LACTATE DEHYDROGENASE KINETICS OF DIVING AND NONDIVING REPTILES.

Salim R. Hurley and Dennis A. Baeyens, Biology Department, University of Arkansas at Little Rock, Little Rock, AR 72204.

*INTERSPECIFIC CORRELATIONS OF HARVEST AND PRICE AS PARAMETERS FOR FUR HARVEST ANALYSIS.

Anita J. Giggelman, James H. Peck, and Gary A. Heidt, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

FANUAL USE OF ABANDONED MINES IN ARKANSAS: VETEBRATE TAXA.

Darrel R. Heath, Gary A. Heidt and David A. Saugey, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204, and the U.S. Forest Service, Mt. Ida, AR 71957.

SURVEY OF BATS IN THE OUACHITA MOUNTAINS OF ARKANSAS.

David A. Saugey, Gary A. Heidt, and Darrell R. Heath, U.S. Forest Service, Mt. Ida, AR 71957, and Department of Biology, University of Arkansas at Little Rock, AR 72204.

POPULATION DECLINE OF THE ENDANGERED INDIANA BAT, *Myotis sodalis*, IN ARKANSAS.

Michael J. Harvey, Department of Biology, Tennessee Technological University, Cookeville, TN 38505, and V. Rick McDaniel, Department of Biological Science, Arkansas State University, State University, AR 72467.

AN ANALYSIS OF BOBWHITE QUAIL POPULATION TRENDS IN ARKANSAS 1967-1983.

Charles R. Preston, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

MODULATION OF THE IMMUNE RESPONSE IN QUAIL BY METHYL PARATHION.

Dale V. Ferguson and Steve Koehler, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

TOE PAD MORPHOLOGY IN PLETHODONTID SALAMANDERS FROM ARKANSAS.

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

ELEMENTS OF THE BAT FAUNA OF SOUTHWESTERN ARKANSAS.

V. Rick McDaniel, Tim W. Steward, Department of Biology, Arkansas State University, State University, AR 72467, and David A. Saugey, U.S. Forest Service, P.O. Box 255, Mt. Ida, AR 71957, and Daniel R. England, Department of Biology, Southern Arkansas University, Magnolia, AR 71753.

ADDITIONAL RECORDS OF THE BAT BUG, *Cimex pilosellus*, ON ARKANSAS BATS.

V. Rick McDaniel, Tim W. Steward, Department of Biology, Arkansas State University, State University, AR 72467, Renn Tumison, Department of Zoology, Oklahoma State University, Stillwater, OK 74078, and Daniel R. England, Department of Biology, Southern Arkansas University, Magnolia, AR 71753.

CHEMISTRY I

Session Chairperson: Dee Palmer

THE PREPARATION OF NOVEL 4-METHYL-5-ARYLOXY PRIMAQUINE ANTIMALARIALS.

Thomas E. Goodwin, Kevin Raney, Christine D. LaRocca, Department of Chemistry, Hendrix College, Conway, AR 72032.

MOBILITY OF NEGATIVE ION IMPURITY CENTERS IN NaCl AND THERMOLUMINESCENCE IN α Al₂O₃.

Louis P. Calderera, Pradip Bandyopadhyay, Chemistry Department, Hendrix College, Conway, AR 72032.

THE PREPARATION OF POTENTIAL ANTIFUNGAL AGENTS.

D. Kilgore and T. E. Goodwin, Department of Chemistry, Hendrix College, Conway, AR 72032.

*ELECTROCHEMICAL STUDIES OF SOME DIHALOGENATED NICOTINIC ACIDS IN AQUEOUS AND APROTIC MEDIA.

Tappi A. Dixon, Lourie A. Battles, Ali U. Shaikh and Frank L. Setliff, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

*VIBRATION RELAXATION IN A PORPHYRIN RING MODEL.

Roger L. Lafarlette and Ralph J. Wolf, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

*COLLISION INDUCED VIBRATIONAL DEACTIVATION OF METHANE. A COMPARISON BETWEEN GAS PHASE AND GAS-SURFACE COLLISIONS.

Lisa D. Schreckenhofer and Ralph J. Wolf, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

SEMICLASSICAL EIGENVALUES.

Ricardo C. Davis and Ralph J. Wolf, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

*EFFECT OF STRETCH-BEND INTERACTIONS ON VIBRATIONAL RELAXATION.

Devinder S. Bhatia and Ralph J. Wolf, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

*SYNTHESIS AND INFRARED SPECTRUM OF HBr: A PHYSICAL CHEMISTRY LABORATORY.

T. A. Dixon, A. F. Gremillion, H. E. Palmer, N. K. Taylor, S. Williams and R. J. Wolf, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

*SYNTHESIS OF POLYURETHANE FOAMS FROM WHEY PERMEATE.

Skip Williams, Tito Viswanathan, University of Arkansas at Little Rock, 33rd & University, Little Rock, AR 72204.

A CHROMATOGRAPHIC METHOD FOR THE SEPARATION AND PURIFICATION OF TRIARYL PHOSPHATES.

Kervin Wynn, Michael A. Heitcamp, and Carl E. Cerniglia, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601, and National Center for Toxicological Research, Jefferson, AR.

IMPLEMENTATION OF THE MICROSCALE ORGANIC CHEMISTRY LABORATORY.

T. E. Goodwin, Department of Chemistry, Hendrix College, Conway, AR 72032.

BIOMEDICAL

Session Chairperson: David Straub

THE NATURE OF BINDING OF CYTOCHROME C TO THE MITOCHONDRIAL MEMBRANE.

Veronica M. Nehus and Randall A. Kopper, Chemistry Department, Hendrix College, Conway, AR 72032.

PROBING SECONDARY STRUCTURE OF OVALBUMIN mRNA BY METHYLATION AND REVERSE TRANSCRIPTION.

James W. Bryan, Randall A. Kopper, Chemistry Department, Hendrix College, Conway, AR 72032, and Charles D. Liarakos,

Arkansas Academy of Science

Biochemistry Department, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

ELUCIDATION OF SECONDARY STRUCTURE OF OVALBUMIN mRNA USING PSORALEN CROSSLINKING AND REVERSE TRANSCRIPTION.

Michael D. Kyzer, Randall A. Kopper, Department of Chemistry, Hendrix College, Conway, AR 72032; and Charles D. Liarakos, Biochemistry Department, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

CHANGES IN PROTEINS AND NUCLEIC ACIDS DURING DEVELOPMENT GROWTH.

Nora Leou and Randall Kopper, Chemistry Department, Hendrix College, Conway, AR 72032.

SURFACE PROTEIN EXPRESSION ON *Tetrahymena thermophila*.

H. D. Love, A. A. Nash, and G. A. Bannon, University of Arkansas for Medical Sciences, Department of Biochemistry, College of Medicine, 4301 W. Markham, Little Rock, AR 72205.

*EFFECTS OF BODY WEIGHT ON DRUG DISCRIMINATION IN THE PIGEON.

Billy W. Massey, Department of Biology, University of Central Arkansas, Conway, AR 72032, and Donald E. McMillan, Department of Pharmacology and Interdisciplinary Toxicology, University of Arkansas for Medical Sciences, 4301 West Markham, Little Rock, AR 72205.

*HISTORY AND USES OF EPHEDRINE.

Michael D. Massey, and Richard Walker, Department of Natural Sciences, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

METHEMOGLOBIN REDUCTION INHIBITION BY DEOXY-HEMOGLOBIN.

Ali Mansouri, University of Arkansas for Medical Sciences and Little Rock Veterans Administration Medical Center, Little Rock, AR 72205.

DOPAMINE-INDUCED SENSITIVITY CHANGE TO TRH IN PITUITARY LACTOTROPHS.

John D. Peck and Jimmy D. Neill, Department of Biology, University of Central Arkansas, Conway, AR 72032, and Department of Physiology and Biophysics, University of Alabama in Birmingham, Birmingham, AL 35294.

PLASMA CORTICOSTERONE CONCENTRATIONS IN COCKERELS BEFORE AND AFTER RUNNING.

Stanley N. David, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

MICROBIOLOGY

Session Chairperson: Jimmy Bragg

ISOLATION OF NUCLEI FROM *Physarum flavicomum*: DEMONSTRATION OF A NUCLEAR CYCLIC AMP PHOSPHODIESTERASE.

Judith A. Bean, Maurice G. Kleve, and Thomas J. Lynch, Department of Biology, University of Central Arkansas, Conway, AR 72032, and Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

**CYCLIC AMP AND CYCLIC GMP PHOSPHODIESTERASE ACTIVITY DURING SCLEROTIZATION OF THE MYXOMYCETE *Physarum flavicomum*.

Keitha R. Smith and Thomas J. Lynch, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204.

MODIFICATION OF STREPTOMYCIN BY A SOIL BACTERIUM. Kyle Weld, Weiner High School, Fisher, AR 72429, and S. Kirkconnell, Arkansas Tech University, Russellville, AR 72801.

*INJURED BACTERIA IN POULTRY PRODUCTS.

Steven Johnson, and S. Kirkconnell, Arkansas Tech University, Russellville, AR 72801, and Robert Waggoner, Tastybird Foods, Russellville, AR 72801.

THYMIDYLATE SYNTHETASE ACTIVITY DURING GROWTH AND DEVELOPMENT OF THE CELLULAR SLIME MOLD, *Dictyostelium discoideum*.

Jo Ann Heslip, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601, and Arthur C. Washington and S. M. Hill, Prairie View A&M University, Prairie View, TX 77446.

ADHERENCE AS A VIRULENCE FACTOR OF *Salmonella enteritidis*.

Jaber Aslanzadeh and Leo J. Paulissen, Department of Botany and Microbiology, University of Arkansas, Fayetteville, AR 72701.

EFFECTS OF pH ON THE EXPRESSION OF FLUORIDE RESISTANCE IN *Streptococcus mutans*.

Karen A. Lau, Susan M. Brussock, and Timothy A. Kral, University of Arkansas, Fayetteville, AR 72701.

TRANSFORMATION OF FLUORIDE RESISTANCE IN *Streptococcus mutans*. Peggy E. Chansley and Timothy A. Kral, University of Arkansas, Fayetteville, AR 72701.

THE EFFECT OF LIVE AND KILLED *Trichomonas vaginalis* ON THE IMMUNE RESPONSE OF MICE.

Terry Hostetler, Roger Rank, and James Daly, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

AQUATIC AND ENVIRONMENTAL II

Session Chairperson: Henry Robinson

ANOMALOUS APPEARANCE OF Cs-137 and Co-58 IN DARDANELLE RESERVOIR.

David M. Chittenden, Department of Chemistry, Arkansas State University, State University, AR 72467.

PARTICULATE MATTER IN FAYETTEVILLE RAINS.

Pat Thasan and Kenneth F. Steele, Department of Geology, University of Arkansas, Fayetteville, AR 72701.

AGE AND GROWTH OF REDEAR SUNFISH, *Lepomis microlophus* (GUNTHER), FROM BOB KIDD LAKE.

Rex R. Roberg, Thoniot T. Prabhakaran and Raj V. Kilambi, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

USEFULNESS OF MICROFICHE READER/PRINTER FOR STUDYING FISH SCALES.

Raj V. Kilambi and Marvin L. Galloway, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

A NEW CAVE CRAYFISH POPULATION IN ARKANSAS.

Arthur V. Brown and C. Stanley Todd, Department of Zoology, University of Arkansas, Fayetteville, AR 72701, and Kenneth L. Smith, Arkansas Natural Heritage Commission, Suite 200, The Heritage Center, Little Rock, AR 72201.

CONTINUED DDT PERSISTENCE IN MISSISSIPPI RIVER DELTA STREAMS: A CASE STUDY.

Stephen A. Sewell and Luther A. Knight, Jr., Department of Biology, University of Mississippi, University, MS 38677.

Program

ACCELERATED TRANSPORT OF MONOMERIC ALUMINUM IN THE HEADWATERS OF TWO OUACHITA MOUNTAIN STREAMS.

J. Nix, Department of Chemistry, Ouachita Baptist University, Arkadelphia, AR 71923.

VERTEBRATE ZOOLOGY II

Session Chairperson: Perry M. Johnston

MORPHOLOGICAL VARIATION IN A POPULATION OF THE WESTERN LESSER SIREN (*Siren intermedia nettingi* GOIN).

Derrick W. Sugg, D. R. Heath, and A. A. Karlin, University of Arkansas at Little Rock, Biology Department, 33rd & University Avenue, Little Rock, AR 72204.

HARVEST TRENDS OF THE BOBCAT (*Felis rufus*) IN ARKANSAS.

Renn Tumblison and V. Rick McDaniel, Department of Zoology, Oklahoma State University, Stillwater, OK 74078, and Department of Biology, Arkansas State University, State University, AR 72467.

A MODEL FOR ULTRAVIOLET-INDUCED CHROMATID ABERRATION PRODUCTION IN VERTEBRATE CELLS.

Susan Kulp and H. Gaston Griggs, Department of Biology, John Brown University, Siloam Springs, AR 72761.

THE RIVER OTTER IN ARKANSAS. IV. WINTER FOOD HABITS IN EASTERN ARKANSAS.

Renn Tumblison, Anthony W. King, and V. Rick McDaniel, Department of Zoology, Oklahoma State University, Stillwater, OK 74078, Graduate Program in Ecology, University of Tennessee, Knoxville, TN 37996, and Department of Biology, Arkansas State University, State University, AR 72467.

OBSERVATIONS OF MALE COMBAT DANCE IN THE COTTON-MOUTH (*A. piscivorus*).

Bart Folgeman, William Byrd, and Earl Hanebrink, Department of Biological Science, Arkansas State University, State University, AR 72467.

CHEMISTRY II

Session Chairperson: Warfield Teague

*OPTIMIZATION FOR KINETIC STUDY OF SUCCINATE DEHYDROGENASE IN RAT LIVER.

Collie B. Shaw, Tara L. Chronister, and John D. Peck, Department of Biology, University of Central Arkansas, Conway, AR 72302.

pH-DEPENDENT SUPEROXIDE DISMUTASE (SOD)-LIKE ACTIVITY OF COPPER(II) ETHYLENEDIAMINE-TETRAACETIC ACID (CuEDTA).

William M. Willingham, John R. J. Sorenson, Darla Long and Anita Groves, Department of Natural Sciences, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601, Department of Biopharmaceutical Sciences, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

*SYNTHESIS OF NAPHTHYL CHROMANONES.

Raymond Hawkins and Uttam K. Jagwani, Natural Sciences Department, University of Arkansas at Pine Bluff, AR 71601.

THE HIGH TEMPERATURE CHEMISTRY OF THE CALCIUM-OXYGEN-SULFUR SYSTEM ON METAL SILICATE SURFACES.

J. Edward Bennett and Luis Morales, Department of Chemistry, Arkansas State University, State University, AR 72467.

CARBON-14 ISOTOPE EFFECTS IN THE BROMINATION OF SUBSTITUTED STILBENES, $X-C_6H_4-CH=CH-C_6H_4-Y$.

Pandurang Kokil and Arthur Fry, Department of Chemistry and Biochemistry, University of Arkansas, Fayetteville, AR 72701.

*DETERMINATION OF TRACE CHROMIUM IN PLANT MATERIALS AND YEAST BY ELECTROTHERMAL ATOMIC ABSORPTION SPECTROSCOPY.

Terry G. Fletcher and Edmond W. Wilson, Jr., Department of Physical Science, Harding University, Searcy, AR 72143.

HYDROGEN TRANSFER CATALYSIS WITH POLYMER BOUND ANTHRANILIC ACID Pd(II) COMPLEXES.

Laurence J. Boucher and Cindy L. Elder, Departments of Chemistry, Arkansas State University, Jonesboro, AR 72401, and Western Kentucky University, Bowling Green, KY 42101.

**DEVELOPMENT OF A SENSITIVE METHOD TO MEASURE AFLATOXIN B₁, B₂, G₁ AND G₂ USING ELECTROCHEMISTRY.

Monica L. Wooley, Benjamin T. Duhart, Stoney E. Shaw and Tina R. Allen, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

CONCANAVALIN A-NONBINDING ENZYMES OF *Crotalus Scutulatus Scutulatus* VENOM.

C. K. Childs, M. W. Hinson, D. H. Sifford, and B. D. Johnson, College of Arts and Sciences, Arkansas State University, State University, AR 72467.

ABSOLUTE CONFIGURATION OF THE CACTUS ALKALOIDS ANHALONIDINE AND PELLONINE.

Richard B. Walker, Department of Natural Sciences, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601, and John C. Craig, Department of Pharmaceutical Chemistry, University of California at San Francisco, San Francisco, CA 94122.

*BOMB CALORIMETRY: THE ENERGY CONTENT OF A HAMBURGER.

Bret Shirley and Edmond W. Wilson, Jr., Department of Physical Science, Harding University, Searcy, AR 72143.

GENERAL

Session Chairperson: Clark McCarty

STYLE AND TIMING OF DISPLACEMENT ALONG THE WASHITA VALLEY FAULT, SOUTHERN OKLAHOMA.

Randy Tom Cox and Roy VanArsdale, Department of Geology, University of Arkansas, Fayetteville, AR 72701.

DEPOSITIONAL HISTORY OF THE ST. JOE-BOONE FORMATIONS IN NORTHERN ARKANSAS.

Phillip R. Shelby, Department of Geology, University of Arkansas, Fayetteville, AR 72701.

COMPARISON OF THE SYMBIOTIC FAUNA OF THE FAMILY PLETHODONTIDAE IN THE OUACHITA MOUNTAINS OF WESTERN ARKANSAS.

Douglas A. Winter and Wojciech M. Zawada, Hendrix College, Conway, AR 72032.

PENETRATING RADIATION IN THE LOWER ARKANSAS AND WHITE RIVER VALLEYS OF ARKANSAS.

C. Epperson, S. Meiners and D. Swindle, University of Arkansas for Medical Sciences, Little Rock, AR 72205.

X-RAY FLUORESCENCE SPECTROSCOPY OF TREATED FENCE POSTS.

H. B. Eldridge, Physics Department, University of Central Arkansas, Conway, AR 72032, and N. C. Jacobus, Applications Laboratory, EG&G-ORTEC, Oak Ridge, TN 37830.

Arkansas Academy of Science

THE EFFECTS OF THE CORIOLIS FORCE AND AIR RESISTANCE ON FALLING BODIES.

Ananda Shastri, Department of Physics, University of Central Arkansas, Conway, AR 72032.

LEAST-SQUARES FITTING A SEMI-EMPIRICAL FUNCTION.

Jeff Sharp, Department of Physics, University of Central Arkansas, Conway, AR 72032.

INVERTEBRATE ZOOLOGY

Session Chairperson: Claudia Bailey

DISTRIBUTION AND SEASONAL OCCURRENCE OF THE COREOIDEA (INSECTA: HEMIPTERA) OF ARKANSAS.

Harvey E. Barton, Arkansas State University, P.O. Box 501, State University, AR 72467, and Linda A. Lee, Pocahontas High School, Pocahontas, AR 72455.

*POST EMERGENCE ASPECTS OF THE LIFE CYCLE OF *Magdicada cassini*.

Johnny T. Stine, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

ANATOMY OF ADULT MALE AND FEMALE REPRODUCTIVE SYSTEMS OF *Menecles insertus* (SAY) (HEMPTERA: PENTATOMIDAE).

Linda A. Lee, Pocahontas High School, Pocahontas, AR 72455, and Harvey E. Barton, Arkansas State University, P.O. Box 501, State University, AR 72467.

A PRELIMINARY STUDY OF SPECIES OF SPIDERS COLLECTED IN PIT TRAPS IN DREW COUNTY AND BRADLEY COUNTY, ARKANSAS WATERSHEDS.

Peggy Rae Dorris, Department of Biology, Henderson State University, Arkadelphia, AR 71923, and Lynn Thompson, Forestry Department, University of Arkansas at Monticello, Monticello, AR 71655.

PROTRACTED OVIPOSITION BY *Hetaerina titia* (DRURY) (ZYGOPTERA: CALOPTERYGIDAE).

George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

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GENETIC VARIABILITY IN PERIODIC CICADIDS FROM NORTHERN ARKANSAS.

Derrick W. Sugg, A. A. Karlin, E. A. Rush, K. Smith, C. Williams, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204 and Department of Zoology, University of Arkansas at Fayetteville, Fayetteville, AR 72701.

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Peggy Rae Dorris, Henderson State University, Arkadelphia, AR 71923.

A CHECKLIST OF THE CERAMYCIDAE OF ARKANSAS.

Robert T. Allen and C. E. Carlton, Department of Entomology, University of Arkansas, Fayetteville, AR 72701.

SELECTED BIOLOGICAL ASPECTS OF *Gomphus ozarkensis* WESTFALL (ODONATA: GOMPHIDAE).

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SCIENCE EDUCATION

Session Chairperson: Dick Hansen

A STUDY OF COLLEGE AND UNIVERSITY PROGRAMS IN GENERAL EDUCATION BIOLOGY.

Neal Buffaloe, Department of Biology, University of Central Arkansas, UCA Box 1721, Conway, AR 72032.

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Stephen R. Addison, Maurice Ayers, Ralva Bass, Denver Prince, and Hudson B. Eldridge, Physics Department, The University of Central Arkansas, Conway, AR 72032.

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H. B. Eldridge and H. L. Pray, Physics Department, University of Central Arkansas, Conway, AR 72032.

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Richard S. Mitchell, Department of Chemistry, Arkansas State University, State University, AR 72467.

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UNIVERSITY OF ARKANSAS AT MONTICELLO'S 1985 SUMMER SCIENCE INSTITUTE.

Eric Sundell, Department of Natural Sciences, University of Arkansas at Monticello, Monticello, AR 71655.

ACTIVITIES AT UALR IN SUPPORT OF SCIENCE EDUCATION.

Richard Hanson and Fred Watson, University of Arkansas at Little Rock, 33rd and University Avenue, Little Rock, AR 72204.

A SUMMER SCIENCE PROGRAM THAT LASTS ALL YEAR.

Fred Watson and Richard Hanson, University of Arkansas at Little Rock, 33rd and University Avenue, Little Rock, AR 72204.

THE EFFECTS OF LOW pH ON LACTATE DEHYDROGENASE KINETICS OF DIVING AND NONDIVING REPTILES

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ABSTRACT

The properties of lactate dehydrogenase were examined in two snake species, *Nerodia rhombifera* and *Elaphe obsoleta*, and a turtle species, *Pseudemys scripta*. Our purpose was to compare the LDH activity of reptiles with limited anaerobic capabilities with that of the well established diver *Pseudemys*. The Michaelis-Menten kinetics of LDH and its susceptibility to inhibition by elevated pyruvate concentrations were investigated in the brain and heart of the three species. All tissue incubations and enzyme activity determinations were done at a pH of 7.0 in order to simulate a diving blood pH in the three species.

In both tissues the LDH activity of the snakes was higher than that of *Pseudemys* at pyruvate concentrations ranging between .03 mM and .50 mM. The K_m values of the snakes were lower than those of *Pseudemys*, suggesting a greater enzyme-substrate affinity in the snake tissues. The V_{max} values were higher in the snake tissues indicating a faster conversion of substrate to product.

Heart LDH activity was reduced to an equal extent by high pyruvate concentrations in each of the three species. *Elaphe* brain LDH was most susceptible to pyruvate inhibition, but *Nerodia* and *Pseudemys* brain LDH were inhibited to an equal extent.

The results indicate that the kinetic behavior of brain and heart LDH of the three species is similar at a pH of 7.4 and a pH of 7.0. The results also suggest that the LDH of *Pseudemys* is no better adapted to withstand anaerobic conditions than that of *Nerodia* or *Elaphe* at a pH of 7.0.

INTRODUCTION

Representative species of each of the vertebrate classes have the ability to remain submerged for extended periods of time. These animals are commonly referred to as the diving animals. In the past the diving birds and mammals have received the most attention, but more recently many studies have focused on diving reptiles.

The diving capabilities of sea snakes are well documented (Graham, 1974; Heatwole and Seymour, 1975; Heatwole, 1975). Less aquatic snakes can also remain submerged for periods in excess of 1 hour (Baeyens et al., 1980). The turtles are, however, the best reptilian divers. Many fresh water turtles can tolerate periods of submergence of several hours at summer temperatures (Burggren and Shelton, 1979; Lucey and House, 1977; Penney, 1974) while at winter temperatures they can remain submerged for periods of four to six months (Musacchia, 1959; Ultsch and Jackson, 1982).

The diving capabilities of reptiles have been attributed to various physiological adaptations, but the most important factor prolonging dive times in reptiles is an especially pronounced ability to liberate energy through anaerobic metabolism (Jackson, 1968). The tissue enzymes of diving reptiles appear to have special properties that enable them to liberate large quantities of ATP by anaerobic means (Lutz et al., 1978; Simon et al., 1979; Storey and Hochachka, 1974).

The kinetic properties and susceptibility to substrate inhibition of the glycolytic enzyme, lactate dehydrogenase (LDH), have been studied in heart and brain of *Nerodia rhombifera*, *E. obsoleta* and *Pseudemys scripta* (Baeyens et al., 1985). These studies were carried out at a pH of 7.4 which simulates a nondiving blood pH in these three species. The results indicated that the kinetic behavior of the enzyme was similar in the three species.

The present study examines LDH in heart and brain of *N. rhombifera*, *E. obsoleta* and *P. scripta*. All incubations and enzyme analyses were done at a pH of 7.0, which simulates a diving pH in the three species. We examined the Michaelis-Menten kinetics of LDH and the susceptibility of LDH to pyruvate inhibition. It was hoped that examining the properties of tissue LDH would lead to a better understanding of the difference in anaerobic threshold between the snakes and *Pseudemys*.

MATERIALS AND METHODS

N. rhombifera (55-63 cm snout vent length [SVL]) were collected from minnow ponds in Lonoke County, Arkansas. *E. obsoleta* (80-105 cm SVL) were collected from wooded areas in Pulaski County, Arkansas. *P. scripta* were obtained from commercial dealers. All animals were maintained at room temperature (20-25°C) and were allowed at least 30 days to acclimate to captive conditions before they were used for experimentation.

Enzyme activity was measured in brain and heart homogenates of the three species. Four individuals of each species were used for enzyme analysis. After determining that there was no significant variation in LDH activity for a specific tissue within a species, the results obtained for the four individuals of that species were pooled and compared with the results obtained from the other two species. Enzyme activity was expressed as a change in absorbency/min/mg protein. Protein concentration was determined by the method of Lowry et al. (1951) using bovine serum albumin as a standard. The differences between the means of K_m and V_{max} values were analyzed by Student's t-tests.

Tissue preparation

Animals were killed by cervical dislocation and samples of brain and heart were immediately removed from the animal. The tissue samples were weighed to the nearest mg and then homogenized in 0.1 M phosphate buffer (pH 7.0) in a ratio of 1 g of tissue to 7 ml of buffer. After homogenization the samples were centrifuged at 2500 x g for 40 minutes. The supernatant was stored at -80°C. Preceding enzyme analysis the supernatant was further diluted with 0.1 M phosphate buffer in a ratio of 1 part homogenate to 9 parts phosphate buffer.

LDH activity determinations

LDH activity was measured by spectrophotometrically recording the oxidation of NADH to NAD^+ with a Varian dual beam spectrophotometer (model DMS90). The assay mixture consisted of 2.8 ml of 0.1 M phosphate buffer (pH 7.0), 100 μ l of sodium pyruvate of variable concentration, and 100 μ l of 6.6 mM NADH. The reaction was initiated by adding 10 μ l of the tissue homogenate to the mixture in a cuvette. After mixing, the decrease in absorbency was measured over a 5 minute period.

The Effects of Low pH on Lactate Dehydrogenase Kinetics of Diving and Nondiving Reptiles

Six concentrations of pyruvate, ranging from 0.03 mM to 0.5 mM, were used to examine the Michaelis-Menten kinetics of LDH. Lineweaver-Burk plots were constructed from the means of four measurements at each pyruvate concentration. Apparent K_m and V_{max} values were calculated from the plots.

Susceptibility of LDH to substrate inhibition was determined by varying the concentration of pyruvate in the reaction mixture between 0.16 mM and 6.6 mM. Four measurements were made at each of six different substrate concentrations within this range and the results were averaged for each concentration.

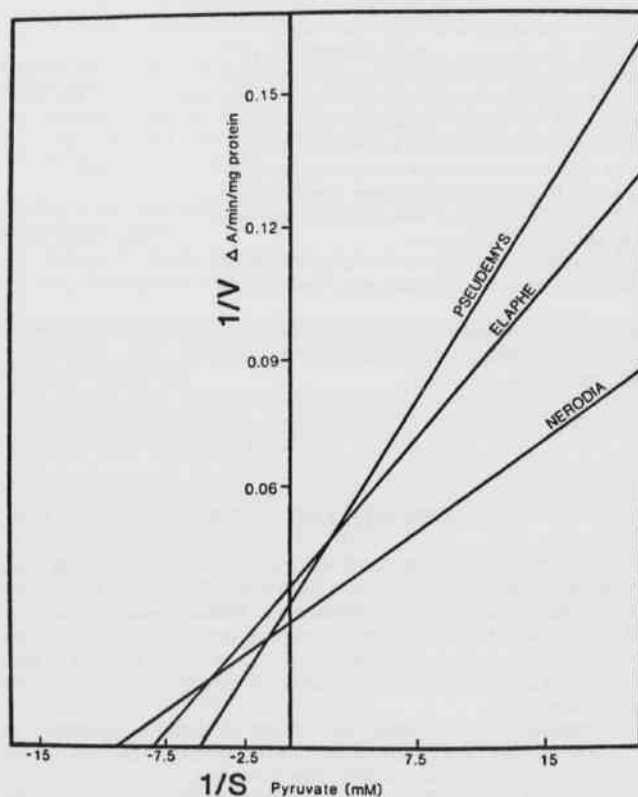


Figure 1. Lineweaver-Burk plot of brain LDH activity in *N. rhombifera*, *E. obsoleta* and *P. scripta*.

Table 1. Summary of the brain and heart LDH kinetic data in *N. rhombifera*, *E. obsoleta* and *P. scripta* at pH 7.0.

SPECIES	TISSUE	V_{max}	K_m
<i>N. rhombifera</i>	Brain	27.03	2.08**
<i>E. obsoleta</i>	Brain	21.28*	2.68
<i>P. scripta</i>	Brain	23.26	4.00
<i>N. rhombifera</i>	Heart	71.43	5.56
<i>E. obsoleta</i>	Heart	71.43	7.69
<i>P. scripta</i>	Heart	62.50***	7.69***

*Significantly different from *P. scripta* and *N. rhombifera* brain ($P < 0.05$)

**Significantly different from *P. scripta* brain ($P < 0.05$)

***Significantly different from *N. rhombifera* and *E. obsoleta* heart ($P < 0.05$)

****Significantly different from *N. rhombifera* heart ($P < 0.05$)

RESULTS

Kinetic Studies

Figures 1 and 2 represent Lineweaver-Burk plots for brain and heart LDH of the three species. *Nerodia* brain LDH activity was highest throughout the range of pyruvate concentrations utilized, while *Pseudemys* brain had the lowest activity (Fig. 1). The V_{max} value of *Nerodia* brain was also the highest of the three species. In contrast, the apparent K_m value of *Nerodia* was the lowest of the three species while that of *Pseudemys* was the highest.

The kinetics of heart LDH are shown in Figure 2. *Nerodia* had the highest activity throughout the range of substrate concentrations and *Pseudemys* had the lowest. The V_{max} values were greater in the two snakes than in *Pseudemys*. The apparent K_m of *Nerodia* was lower than that of *Pseudemys* and *Elaphe*. The K_m and V_{max} values for brain and heart are summarized in Table 1.

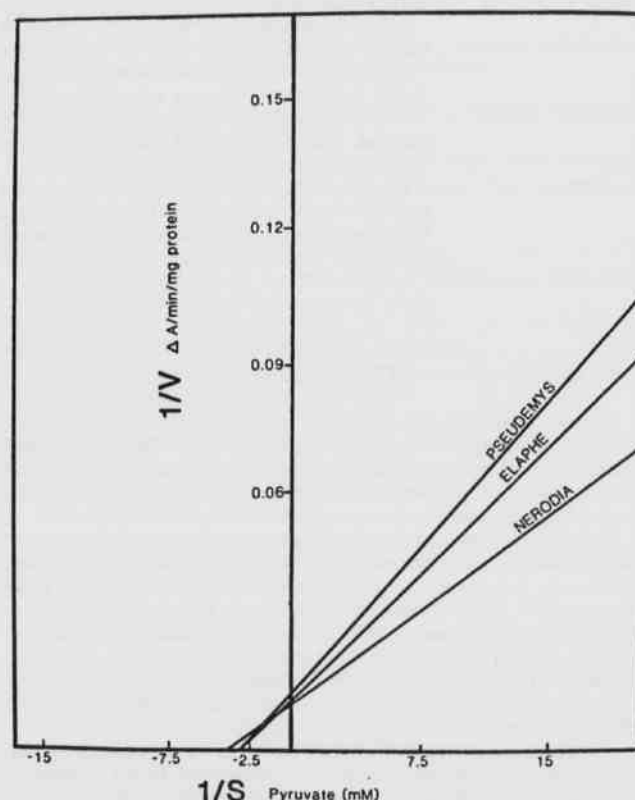


Figure 2. Lineweaver-Burk plot of heart LDH activity in *N. rhombifera*, *E. obsoleta* and *P. scripta*.

Substrate Inhibition Studies

Highest brain LDH activity occurred at a 0.5 mM pyruvate concentration in all three species (Fig. 3). At higher substrate concentrations there was a progressive and equal reduction in enzyme activity in *Nerodia* and *Pseudemys*. The degree of substrate inhibition was greater in *Elaphe* than in either of the other two species.

Highest heart LDH activity occurred at a 1.0 mM pyruvate concentration in *Pseudemys*, a 1.33 mM pyruvate concentration in *Elaphe* and 1.66 mM pyruvate concentration in *Nerodia* (Fig. 4). At substrate concentrations between 1.0 mM and 3.33 mM *Pseudemys* demonstrated the greatest degree of substrate inhibition. At substrate concentrations in excess of 3.33 mM the degree of substrate inhibition was approximately equal in the three species.

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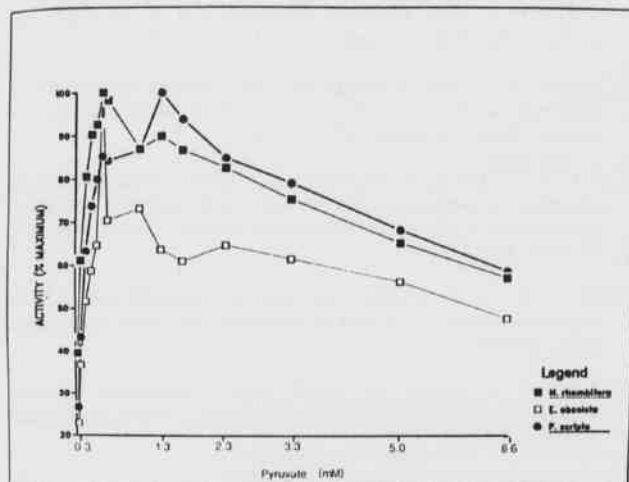


Figure 3. Substrate inhibition plot of brain LDH activity in *N. rhombifera*, *E. obsoleta* and *P. scripta*.

DISCUSSION

An increased reliance on anaerobic glycolysis during diving seems to be of particular importance in extending the dive times of reptiles. Belkin (1962) found that blocking glycolysis with iodoacetate in the loggerhead musk turtle, *Stenothaerus minor*, resulted in a significant decrease in underwater survival time. Similarly, blocking glycolysis in the river cooter, *Pseudemys concinna*, permitted indefinite survival in air but rendered the animal incapable of prolonged diving (Belkin, 1961).

An increased reliance on anaerobic glycolysis during diving is also indicated by the increased levels of pyruvate and lactate which accumulate in the blood and tissues. Altman and Robin (1969) noted progressive increases in blood pyruvate and lactate while diving for a 24 hour period in *P. scripta*. There was an approximate doubling of the pyruvate level and the lactate level increased over 8-fold. Clark and Miller (1973) found increases in the levels of pyruvate and lactate in brain, heart and liver of *P. scripta* following a 3 hour period of anaerobiosis. The pyruvate levels increased in each tissue, more than doubling in brain and heart to values in excess of $0.2 \mu\text{M/g}$, while the lactate levels increased from approximately $5 \mu\text{M/g}$ to over $40 \mu\text{M/g}$ in the same time period. Similar increases in blood lactate and pyruvate during diving have been reported in the sea turtle, *Chelonia mydas*, (Berkson, 1966; Hochachka et al., 1973) and the western painted turtle, *Chrysemys picta* (Jackson and Heisler, 1982). Diving induced increases in blood lactate have also been observed in snakes. Seymour and Webster (1975) measured blood lactate in four species of sea snakes (following forced dives of 0.5 hour duration and found that the values increased from pre-dive levels of 10 mg% to over 60 mg%. We have found similar increases in blood lactate in *N. rhombifera* following 20 minute forced dives in our laboratory (unpublished observation).

In addition to the accumulation of pyruvate and lactate, there is a concomitant decrease in blood pH as a result of diving. Berkson (1966) found that the arterial pH of the Pacific green turtle, *Chelonia mydas*, fell from a pre-dive value of 7.4 to approximately 7.0 after 1 hour of submergence. Likewise, Ullsch et al. (1984) measured precipitous drops in blood pH, to values approaching 7.0, in four species of fresh water turtles during period of anaerobiosis.

The increased accumulation of pyruvate and lactate with the fall in blood pH suggests a greater glycolytic activity during diving. Miller and Hale (1968) measured the activity of the glycolytic enzyme LDH in *P. scripta* and rat brain. They found significantly greater enzyme activity in *Pseudemys* brain and concluded that this was at least partially responsible for the ability of the turtle brain to withstand longer periods of anaerobiosis.

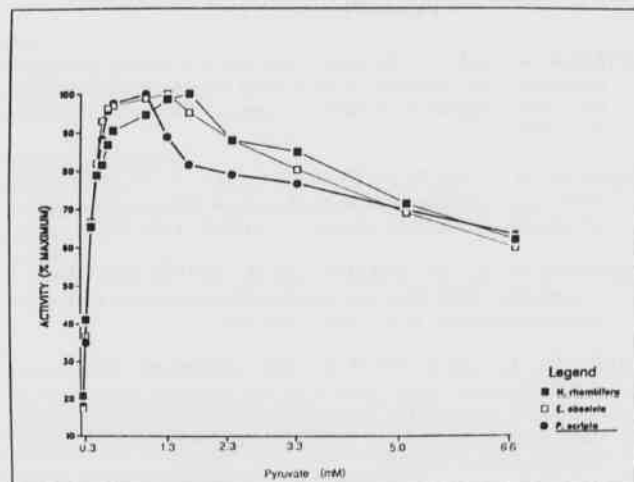


Figure 4. Substrate inhibition plot of heart LDH activity in *N. rhombifera*, *E. obsoleta* and *P. scripta*.

The Michaelis-Menten kinetics of LDH in brain and heart of *N. rhombifera*, *E. obsoleta* and *P. scripta* have been compared at a pH of 7.4 in a previous study (Baeyens et al., 1985). The results of that study indicated that there was no relationship between the LDH activity of brain and heart and the ability to withstand anaerobic conditions in the three species.

In the present study, carried out at a pH of 7.0, we found that there was less LDH activity in brain and heart of *Pseudemys* than in either *Nerodia* or *Elaphe* at pyruvate concentrations ranging between 0.03 and 0.50 mM. Furthermore, the K_m values of snake brain and heart were lower than those of *Pseudemys* suggesting a greater affinity of LDH for pyruvate in the snakes. Finally, the higher V_{max} values of snake brain and heart suggest a faster conversion of pyruvate to lactate when the enzyme is saturated with substrate. Thus, the enzyme demonstrates similar kinetic behavior at a pH of 7.4 and a pH of 7.0 in brain and heart and there appears to be no correlation between LDH activity and anaerobic threshold in the three species.

The capability of prolonged underwater survival may be related to the tissue distribution of LDH isozymes in diving reptiles. For example, Miller and Hale (1968) found a higher proportion of M subunits in brain and heart of *P. scripta* than in the same tissues of the albino rat. Furthermore, the proportions of M subunits in turtle brain, heart and skeletal muscle were similar to those in mammalian skeletal muscle. Since mammalian skeletal muscle is highly adapted to anaerobic conditions, they reasoned that the turtle tissues were similarly adapted.

Altman and Robin (1969) found that both heart and skeletal muscle LDH of *P. scripta* had similar proportions of H and M subunits. In addition, the pyruvate inhibition patterns were virtually identical in both tissues. In a related study, the properties of LDH M and H subunits were examined in liver and skeletal muscle of the marine turtle *Caretta caretta* (Baldwin and Gyuris, 1983). Using purified H₄ and M₄ isozymes they found that the H₄ activity progressively fell with increasing pyruvate concentrations. In contrast, the M₄ activity was completely insensitive to substrate concentration.

Having LDH with a high M subunit activity would clearly be advantageous during a dive because of its ability to remain functional in the presence of high substrate concentrations. Comparisons of heart LDH activity in the present study reveals that *Pseudemys* LDH is no more resistant to substrate inhibition than is the snake enzyme. Likewise, in brain the degree of substrate inhibition was no greater in *Nerodia* than in *Pseudemys*. These findings suggest that a possible M subunit adaptation to anaerobic conditions may be important in extending the dive times in all three species. The results also indicate that the greater dive times of *Pseudemys* cannot be explained solely on the basis of a unique M subunit adaptation in this species.

The Effects of Low pH on Lactate Dehydrogenase Kinetics of Diving and Nondiving Reptiles

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THE ISOLATION OF NUCLEI FROM *PHYSARUM FLAVICOMUM*: DEMONSTRATION OF A NUCLEAR CYCLIC AMP PHOSPHODIESTERASE

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ABSTRACT

Cyclic AMP phosphodiesterase activity in the nucleus of the myxomycete *Physarum flavicomum* was demonstrated by cytochemical staining utilizing electron microscopy and by enzymatic assays with tritiated cyclic AMP as the substrate. Cytochemical staining showed *Physarum's* plasmodial phosphodiesterase activity to be located in the nucleus, along the plasma membrane, in vesicles, and free in the cytoplasm. Nuclear phosphodiesterase, which may be cell cycle dependent, was primarily located in the nucleolus. Nuclei from three to five day old microplasmodial cultures were isolated by the method of Henney and Yee. Whole cells were collected through centrifugation and washed. Pellets were homogenized in a medium composed of 0.01 M Tris-HCl (pH 7.2 at 4 °C), 0.25 M sucrose, 0.01% Triton X-100, and 5 mM CaCl₂. Nuclei were collected through double filtration and two 1.0 M sucrose density gradient centrifugations. After the nuclei were washed, microscopic examination revealed a purity of over 90%. Radioactive assays of the nuclear preparations demonstrated phosphodiesterase activity consistent with that indicated by cytochemical localization. The specific activity of the nuclear enzyme was 15 nMole of cyclic AMP hydrolyzed /min/mg. of protein.

INTRODUCTION

Adenosine 3',5'-monophosphate (cAMP) is involved in the modulation of an array of metabolic, growth, and differentiation events (Konijn et al., 1967; Whitfield et al., 1979; Bombik and Burger, 1973; Froehlich and Rachmeler, 1972; Burger et al., 1972). Cyclic AMP functions both as an intracellular and intercellular signal transducer. The level of cAMP in and around cells is regulated by the interplay of the cAMP synthetic enzyme adenylate cyclase and the enzyme responsible for the hydrolysis of cAMP, which is cyclic 3',5'- nucleotide phosphodiesterase.

Myxomycetes are excellent models for the study of cAMP and its regulatory enzymes. The multistaged life cycle of myxomycetes alternates between diploid and haploid vegetative forms which may reproduce asexually by spore formation or sexually by fusion of haploid cells to form a zygote. The predominate structure in the diploid phase is the plasmodium. The plasmodium is a large single cell that is multinucleated. Each plasmodium contains millions of nuclei and all the nuclei within one plasmodium divide at the same time demonstrating mitotic synchrony. The typical *Physarum* cell cycle takes 10-12 hours, 20 minutes of which are required for mitosis. These events in the plasmodium provide a valuable model for the study of mitotic regulation.

Several molecular forms of intracellular and intercellular phosphodiesterase are found in the various life cycle stages of myxomycetes (Lynch and Farrell, 1984a; 1984b, and 1985). Since phosphodiesterase is the only enzyme known to hydrolyze cAMP, each of these forms may play a role in the function of cAMP in life cycle events. Knowledge of the state specific cellular location of phosphodiesterase will increase our understanding of the role of cAMP in myxomycetes.

This report will describe the electron microscopic localization of phosphodiesterase in the plasmodia of the myxomycete *Physarum flavicomum* and the demonstration of phosphodiesterase activity by the hydrolysis of ³H-cAMP in isolates of purified plasmodial nuclei.

MATERIALS AND METHODS

Microplasmodia of *Physarum flavicomum*, grown in liquid shake cultures (Lynch and Farrell, 1984), were harvested at 5 days by cen-

trifugation at 2500 xg for 10 min. and washed with cold distilled water. Microplasmodia were prepared for electron microscopic localization of phosphodiesterase by the technique of Florendo, et al., 1978. The cells were fixed in 0.2% glutaraldehyde buffered with 0.25 M sodium cacodylate at pH 7.4. Following a buffer wash the cells were preincubated for 30 min. at room temperature in a reaction medium containing 80 mM Tris Maleate, 250 mM sucrose, and 3 mM MgSO₄, at pH 7.4. This media included 5 mg/ml snake venom from *Crotalus atrox* (as a source of exogenous 5' nucleotidase) which hydrolyzes all existing 5' nucleotides that may yield a false reaction product. Free phosphate was removed by washing the cells in reaction medium without snake venom. They were then incubated at 37 °C for 30 min. in reaction media containing 80 mM Tris maleate, 250 mM sucrose, 3 mM cyclic AMP (as an exogenous substrate), 3 mg/ml snake venom, and 2 mM lead nitrate at pH 7.4. This incubation results in the hydrolysis of exogenous cAMP to 5'AMP which is then hydrolyzed to liberate phosphate which in turn reacts with available lead ions to form an electron opaque precipitate at the reaction site. Controls were incubated in reaction medium without 3 mM cyclic AMP as an exogenous substrate. This control demonstrates any non-specific lead-phosphate deposition. After incubation, the cells were rinsed with 0.1 M cacodylate buffer and postfixed with 1% osmic acid for 30 min. The tissues were dehydrated through graded acetone series and embedded in Spurr's epoxy resin (Spurr, 1969). Ultrathin and semithin sections were cut with a Porter-Blum MT2 ultramicrotome, poststained with saturated methanolic uranyl acetate, and examined in the STEM mode on an ISI DS 130 electron microscope.

Microplasmodial nuclei were isolated and purified using the method of Henney and Yee (1979). Cells were homogenized in a media containing 0.01 M Tris-HCl, 0.25 M sucrose, 0.01% Triton X-100 and 5 mM CaCl₂ at pH 7.2 and 4 °C. Nuclei were separated from cellular debris by two successive filtrations through milk filters. Isolated nuclei were disrupted by treatment in a Mickel Disintegrator min at 4 °C. Cyclic AMP phosphodiesterase activity was measured by a well established resin procedure using ³H-cyclic AMP as the substrate (Lynch and Cheung, 1975).

The Isolation of Nuclei from *Physarum flavicomum*: Demonstration of a Nuclear Cyclic Amp Phosphodiesterase

RESULTS

Cyclic AMP phosphodiesterase activity was ultrastructurally localized in the microplasmodia of *Physarum flavicomum* by the presence of electron opaque lead phosphate precipitate at the enzyme reaction site (Figures 1 and 2). Enzyme activity appeared to be located in four distinct regions; (1) bound to the plasma membrane, (2) free in the cytosol, (3) inside vesicles and (4) in the nucleus. In Figure 1 the enzyme activity is localized in the cytosol and bound to the membrane of cytoplasmic vesicles. No nuclear labeling is seen in these cells. In some cells observed, the label also appears bound to the outside of the plasma membrane. In Figure 2 the enzyme is localized in the cytosol and in the nuclei. The nuclear enzyme appears to be exclusively located in the nucleolus. The staining pattern of the nucleolar enzyme indicates that it exists in both an active and inactive form. Control tissue demonstrated no significant lead deposition.

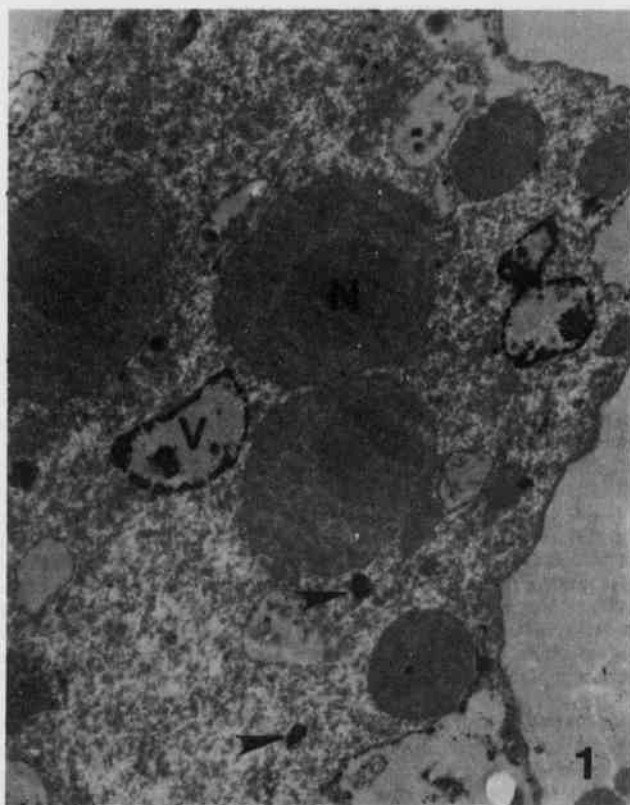


Figure 1. Electron micrograph of cytochemical localization of phosphodiesterase activity in microplasmodium. Dense label is localized in cytoplasmic vesicles (V). Light localization is seen in the cytosol (arrows). The nucleus and nucleolus (N) demonstrate little or no labelling. X 6000

To further demonstrate the presence of a nuclear enzyme, we isolated and purified plasmodial (Figure 3) nuclei and directly assayed these nuclear fractions for phosphodiesterase activity. These nuclei were disrupted with a Mickel Disintegrator and aliquots were assayed for enzyme activity. As seen in Table 1, these isolated nuclear preparations contained enzyme activity of about 15 nMole of cyclic AMP hydrolyzed/min/mg of protein.

DISCUSSION

We previously reported on both intracellular and extracellular

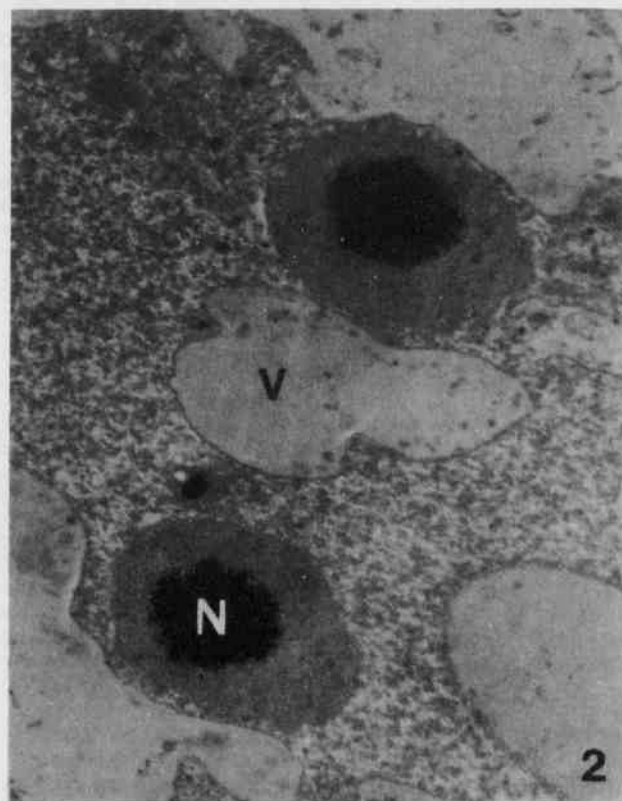


Figure 2. Electron micrograph of cytochemical localization showing intense labelling of phosphodiesterase activity in the nucleolus (N). Light labeling occurs in the cytoplasm. No label was noted in cytoplasmic vesicles (V). X 6000

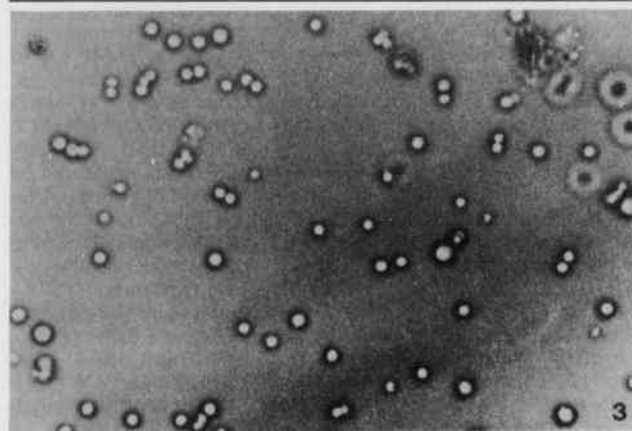


Figure 3. Light micrograph of isolated nuclei diluted from the final centrifugation pellet. X 600

phosphodiesterase from the plasmodium of *P. flavicomum*. The intracellular enzyme was most likely a mixture of the various enzymic forms indicated by Figures 1 & 2. Indeed, as indicated by our first publication on this enzyme, we showed that soluble enzyme activity would vary depending on how fast we centrifuged our homogenates (Lynch and Farrell, 1984a). The data in this paper suggest that the results may have been due to the heterogenous nature of the enzyme.

The enzyme localized inside vesicles in Figure 1 may indeed be the same extracellular enzyme that we reported on previously. If so, the

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Table 1. Cyclic AMP phosphodiesterase activity from isolated, broken nuclei.

Cyclic AMP Phosphodiesterase Activity From Isolated, Broken Nuclei			
Sample Size	cpm	nMole/min/mg of protein	
30 μ l	4231	13.8	
30 μ l	3851	10.4	Average
			15.2
60 μ l	6500	17.8	
60 μ l	6790	19.0	

enzyme in Figure 1 may represent newly synthesized enzyme that has been packaged into vesicles for subsequent release into the medium.

We have demonstrated the presence of a nuclear enzyme by both cytochemical techniques and also direct enzyme measurements in isolated nuclei. One other report of a nuclear phosphodiesterase in a myxomycete is available for *Physarum polycephalum*. (Kupetz and Jeter, 1985). That data represent only an enzyme assay. Their specific activity ranged from 9 nMole/min/mg protein to 11 nMole/min/mg of protein, which is very similar to that reported in this paper (15 nMole/min/mg of protein).

The pattern of lead deposition for the nuclear enzyme shown here suggests that this enzyme is preferentially activated (or inactivated) at unique time periods in the plasmodium. The variable activity of the nuclear phosphodiesterase and the established role of cyclic AMP in controlling mitosis suggests that cyclic AMP regulated mitosis may occur in these cells. Mitosis is synchronous within each microplasmodium; however, microplasmodia are not in mitotic synchrony with each other. In the same culture flask, each microplasmodium would be in its own stage of the cell cycle. Activation of nucleolar phosphodiesterase may represent a connection of cyclic AMP to specific cell cycle events.

Concrete data for the role of cyclic AMP in the *Physarum* cell cycle is not only sparse but also ambiguous. Some of the first evidence showed great promise (Lovely and Threlfall, 1976, 1978, 1979). Since then, this data has been shown to be equivocal (Garrison and Barnes, 1980; Trakht et al., 1980; Oleinick et al., 1981). The relationship of our study to the above data and the role of a nuclear phosphodiesterase in the cell cycle in *Physarum* is still open for further investigation.

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CONCANAVALIN A-NONBINDING ENZYMES OF *CROTALUS SCUTULATUS SCUTULATUS* VENOM

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ABSTRACT

Crotalus scutulatus scutulatus crude venom was separated into two fractions by Concanavalin A Sepharose 4B affinity chromatography. The Concanavalin A-nonbinding fraction (F-I) exhibited phosphomonoesterase (orthophosphoric monoester phosphohydrolase EC 3.1.3.2), phosphodiesterase, 5'-nucleotidase (5'-ribonucleotide phosphohydrolase EC 3.1.3.5), phospholipase A (phosphatidate 2-acylhydrolase EC 3.1.1.4), hyaluronidase (hyaluronate glycanohydrolase EC 3.2.1.d), N-benzoyl-L-arginine ethyl ester, p-toluenesulfonyl-L-arginine methyl ester, L-amino acid oxidase (L-amino acid: O₂ oxidoreductase [deaminating] EC 1.4.3.2), and caseinolytic activities. Thrombin-like and NAD nucleosidase (5'-ribonucleotide phosphohydrolase EC 3.1.3.5) activities were not observed.

DEAE Sephadex A-50 ion exchange chromatography by two stage elution of F-I yielded several fractions having proteinase activities. Proteinase activity was observed in the latter fractions of the first elution and in the fractions of the second elution.

INTRODUCTION

Previously we reported the separation of *Crotalus scutulatus scutulatus* crude venom into two fractions by Concanavalin A Sepharose 4B (Con A) affinity chromatography: Fraction I (F-I) consisting of non-binding proteins and Fraction II (F-II) consisting of binding proteins. Numerous enzyme activities were observed in the crude venom and F-II. The crude venom and the glycoproteins (F-II) which bound to the Con A were fractionated by ion-exchange chromatography, and the resulting fractions demonstrated a broad distribution of proteinase activities (Hinson *et al.*, 1985). This study compares enzyme properties of Con A-nonbinding proteins (F-I) with those of the previously reported binding proteins of F-II and the crude venom.

MATERIALS AND METHODS

Lyophilized *C. s. scutulatus* venom was provided by Dr. H. L. Stahnke of Arizona State University. N-benzoyl-L-arginine ethyl ester (BAEE), p-toluenesulfonyl-L-arginine methyl ester (TAME), 5'-adenylic acid, bis-p-nitrophenyl phosphate sodium salt, beef plasma thrombin, B-NAD⁺, bovine fibrinogen (F-4000), and bovine albumin Fraction V were purchased from Sigma Chemical Company; disodium p-nitrophenyl phosphate from Nutritional Biochemicals Corporation; Tris-(hydroxymethyl)aminomethane, glycine, ammonium molybdate, hydroquinone, sodium sulfite, magnesium chloride, L-leucine, trichloroacetic acid (TCA), potassium cyanide, potassium hydrogen phosphate, and calcium chloride were purchased from Fisher Scientific Company; sodium hydrogen sulfite from J. T. Baker Chemical Company; hyaluronic acid from Worthington Biochemical Corporation; magnesium sulfate and sodium hydrogen phosphate from Mallinckrodt Chemical Works; casein from ICN Pharmaceuticals, Inc.; Sephadex G-25, Concanavalin A-Sepharose 4B (Con A), DEAE Sephadex A-50, and columns from Pharmacia, Uppsala 1, Sweden.

Phosphomonoesterase and phosphodiesterase (Richards *et al.*, 1965), 5'-nucleotidase (Lo *et al.*, 1966; Ging, 1956), phospholipase A (Marinetti, 1965), N-benzoyl-L-arginine ethyl ester (BAEEase) and p-toluenesulfonyl-L-arginine methyl ester (TAMEase) (Tu *et al.*, 1965; Schwert and Takenaka, 1955), thrombin-like (Sato *et al.*, 1965), proteinase (Kunitz, 1947; Rick, 1965), L-amino acid oxidase (Paik and Kim, 1965), NAD nucleosidase (Colowick *et al.*, 1951; Kaplan *et al.*, 1951), and hyaluronidase (Kass and Seastone, 1944) assay procedures included the minor modifications used in previous works (Sifford and Johnson, 1978; Hinson *et al.*, 1985).

A column (2.5 x 15 cm) of Con A gel was used to separate the Con

A-nonbinding proteins from Con A-binding proteins (Iscoe *et al.*, 1974; Aspberg and Porath, 1970; Hinson *et al.*, 1985). DEAE Sephadex A-50 ion exchange chromatography was accomplished by the methods of Cheng and Ouyang (1967), Ouyang *et al.* (1971), Sifford and Johnson (1978), and Hinson *et al.* (1985).

RESULTS AND DISCUSSION

Phosphomonoesterase, phosphodiesterase, 5'-nucleotidase, phospholipase A, BAEEase, TAMEase, proteinase, L-amino acid oxidase, and hyaluronidase activities were present in *C. s. scutulatus* crude venom and in the Con A-binding venom proteins of F-II. Mean activities of enzymes assayed in F-II, with the exceptions of hyaluronidase,

Table 1. Mean specific enzyme activities of *Crotalus scutulatus scutulatus* crude venom and the Concanavalin A Fractions I and II*.

Enzyme	Crude Venom****	Concanavalin A Fraction I (nonbinding proteins)	Concanavalin A**** Fraction II (binding proteins)
Phosphomonoesterase	7.67	5.8	49.7
Phosphodiesterase	1.73	0.2	26.2
Phospholipase A	200	250	500
Thrombin-like	0.0	0.0	0.0
5'-nucleotidase	1.8	0.03	8.7
Proteinase	0.068	0.12	0.23
Hyaluronidase**	120	42	25
NADase	0.0	0.0	0.0
TAMEase	850	970	710
BAEEase	2600	1620	2000
L-amino acid oxidase***	62	31	327

* All enzyme assays were performed at the optimum pH obtained by using the crude venom.

** Hyaluronidase activity is expressed as Turbidity Reducing Units/mg.

*** L-amino acid oxidase activity is expressed as $\mu\text{l/hr/mg}$.

**** Results from Hinson *et al.*, 1985.

TAMEase, and BAEEase, were greater than those in the crude venom (Hinson *et al.*, 1985). These enzyme activities were also observed in the *C. s. scutulatus* Con A-nonbinding venom proteins of F-I. In F-I,

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however, only phospholipase A, proteinase, and TAMEase activities were greater than those of the crude venom. Also, thrombin-like and NAD nucleosidase activities were not observed in F-I (Table 1).

The enzyme activities of F-I differed quantitatively from those observed in F-II by Hinson *et al.* (1985). The mean 5'-nucleotidase, phosphodiesterase, phosphomonoesterase, L-amino acid oxidase, phospholipase A, and proteinase activities of F-I were significantly lower than those observed in F-II. F-I BAEase activity was only slightly less than F-II BAEase activity. Hyaluronidase and TAMEase activities were slightly higher in F-I than in F-II (Table 1).

There was a broad distribution of proteinase activities in the *C. s. scutulatus* crude venom fractions obtained by DEAE Sephadex A-50 chromatography. These activities occurred in the first and latter fractions of the first elution and in the fractions of the second elution. And, when F-II was fractionated by DEAE Sephadex A-50, the proteinase activities were concentrated in the first fractions of the first elution (Hinson *et al.*, 1985). In this work, F-I eluates were pooled, lyophilized, and desalted by using G-25 Sephadex. After rehyophilization, this sample of Con A-nonbinding proteins was applied to a DEAE Sephadex A-50 column. After a two stage fractionation at 4°C using ammonium acetate buffer, the eluates were assayed for proteinase activity. Proteinase activity was observed in the eluates of the latter fractions of the first elution and in the fractions of the second elution (Fig. 1). This further substantiates that multiple proteolytic enzymes are present in *C. s. scutulatus* venom. Caseinolytic activities are present in the DEAE Sephadex A-50 fractions of the crude venom, the Con A-binding proteins, and Con A-nonbinding proteins.

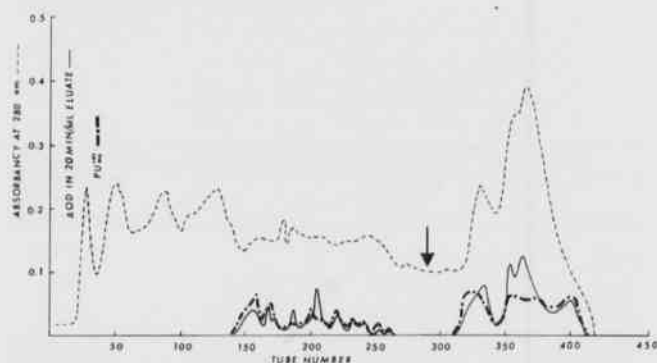


Figure 1. Distribution of proteinase activity in the eluates from DEAE Sephadex A-50 ion exchange chromatography of Fraction I (124 mg) from Concanavalin A-Sepharose 4B affinity chromatography of *Crotalus scutulatus scutulatus* crude venom. The ion exchange chromatography was performed on a column 2.5 x 50 cm at 4°C by two stage elution. The arrow indicates the start of the second stage elution. Eluates of 3.25 ml each were collected with a flow rate of 17 ml/hr. Protein content estimated by absorbancy at 280 nm is shown by —. Rates of substrate hydrolysis in 20 min per ml eluate measured by change in optical density (ΔOD) are indicated by ---. Specific activities of Fraction I proteinase (PUS_{mg}) are indicated by - - -.

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ANOMALOUS CONCENTRATIONS OF ^{58}Co AND ^{137}Cs IN DARDANELLE RESERVOIR

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ABSTRACT

The unforeseen occurrence of significant concentrations of Co-58 and Cs-137 in a quiescent backwater of Dardanelle Reservoir provided an opportunity to observe the equilibrium distribution of Cs-137 between solution and suspended solids. This equilibrium has not been observed in other areas of the reservoir because small amounts of this nuclide are regularly injected into the lake by the AP&L Nuclear I facility. The systematics of the Co-58 concentration lead to the conclusion that significant amounts of these two nuclides had been injected into the sampling area from a source unknown.

INTRODUCTION

The distribution of Cs-137 between solution and the surface of clay minerals in the Dardanelle Reservoir has been studied by Chittenden (1983). A statistical study of the data showed that, in those parts of the reservoir accessible to the cooling water released from the Arkansas Nuclear I facility, the concentration of Cs-137 in the water is simply a function of the amount of activity of the nuclide released from the reactor and that, consequently, ion exchange of Cs-137 between solution and the surface of suspended particles was not a significant factor in controlling the nuclide's concentration in solution. The residence time of water in the reservoir was too short for equilibrium to be attained and thus no significant correlation was observed between the concentrations of Na(I) and Cs-137 at the stations sampled continuously through the four years of the study.

Upon examining the data (Chittenden, 1978) from an infrequently sampled station (#6), the possibility of a correlation between the aqueous Cs-137 activity and the total dissolved solids (TDS) present in the water can be seen. TDS is used as a measure of Na(I) concentration because the concentrations of individual ionic species were not determined during the 1975-1977 portion of the study. This station is unusual among the stations sampled in that it is outside of the normal circulation pattern which is induced in the reservoir by the pumping of cooling water for the AP&L facility. The station is located in a "bay" on the western bank of the Illinois Bayou where Highway US 64 crosses the stream. This area is marked by quiescent surface and subsurface waters (Bechtel Corporation, 1969).

Attention was first brought to this backwater by the appearance of high concentrations of Co-58, summarized in Table 1. The monotonic decrease of this nuclide's concentration over a period of fifteen months was quite unusual. Once plotted (Figure 1), the data resembled closely a radioactive decay curve with a half-life of 72.6 days. The half-life of Co-58 is 71.3 days. It seems that the concentration of aqueous Co-58 depends only on the half-life and that the nuclide is not being washed out of the sampling area by turnover that would be expected even in quiescent areas. It can thus be concluded that the source of this aqueous Co-58 is one fixed in position, i.e. absorbed on the bottom sediment with small amounts being released to the water through ion exchange with aqueous ions.

The concentrations of a number of divalent transition metal ions have been measured in the Arkansas River at Van Buren and the combined concentration was fairly constant (United States Geological Survey, 1978). It can then be assumed that the elution rate of Co-58 remained constant over the period of this study. The distribution coefficient of trace quantities of Co(II) between clay and solution in the presence of di- and trivalent aqueous ions can be estimated from Erickson (1979) to be greater than 10^4 L/kg.

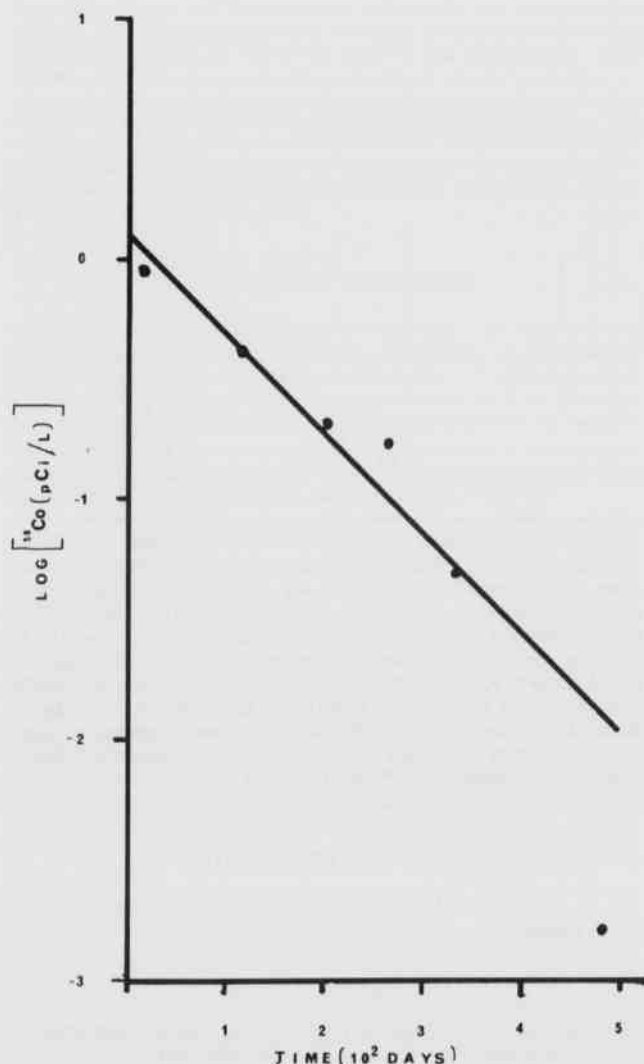


Figure 1. Variation of the Aqueous Co-58 Concentration with Time (t_0 = December 1, 1975)

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CONCLUSIONS

It can be concluded that a significant amount of Co-58 found its way to this quiescent backwater area and was adsorbed by the bottom sediment where it slowly decayed with only a minute and constant fraction of the activity being released from the clay by ion exchange.

It was observed, in June, 1976, that when significant amounts of Co-58 were found in water samples, Cs-137 was also present in relatively large quantities. If Cs-137 was injected into the area of station #6, it is possible that an ion exchange equilibrium could have been established between aqueous and adsorbed Cs-137 in this area of the reservoir where injections of newly formed radionuclides would be rare due to its isolation from the lake's main circulation patterns (Chittenden, 1978; 1981; 1983). The variation in the aqueous concentration of Cs-137 should be predictable by an equation derived from ion exchange theory,

$$\frac{1}{C_s} = C_1 + \frac{C_2}{TDS}$$

where

C_s = the activity of aqueous Cs-137 in pCi/L

TDS = total dissolved solids in g/L

C_1, C_2 = constants

The variation of Cs-137 with TDS is summarized in Table 1 and Figure 2. The points in Figure 2 were fit to the best straight line by linear regression analysis.

$$\frac{1}{C_s} = -14.7 + \frac{7.172}{TDS}$$

Table 1. TDS and Aqueous Concentrations of ^{137}Cs and ^{58}Co

Collection Date	TDS(g/L)	^{137}Cs (pCi/L)	^{58}Co (pCi/L)
12/14/75	---	---	0.88 ± 0.13
3/27/76	0.159	0.053 ± 0.020	0.41 ± 0.05
6/21/76	0.511	1.30 ± 0.10	0.20 ± 0.02
8/19/76	0.312	0.24 ± 0.03	0.17 ± 0.04
10/29/76	0.375	0.081 ± 0.007	0.047 ± 0.019
1/23/77	---	---	0.018 ± 0.022
3/26/77	0.101	0.016 ± 0.003	0.000 ± 0.023

Although the standard deviation of the observed values of $1/C_s$ from those predicted by the regression line was large (9.2 L/g), the value of R^2 was 86.4%, indicating that the equation is an adequate predictor of the aqueous Cs-137 activity. Ion exchange is the major factor determining the concentration of this nuclide at station #6 where there is little occasion for upsetting the equilibrium.

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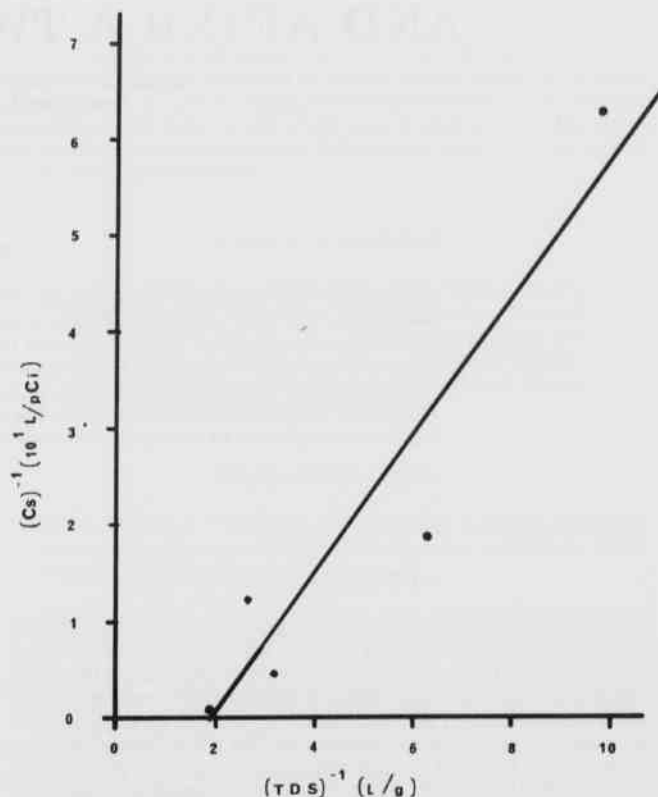


Figure 2. Variation of the aqueous Cs-137 concentration with TDS.

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PLASMA CORTICOSTERONE LEVELS IN CHOLESTEROL-FED COCKERELS BEFORE AND AFTER A TWENTY MINUTE RUN

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ABSTRACT

Cockerels were exercised to observe the influence of physical activity on plasma corticosterone concentrations. The birds were maintained on a commercial mash or on an atherogenic diet. Plasmas were collected on the first day, fifteen days after the first collection and immediately after a 20 minute run on that fifteenth day. The plasma corticosterone levels as determined by radioimmunoassay showed extreme variations within collections. Hence, the data analysis indicated no significant changes of the Compound B in the blood of the cockerels due to diet, or exercise or the combination of both. The causes for the wide variation of plasma corticosterone levels in these birds remain unknown.

INTRODUCTION

Running on an electrically rotated treadmill, twenty minutes, twice daily, five consecutive days per week for ten weeks by cholesterol-fed cockerels resulted in the decrease of plasma cholesterol and in the reduction of atherosclerosis. These effects of physical activity were postulated as the consequences of an enhancement of the enzymatic degradation of cholesterol. Further, it was hypothesized that the cholesterol oxidizing enzymes were activated by corticosterone in response to the muscular exertion (Orimilikwe et al., 1983). This study investigates the influence of physical activity on cockerel plasma corticosterone levels.

MATERIALS AND METHODS

Twenty, 16-week-old, Hy-line cockerels were used in this study. At the start of the experiment the birds were fasted over night, their body weights were determined and blood samples were collected from their alar veins. The bloods were centrifuged at 2250 G in an International Clinical Centrifuge and the separated plasmas were stored at -10°C in sealed vials until assayed.

The cockerels were separated into two equal groups: the Plain Mash + Exercise (PM + Ex), and the Atherogenic Diet + Exercise (AD + Ex). They were housed in separate floor pens ($12' \times 10'$). The PM + Ex was fed a commercial mash (Allied Mills, Inc.) and the AD + Ex was maintained on a diet which consisted of 2% cholesterol and 5% cottonseed oil, w/w, added to the commercial mash. The birds were exercised 20 min, twice daily, five consecutive days per week on a motor driven 6-foot diameter circular treadmill rotated at 5 ± 0.5 r.p.m. This exercise was similar to running 500 yards in 20 min two times per day for the cockerels.

On the fifteenth day of the dietary and exercise regimens, the body weights of the birds were recorded and plasma samples were collected. Then the cockerels were exercised for 20 min and final blood samples were collected as described above.

The steroids from the plasmas were extracted with methylene chloride. Purified corticosterone was recovered by column chromatography from the extract. The quantities of pure corticosterone in the samples were determined by radioimmunoassay.

The data were analyzed by two-way analysis of variance and by paired T-test.

RESULTS AND DISCUSSION

The body weight gains were similar in both groups (Table 1). Cholesterol concentrations were not changed in the birds consuming

Table 1. Body Weights of the Cockerels

Groups	Number of Birds (N)	Body Weights (grams)		
		Initial	Final	Gain
Plain Mash + Exercise	6	1440 \pm 22*	1554 \pm 15	114 \pm 18
Atherogenic Diet + Exercise	6	1446 \pm 175	1557 \pm 42	111 \pm 31

*Standard Error of the Mean

Exercise—forced running 500 yards in 20 minutes, twice daily, 5 consecutive days per week for two weeks.

Atherogenic Diet—2% cholesterol plus 5% cottonseed oil (w/w) of mash.

Table 2. Influence of Exercise on Plasma Cholesterol Concentrations of Cockerels

Groups	Number of Birds (N)	Plasma Cholesterol (mg/dl)	
		Initial	Final
Plain Mash + Exercise	6	142 \pm 15*	142 \pm 12
Atherogenic Diet + Exercise	6	145 \pm 5	315 \pm 34

*Standard error of the mean

Exercise—forced running 500 yards in 20 minutes, twice daily, 5 consecutive days per week for two weeks.

Atherogenic Diet—2% cholesterol plus 5% cottonseed oil (w/w) of mash.

the commercial mash only but the cholesterol-fed cockerels had elevated plasma cholesterol levels (Table 2). This high level was significantly lower than the increase of plasma cholesterol in non-exercised cockerels maintained on a similar diet (Orimilikwe, et al., 1983).

In the initial plasma samples the Plain Mash + Exercise birds showed 0.67 ± 0.27 microgram per dl. and the Atherogenic Diet + Exercise cockerels had 0.82 ± 0.45 microgram per dl. corticosterone. The difference between these mean values was not significant. After 15 days of diet and exercise, the Plain Mash + Exercise cockerels were ob-

Table 3. Influence of 20 minute Running on Plasma Corticosterone of Cockerels.

Groups	Number of Birds (N)	Plasma Corticosterone Concentration Microgram %		
		Initial	After Two Weeks Before Run	After Run
Plain Mash + Exercise	6	0.67 \pm 0.27*	0.63 \pm 0.2	0.48 \pm 0.09
Atherogenic Diet + Exercise	6	0.82 \pm 0.45	0.79 \pm 0.34	0.61 \pm 0.49

*Standard deviation of the mean

Exercise—forced running 500 yards in 20 minutes

Atherogenic diet—2% cholesterol plus 5% cottonseed oil (w/w) of mash

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served to have 0.63 ± 0.2 micrograms per deciliter, corticosterone. This value was similar to the initial value. After 20 min of running there was a reduction of the hormone in the plasmas of these birds to 0.46 ± 0.09 micrograms per deciliter. However, the decrease was statistically insignificant. Similarly, the Atherogenic Diet + Exercise cockerels showed 0.77 ± 0.54 micrograms per dl. corticosterone after remaining on the diet and exercise regimens for 15 days. This and the previously observed level of the hormone in these birds were not markedly different. The hormone concentration of 0.61 ± 0.49 micrograms per dl. in the plasmas collected after the 20 min run was not statistically lower than the pre-exercise values (Table 3).

The plasma corticosterone concentrations in the bloods of the cockerels were within a range of 0.23 micrograms per dl. to 1.53 micrograms per dl. Due to this extreme variation within samples, the statistical analysis of the data by two-way analysis of variance or by paired T-test indicated no significant differences between the arithmetic means of the values of corticosterone. According to Yates and Urquhart (1962) the plasma concentrations of glucocorticoids fluctuate with changes in the physiological state of the animal. There was no uniformity in the corticosterone levels of the cockerels used in this study. The causes for these differences among the cockerels are not known.

The amount of corticosterone in the plasma is quantitatively the balance between the quantity released by the adrenal cortex and the sum of the quantities of the substance bound to the tissues, metabolized and excreted. The plasma level of Compound B should decrease when the rates of tissue uptake, metabolism and excretion exceed the rates of secretion and release by the gland. Or, the level of the hormone should rise when the secretion and release is at faster rates than the rates of tissue binding, metabolism and excretion. The data from this study do not indicate excessive addition or removal of corticosterone from the plasmas of the cockerels.

Reports on the influence of muscular work on plasma corticosterone concentration are very few in number. Chin and Evonuk (1971) reported that there was no significant change of corticosterone concentration in the bloods of rats which were moderately exercised daily for six weeks. Rose et al. (1970) observed no difference between the amounts of cortisol in the blood of men while at rest and after running a mile. John and George (1973) electrically stimulated the pectoral muscles of anesthetized pigeons to give five wing beats per second for two hours. These investigators reported that there was no significant alterations in the pre and post-experimental plasma levels of Compound B in these birds. The data from our study is similar to the results of these investigations.

A minimum work load, requiring at least 60 percent of maximum aerobic power, is needed to cause a significant change in the plasma level of hydrocortisone in man (Davies and Few, 1973). In rats which were forced to swim daily until exhaustion, for three weeks, Frenkel and Csalay (1962) observed an increase of circulating corticosterone. Seaman and Evonuk (1970) reported a 43% increase in the plasma corticosterone concentration in rats which were forced to swim until they were tired and about to drown. According to these reports, our results suggested that the degree of physical exertion was not strenuous for the cockerels.

However, the data obtained from this study is not conclusive of the influence of physical activity on the plasma concentrations of cockerels. This is due to the overwhelming individual variations of the amounts of Compound B in the bloods of the experimental animals. The causes for the extreme variations among the cockerels with regard to the hormone level remain obscured.

ACKNOWLEDGEMENT

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SPECIAL ADAPTATIONS OF ORB WEAVERS AND PREY

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ABSTRACT

Orb weaving spiders have devised both webs and special devices for capturing prey. The prey have also evolved mechanisms for eluding spiders and for living with them. Some of the mechanisms involved are discussed in this paper.

INTRODUCTION

Orb weavers have devised webs and other devices for capturing prey. Prey have also evolved mechanisms for eluding spiders. Eberhard (1976, 1977) discussed physical properties of sticky spirals and their connections and aggressive chemical mimicry by a bolas spider. Eisner (1964) also commented on the adhesiveness of spider silk. Craig, Akira, and Viggo (1985) indicated that oscillation of orb webs had an effect on prey interception. Ploy and counterploy in predator-prey interactions was discussed by Eisner and Dean (1976). Some spiders are so small that they are unnoticed in other webs as pointed out by Exline and Levi (1962). Web structure and function is cited by Lubin (1973). Some spiders show adaptive advantage by living in colonies (Lubin, 1974). Rypstra (1984) discussed the importance of food and space in limiting web-spider densities. McMillan (1975) observed flies of the family Milichiidae cleaning the anus of *Araneus* and *Nephila*. Predatory behavior is discussed by Robinson (1969, 1973). Thornhill (1975) referred to scorpionflies as kleptoparasites because of the way in which they steal food from spiders webs. Mechanisms involved in predator-prey relationships have been noticed by various investigators.

MATERIALS AND METHODS

A 35 mm camera with various lenses was used to photograph webs of spiders. Some webs were sprayed with white spray paint with a black velvet cloth used as a background, some webs were photographed in the wild without a background, others were photographed from books or journals where appropriate.

Spiders and insects were collected from webs, put in 70% ethyl alcohol and brought to the laboratory for identification with a stereoscopic microscope.

RESULTS

Of the approximately 35,000 species of spiders, one half make webs for trapping prey. Rypstra (1984) pointed out that prey availability and habitat structures were possible limiting factors of web spider density. It appears that large numbers of prey and suitable habitat structures almost always determine spider densities. However, some New Guinea spiders live in large colonies that span huge areas with contiguous webs. These webs are not removed often and they catch few insects. Orb webs, sheet webs, and irregular webs comprise the basic types of webs. There are trip lines leading from tubes, bits of bark or webbing situated in webs to mimic spiders and many other modifications of these three basic types of webs used for trapping prey. Spiders may also build a retreat in a crack of wood or a rolled leaf, (Figure 1). Orb weavers use viscid sticky silk or hackled wooly threads in the permanent spiral threads which adhere to prey. It was also shown by Craig, Akira, and Viggo (1985) that orb webs are not static nets and capture reflects a dynamic interaction between spider and insect. One component of this interaction is web oscillation. The natural oscillations of orb webs greatly



Figure 1. Bits of webbing used to mimic spiders sitting in web. (See spider at top of plant.)

enhances web interception of small and slow flying prey. Size of mesh also has a distinct bearing upon prey trapped, (Figures 2 and 3). Generally speaking, spiders run from a nearby retreat and thrust their poison fangs into prey caught in the web; (Figure 4) however, if the prey is a stinging insect the spider will usually immediately attack-wrap by throwing swaths of silk over it and then rolling the insect into the silk to prevent counter attack (Figure 5).

In some species of orb weavers the spider bites the center out entirely and leaves a hole, (Figure 6) which permits the spider to move from one face of the web to the other. Some spiders control web tension by holding to the rim of the hole. In a zigzag fashion a stabilimentum which is a heavy decorative band of silk may be added above and below the hub. Many orb-weavers place irregular threads — a barrier web — in front of or behind the main web, perhaps as an alarm system to warn of the approach of larger predators. Some species sit on a branch holding a single line with a visual glob at its end: they attract male moths with a pheromone that mimics the pheromone of the female moth according to Eberhard (1977).

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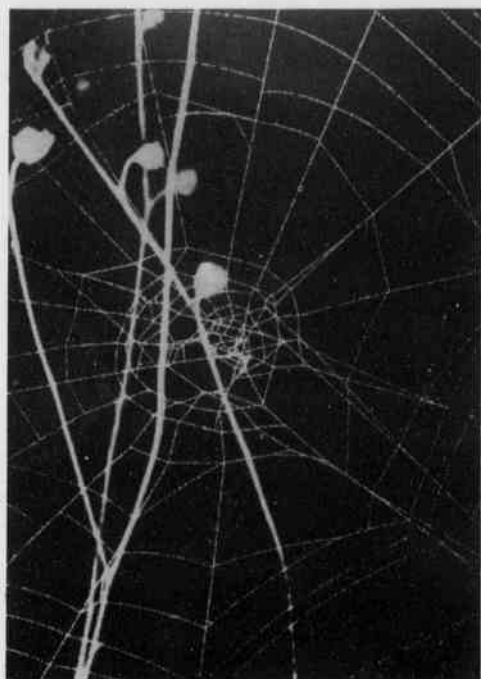


Figure 4. Spiders run from a retreat and thrust fangs into prey.



Figures 2 & 3. Size of mesh has a distinct bearing upon prey trapped.

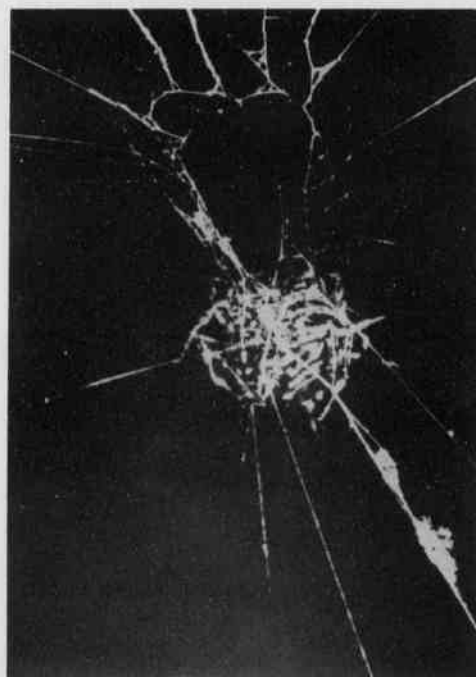


Figure 5. Insect wrapped.

Special Adaptations of Orb Weavers and Prey



Figure 6. Spider bites out center of web and leaves hole to move from one face of the web to the other.



Figure 7. Spider tearing down its web to prevent kleptoparasitism by spiders and to prevent other prey from locating them so easily.



Figure 8. The trapdoor spider's door is flush with the ground and at night it opens the door slightly and preys on passersby.

Some orb-weavers make webs during different times of the day or night to attract different insects and many species tear down their webs each day to prevent an abundance of kleptoparasites, web robbers, diurnal predators, human spider collectors, and other prey from locating them so easily (Figure 7).

The trapdoor spider's trap is an example of a different approach to catching prey. It lives in a silk-lined burrow that has a trapdoor flush with the ground (Figure 8). At night the spider opens the trapdoor slightly and preys on passersby. Wolf spiders, jumping spiders, fishing spiders, and some ground spiders hunt, fish or prey without the use of webs.

Once the prey is safely ensheathed it cannot use bites, stings, kicking legs, or noxious defense fluids. Various authorities have reported adaptations of prey to thwart spiders. Robinson (1976) reported on a pyralid moth that rests on silk strands of a *Nephila* web. The fact that it looks like debris protects it from birds flying above and prevents attack from the spider also. Eisner (1964) showed that moths and butterflies are protected from sticky threads. Scales covering their wings get stuck to the web, but the moths can easily pull away from the scales and elude the owners of their temporary retreat. According to Robinson (1969) some orb weavers can differentiate moths and butterflies from other insects and employ different attack strategy. Moths are immediately bitten and held down until their movements cease.

Panorpa species of scorpionflies which scavenge on dead and dying insects, have been observed removing silk from wrapped insects in webs by regurgitating a brown fluid which dissolves the webbing; thereby permitting the scavenger to fly away with the insect. According to Thornhill (1975) 59% of scorpionfly mortality is due to getting caught by orb weavers.

Levi (1978) watched small phorid flies sitting around the head of the orb-weaver *Araneus bogotensis*. As soon as the spider retrieved an insect the flies started feeding at one end while the spider fed more slowly at the other end. Robinson and Robinson (1978) observed drosophiloid flies sitting on the head of a golden silk spider waiting for it to catch food.

Spiders must adapt not only to the defense mechanisms of potential

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prey but to web-robbers as mentioned above. The most common kleptoparasites are not insects but spiders. Tiny spiders of the genus *Argyrodes* (family Theridiidae) have been observed at one time with some feeding and removing prey in the daytime and some at night. This behavior has also been noted in webs of spiny bellied spiders such as *Microthema* and *Gasteracantha*. Most spiders tear down their webs daily to prevent kleptoparasitism.

Symbiotic relationships have been observed by McMillan (1975). A mechilid fly in Australia cleans orb-weavers. It licks around the anal area and is allowed to clean up food remains.

Spiders obviously have evolved many strategies and counter-strategies against protective devices, kleptoparasites, web robbers and other would-be enemies or prey. Likewise, prey have evolved mechanisms to cope with these adaptations and strategies.

DISCUSSION

The present research has indicated that spiders and their webs show certain adaptations for trapping prey; whereas, some prey also seem to be anatomically, physiologically, behaviorally, or ecologically adapted for obtaining food from spiders webs or for eluding spiders while trying to steal food. Webs are ideal for studying spider's adaptations to the food supply and to prey's evasive behavior. Different web configurations and the expense of making webs compared to the energy obtained from catching prey are all interesting aspects associated with adaptations of spiders and prey.

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PENETRATING IONIZING RADIATION LEVELS OBSERVED IN THE LOWER ARKANSAS AND WHITE RIVER VALLEYS OF ARKANSAS

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ABSTRACT

Environmental levels of penetrating ionizing radiation were measured in the lower Arkansas and White River valleys of Arkansas. Measurements of environmental gamma and cosmic rays were made using a portable high pressure ionization chamber. The surveyed area encompassed a large coal-fired industrial plant. Observed exposure rates ranged from 5.9 microRoentgens per hour ($\mu\text{R/h}$) to 13.4 $\mu\text{R/h}$. The average exposure rate for the region was 8.8 $\mu\text{R/h}$. This value corresponds to 77 millirem (mrem) or 0.77 millisieverts (mSv) per year. In comparison, a prior state-wide survey reported an average dose equivalent rate of 78.2 mrem (0.782 mSv) per year in Arkansas.

INTRODUCTION

Man has always been exposed to radiation since the environment in which we evolved is radioactive. This environmental radio-activity is composed of natural radioactivity (terrestrial and cosmic) as well as man's contribution from nuclear fallout and industrial practices. Until less than a century ago however, natural radiation was man's only source of exposure. The exposure to man has increased over the past 40 years because of widespread fallout from nuclear weapons tests, increased use of nuclear energy, and a greater use of radioisotopes. Nevertheless, natural background still remains the greatest contributor to the radiation exposure of the United States population today (Spires, 1956; Salom, Lowder, Shambon and Blatz, 1960; Oakley, 1973; and Harley, 1975).

There have been few systematic studies of environmental penetrating radiation exposure. Most such efforts in the United States have been devoted to aerial surveys of limited areas around large nuclear installations. A variety of instruments and methods have been applied to measuring environmental exposure rates (Lowder, Beck and Condon, 1967; Lowder and Condon, 1965) which are typically at levels of microRoentgens per hour ($\mu\text{R/h}$). The recent advent of portable, rugged and highly sensitive large volume, high pressure ionization chambers has vastly simplified the process of environmental surveys.

Ion chambers measure ionizing radiation exposure. The Roentgen is the unit of Exposure to X- and gamma rays. It is a direct physical measure of the ionization produced per unit mass of air. For regulatory and administrative purposes, a Dose Equivalent unit is used. The Dose Equivalent combines absorbed energy per unit mass with estimates of biological detriment to produce a single normalized value. The SI unit of Dose Equivalent is the Sievert (Sv) which replaces the old unit, the rem (ICRU, 1980). For X- and gamma rays, one Roentgen is essentially equal to .01 Sievert (or 1 rem).

Portable pressurized ion chamber surveys have recently been reported for some areas in the United States and in Europe (Stranden, 1977; Powers and Watson, 1978; and McAuley and Colgan, 1980). A Georgia survey reports 3.5 to 40 $\mu\text{R/h}$. Surveys in Norway (6.2 - 9.1 $\mu\text{R/h}$) and Ireland (10.2 - 14.3 $\mu\text{R/h}$) have been reported.

The measured average exposure rate in the United States from naturally occurring gamma-ray emitters is about 8.2 $\mu\text{R/h}$ at one meter above the soil. Natural radiation contributes a dose equivalent of 70 to 200 mrem (0.70 to 2.0 mSv) per year to the United States population (Oakley, 1973, and Harley, 1975).

Rolnick (Rolnick, 1982) conducted a population weighed study in 1980-1981 with a pressurized ion chamber to establish the natural penetrating radiation background component in all Arkansas cities with a population greater than 5,000. He found readings in the Arkansas and White River Valleys, south of Interstate Highway 40 to be higher than the rest of the state. There was no apparent reason for these higher

exposure rates. It was suggested that this area be more extensively surveyed in the future.

The purpose of the study was twofold. The major objective was to more clearly define the magnitude and profile of environmental penetrating background radiation in the Arkansas and White River valleys south of the U.S. Interstate Highway 40. Was this area really more radioactive than the rest of the state of Arkansas? Additionally, a detailed survey of the area would for future reference generate an exposure baseline for the entire area.

MATERIALS AND METHODS

The area surveyed was bounded on the north by Interstate 40 from North Little Rock to Brinkley; on the east by Highway 49-S and I-55 from Brinkley to McGehee; on the south by a line from McGehee to Monticello to Fordyce; and on the west by Highway 167 from Fordyce to North Little Rock.

The area encompasses the counties of Arkansas, Jefferson, Lincoln, most of Cleveland, Southern Prairie and Lonoke, northern Drew and Desha, and eastern Grant. A large coal-fired electric power plant is located in the Northwest quadrant of this area. Measurements were also made over the plant's coal pile and fly ash waste dump. Total coverage represents approximately 5600 sq. miles.

Exposure measurements were made with a Reuter-Stokes Model RSS-111 Environmental Radiation Monitor, a portable high-pressure ionization chamber (PIC) especially designed for environmental surveys. The spherical detector, containing ultra-pure argon gas at 25 atmosphere of pressure, responds to X- and gamma rays only. Accuracy is $\pm 5\%$ at 10 $\mu\text{R/h}$. Exposure readings are displayed by an instantaneous digital reader (in $\mu\text{R/h}$), by an integral strip chart recorder and by a mechanical scaler (in accumulated μR).

The PIC was initially calibrated with Ra-226 by the manufacturer. During the study, instrument reproducibility was checked daily using a calibrated disc source of Co-60 affixed to a reference point on the PIC housing. The Co-60 disc was of sufficiently low activity as to produce an instrument response twice that of normal background. The value of the standard was determined to be 81.18 $\mu\text{R}/\mu\text{Ci}$ Co-60 with a permissible error of $\pm 5\%$ as this was the manufacturers stated accuracy for the RSS-111. Calibration checks using the Co-60 source were performed both before and after each day of field use. Variance of daily check source readings never varied more than $\pm 3\%$ of calibration value.

Two different modes of data collection were used. Stationary integrated readings at selected sites and instantaneous readings while driving from site to site were made.

The PIC was mounted in a low density foam rubber housing while travelling from site to site. The detector, about one meter above ground level, was located in the rear of the vehicle which was used throughout

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the survey. Instantaneous readings were made every eight kilometers (5 miles) while travelling from one location to the next. An instantaneous reading was also made at every county line, city limit, train track, and major road intersection. The vehicle acted as a shield for the radiation from outside. Values measured inside the vehicle had to be multiplied by a factor of 1.21 to obtain the proper value for unshielded external radiation exposure.

The survey area was divided into a 16.1 by 16.1 kilometer (10 x 10 mile) grid for stationary open-air measurements. At least one stationary measurement was made within each of the grids. Readings were made as close as feasible to the grid center. Sites were also chosen to be near a location which would be easily found on a state or county road map, such as major road intersections. Measurement locations were from 75 to 100 meters (246-328 feet) off the highway, usually utilizing dirt-access roads. In all cases, the chosen area was level, with good soil permeability, and where no overwash would occur. The detector was tripod-mounted well away from the car at one meter above ground level. One meter was chosen as the sampling height since this is the accepted gonadal dose level to man and because gamma flux and exposure are nearly identical at one meter above the ground. Ten minute measurements were made at each site. The instantaneous value was recorded once every 30 seconds. The mean of these 20 values was used to develop an environmental penetrating radiation contour map (Figure 1).

Table 1. Averaged stationary exposure rates observed in the surveyed area. Units are $\mu\text{R}/\text{h}$.

Fairdale	7.0	Sherrill	8.4
Monticello	6.2	Gethsemane	9.3
Backgate	5.9	Hwy 165 E/England	9.4
Redfield	8.0	England	8.8
Noble Lake	10.4	Scott	8.6
Gould	8.2	Hwy 161 N/England	9.9
Garrett Bridge	8.7	Hwy 31 North of Pettis	9.2
Hazen	8.9	Hwy 381 North of Culler	8.7
Wattensaw Wildlife Area	8.8	Humphrey	8.7
Hwy 33 & 86	8.0	Bayou Meto	8.4
Preston Ferry	9.2	St. Charles	9.7
Hwy 146 E/Preston Ferry	9.4	Hwy 146 E/Holly Grove	9.0
Almyra	8.7	Hwy 1 N/Crossroads	9.5
Hwy 152 S/Dewitt	8.9	Hwy 65, 167	13.4
Hwy 276 & 11	8.3	Dixon Road (S/L. Rock)	11.0
Hwy 343 (end of road)	8.9	Hwy 46 North of Sheridan	11.3
Hwy 86 South of Carlisle	8.2	Hardin	8.4
Hwy 343 & 165	7.5	Pine Bergen	7.1
Crookets Bluff	8.3	Nebo	9.1
Hwy 153 W/Crookets Bluff	8.4	Ticnor	9.4
Hwy. 153 & 1	8.0	Ethyl	9.7
Hwy 33 & 130	8.4	Clarendon	8.9
Hwy 165 West of Dewitt	8.4	Hwy 190 South of Hardin	7.6
Rydel	10.0	Hwy 54 E/Grapevine	8.0
Hwy 88 South of Altimer	9.1	Toltec	9.8
Hwy 15 & 79	9.2	Hwy 161 South of Scott	9.8

RESULTS

Stationary outdoor exposure rate measurements obtained at the selected locations within the study area are shown in Table 1. These values are expressed as $\mu\text{R}/\text{h}$ and include all background contributions. The values range from 5.9 to 13.4 $\mu\text{R}/\text{h}$ with a mean of 8.8 $\mu\text{R}/\text{h}$ and a standard deviation of $\pm 1.2 \mu\text{R}/\text{h}$. The value of 8.8 $\mu\text{R}/\text{h}$ compares favorably with Rolniak's (1982) average value, 9.3 $\mu\text{R}/\text{h}$ for the state of Arkansas. Forty-eight of the 52 values fall within two standard deviations of the mean. Two values were greater than plus two standard deviations from the mean and two were less. The two high deviations are believed due to outcrops of igneous rocks from Granite Mountain. The two low deviations were made in regions of sand and sandy-loam soils which are high in silica.

A few highly localized areas in Arkansas exhibit significantly high exposure rates. Two prime examples are Granite Mountain near Little Rock with 14-16 $\mu\text{R}/\text{h}$ and the thermal springs in Hot Springs National Park with 50-80 $\mu\text{R}/\text{h}$. Even portions of Interstate 40 East and West of Little Rock show readings as high as 14.8 $\mu\text{R}/\text{h}$.

Measurements made in the middle of the power plant's coal field registered exposure rates of 6 $\mu\text{R}/\text{h}$. Readings in the plant's flyash dumps

were 12 $\mu\text{R}/\text{h}$. Flyash was expected to be higher than coal, since it represents a coal "ash" residue consisting mainly of silica and concentrated metals.

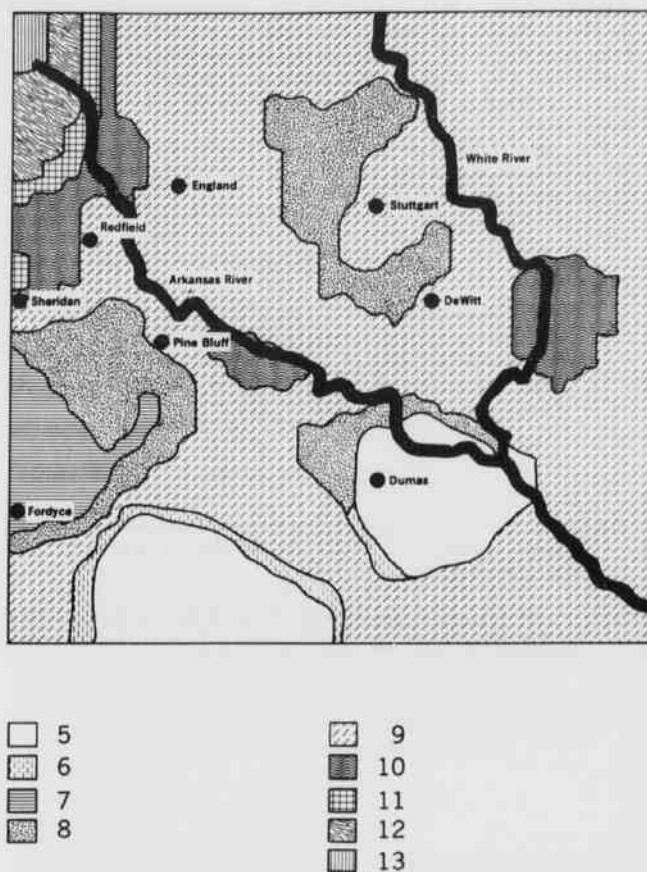


Figure 1. Background penetrating radiation contour map of study area. Units are $\mu\text{R}/\text{h}$.

A background penetrating radiation contour map of the study area is depicted in Figure 1. This map was computer-generated using the data obtained by this study. The contours are approximations since they were generated by mathematical extrapolations from observed data points.

DISCUSSION

Potassium-40, cosmic radiation, and a half dozen members of the uranium/thorium-series radioactive chain produce almost all the natural-occurring gamma rays. Igneous rock (granite), clays and dark shales (organically enriched) are usually enriched in K-40 and members of the uranium and thorium chains. Sand and sandstones are typically very low in radionuclides species. Rolniak (1982) found this to be true of most all sandy soils, sandstones and clays in Arkansas. This was also born out in our survey.

Rolniak's observations in east central Arkansas were based largely on highway measurements. The elevated readings were due to roadbed materials, such as granite and clay foundations and igneous chat used in road surfacing materials. Readings as high as 14 $\mu\text{R}/\text{h}$ have been observed on the roadbed, whereas the surrounding countryside has usually read no more than 6 to 8 $\mu\text{R}/\text{h}$.

A roadbed effect was noted in this study. Subsequently, highway readings were excluded from the data. Only those readings taken off-

Penetrating Ionizing Radiation Levels Observed in the Lower Arkansas and White River Valleys of Arkansas

road and outside the vehicle were used to generate usable data in the final results.

The flyash from the western coal burned by the power plant measures somewhat higher than the average for the entire area surveyed. However, the plant's electrostatic precipitators remove more than 99.9% of flyash from stack discharge. Virtually all flyash is scrubbed, recovered from stack gases, and stored on plant property. The flyash from the power plant is believed to make no contribution to the area-wide radiation background.

The range of exposure rates found in East Central Arkansas speak for themselves. Radiation levels in this area are essentially the same as the rest of the state of Arkansas.

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ABANDONED MINE FAUNA OF THE OUACHITA MOUNTAINS, ARKANSAS: VERTEBRATE TAXA

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ABSTRACT

Numerous visits, over the past four years, of 27 abandoned mines in the Ouachita Mountains of Arkansas revealed that the mines are serving as hibernacula, breeding sites, and permanent or temporary habitats for numerous vertebrates. The following species were observed either directly or by sign: Class Amphibia, Order Urodela — *Eurycea multiplicata*, *Desmognathus brimleyorum*, *Plethodon caddoensis*, *P. glutinosus*. Order Anura — *Gastrophyrne carolinensis*, *Rana palustris*, *R. catesbeiana*. Class Reptilia, Order Squamata, Suborder Serpentes — *Thamnophis proximus*, *Diadophis punctatus*, *Elaphe obsoleta*, *Nerodia erythrogaster*, *Agkistrodon contortrix*. Class Aves, Order Passeriformes — *Sayornis phoebe*. Order Strigiformes — *Otus asio*. Class Mammalia, Order Marsupialia — *Didelphis virginiana*. Order Chiroptera — *Lasiurus borealis*, *L. seminolis*, *Myotis lucifugus*, *M. keenii*, *M. austroriparius*, *Eptesicus fuscus*, *Lasionycteris noctivagans*, *Pipistrellus subflavus*. Order Rodentia — *Neotoma floridana*, *Peromyscus attwateri*. Order Carnivora — *Procyon lotor*, *Ursus americanus*.

INTRODUCTION

Physiographically, Arkansas can be broadly divided into the Interior Highlands (Ozark and Ouachita Mountains) and Gulf Coastal Plain. The boundary between the mountain ranges is not always well delineated, however, the Arkansas River Valley is generally considered to separate the two. The Ozark Mountains consist primarily of dolomite while the Ouachita Mountains include shale, sandstone, and novaculite. Consequently, the Ozark Mountains contain a great many natural caves which are absent in the Ouachita Mountains; however, because of mining activities there are a large number of abandoned mines located in the Ouachita Mountains (Foti, 1974).

Caves and mines play an important role in the ecology of a great many species, serving as permanent or temporary habitats. Studies of cavernicolous fauna in Arkansas have centered around the caves of the Ozark Mountains (Bishop, 1944; Hubricht, 1950; Sealander and Young, 1955; Smith, 1960, 1964, 1968; Brandon, 1962; McDaniel and Smith, 1976; and McDaniel and Gardner, 1977) with only incidental mention of vertebrate fauna in one mine in the Ouachita Mountains (see McDaniel and Gardner [1977] for a summary). This study was undertaken to investigate as many abandoned mines as possible, in the Ouachita Mountains, in an effort to document the occurrence and use of the mines by vertebrate taxa.

METHODS AND MATERIALS

During the past four years, 27 abandoned mines in Garland (8 mines), Montgomery (3 mines), Polk (12 mines), and Pike (4 mines) counties, Arkansas (Fig. 1, Table 1) were located and visited a minimum of eight times (at least once each season). In several cases, where unusual species occurred or breeding populations were found, mines were visited several times each year. Collections were minimal and voucher specimens are located in the Vertebrate Collections at UALR and Arkansas State University.

Following McDaniel and Smith (1976), we have included the probable ecological position of the species in the mine environment, all Arkansas mine records assembled by writers to date, and a comment concerning the status, collection, or life history of the species. Following Barr (1963) and McDaniel and Smith (1976) the terms "troglobite" (obligate cavernicoles), "troglophile" (commonly found in caves), "trogloxenes" (may be common in caves but must leave to complete their life history, e.g. bats), and "accidental" (unable to survive long in the cave environment) have been employed in the species accounts.

RESULTS

No fish or troglobitic vertebrate fauna were found in any of the mines examined. McDaniel and Gardner (1977) reported three species of fish, including two troglobites (*Amblyopsis rosae* and *Typhlichthys subterraneus*) and one troglobitic salamander (*Typhlotriton spelaeus*) in Ozark caves.

ANNOTATED LIST OF VERTEBRATE FAUNA IN ABANDONED MINES

CLASS AMPHIBIA

Order Urodela

Family Plethodontidae

Plethodon glutinosus glutinosus (Green). Troglophile. Although primarily epigean, this salamander has been commonly reported in caves (McDaniel and Gardner, 1977; Barnett, 1970). In this study, numerous slimy salamanders were found in Milk, Slimy, Vawter, Twin Upper, and Twin Lower mines. Breeding populations were found in Slimy and Vawter mines; and brooding behavior has been observed and studied by one of the authors (DAS).

Plethodon caddoensis Pope and Pope. Troglophile. The Caddo Mountain salamander is primarily epigean; however, large aggregations in Twin and Sugarstick mines were previously reported by the authors (Saugey et al., 1985). Another small population was found in Camp Wilder Mine and individuals are occasionally found in Pipistrelle and Big Ear mines. Egg clusters, for the past two consecutive years, have been found in one mine. This species is endemic to the Novaculite Uplift of the Ouachita Mountains and is listed as endangered in Arkansas (Reagan, 1974) and a status review is currently being conducted by the Jackson, Mississippi, Endangered Species Field Station.

Desmognathus brimleyorum (Stejneger). Troglophile. The Ouachita dusky salamander is primarily epigean; however, the salamander has been numerous in the mines where it has been found (Recreation, Stinger, Twin Creeks, and Pipistrelle mines). Egg clutches have been observed (deposited on the underside of rocks) in one mine and larvae in two mines. In those mines with larvae, the pools contained abundant leaf litter and isopods. One of the authors (DAS) observed *Desmognathus* larvae feeding on the isopods.

Eurycea multiplicata (Cope). Troglophile. This species is primarily aquatic being found under stones, logs, and other debris in streams and springs, both in the open and in caves (Bishop, 1943). In Arkansas, Strecker (1908) reported the many-ribbed salamander in

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Table 1. Abandoned mines of Arkansas Ouachita Mountains. Letters refer to keyed mines in Figure 1.

A. Conquistador	O. Golden One
B. Milk	P. Golden Two
C. Slimy (Spillway)	Q. Elf
D. Sleeping Child	R. Twin Upper
E. Shallow	S. Twin Lower
F. Vawter	T. Pipistrelle
G. Recreation	U. Big Ear
H. Walnut	V. Camp Wilder
I. Silver	W. Candy
J. Gardner	X. Langley Hillside Upper
K. Stinger	Y. Langley Hillside Lower
L. Heath	Z. Mercury One
M. Silverworld	Z ₁ Mercury Two
N. Twin Creeks	

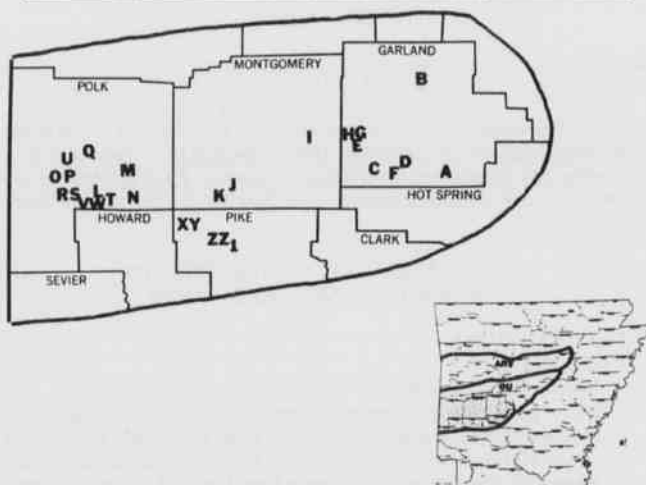


Figure 1. Map illustrating abandoned mines in the Ouachita Mountains, Arkansas. See Table 1 for the names of mines corresponding to the letters. Inset map shows relative position of study area (stippled portion) to Ouachita Mountains (OU) and Arkansas River Valley (ARV).

association with the Ouachita dusky salamander. Larvae and adults were found in Golden One and Recreation mines. Larvae in Recreation Mine were in the same pools as those of *D. brimleyorum*. The mines with larvae contained shallow streams with a gravel substrate.

Order Anura

Family Microhylidae

Gastrophryne carolinensis (Holbrook). Accidental. This species was found at the entrance to Slimy Mine.

Family Ranidae

Rana palustris Le Conte. Troglaxene or Troglophile. This was the most common frog found in the mines (Stinger, Silverworld, Twin Creeks, Golden One, Golden Two, Big Ear, and Camp Wilder mines). McDaniel and Gardner (1977) also reported this species to be quite common in Ozark caves. As in the Ozarks, these animals often were found past the twilight zone. During the winter months 8-10 individuals were found hibernating in Big Ear and Silverworld mines.

Rana catesbeiana Shaw. Troglaxene or Accidental. Several individuals were found hibernating in the total dark zone of Big Ear Mine. Bullfrogs have been previously reported to utilize caves, including

those of the Ozarks (Barr, 1953; Grove, 1974; McDaniel and Gardner, 1977).

Class Reptilia

Order Squamata

Suborder Serpentes

Family Colubridae

Thamnophis proximus (Say). Accidental. One specimen was found near the entrance to Twin Upper Mine.

Diadophis punctatus stictogenys Cope. Accidental. One specimen was found about 10 meters from the entrance to Slimy Mine. A specimen of this species was also reported from an Ozark Cave (McDaniel and Gardner, 1977).

Elaphe obsoleta obsoleta (Say). Troglaxene. One specimen was found, in the summer, coiled in roots at the ceiling near the entrance of Silver Mine. Mines would provide refugia and ready food sources (e.g., bats) for this species (Wright and Wright, 1957) and these snakes are probably more common around entrances to the mines than recorded. A black rat snake was reported in a cave in the Ozarks (McDaniel and Gardner, 1977).

Nerodia erythrogaster flavigaster Conant. Troglaxene. This species was found near the entrances of Pipistrelle and Candy mines. Permanent water in the mines may offer an alternative temporary habitat as epigeal water becomes scarce during the summer months.

Family Viperidae

Agkistrodon contortrix contortrix (Linnaeus). Troglaxene. One specimen was found near the entrance to Candy Mine.

Class Aves

Order Passeriformes

Family Hirundinidae

Sayornis phoebe (Latham). Troglaxene. Several eastern phoebe nests were found within the entrances to Gardner, Big Ear, and Candy mines.

Order Strigiformes

Family Strigidae

Otus asio (Linnaeus). Accidental. Two eastern screech owl pellets were found, during the summer, at the entrance to Candy Mine. The owl may have utilized the mine for water or a midday resting area.

Class Mammalia

Order Marsupialia

Family Didelphidae

Didelphis virginiana Kerr. Troglaxene. Opossum tracks were found several times in Slimy mine. One of the authors (DAS) has noted that when opossum tracks were present, egg clutches of *Plethodon glutinosus* were missing from their deposition site.

Order Chiroptera

Family Vespertilionidae

Eptesicus fuscus (Palisot de Beauvois). Troglaxene. Big brown bats were typically found in the cooler entrances of Conquistador, Walnut, Golden Two, and Mercury One mines. While quite common in the Ouachita area, individuals of this species were usually solitary in the mines.

Lasiurus borealis (Muller). Accidental. Swarming behavior was observed at the entrances to Recreation, Walnut, and Golden mines. Red bats were reported by McDaniel and Gardner (1977) in two Ozark caves and Saugey et al. (1978) found the remains of 140 red bats in another Ozark cave. The red bat normally inhabits trees.

Lasiurus seminolis (Rhoads). Accidental. A single specimen was netted outside the entrance to Golden Mine. This record represented a range extension for the species and has been previously reported (Heath et al., 1983). The seminole bat's habits are similar to those of the red bat.

Myotis austroriparius (Rhoads). Troglaxene. This species has been observed on two separate occasions in Mercury One Mine which is located on a peninsula in Lake Greeson, Pike County. The entrance shaft projects some 20 meters into the mountain before it expands forming a chamber some 7 meters in diameter and 7 meters in height. The height of the entrance shaft is approximately 2 meters. During a winter visit (January, 1984) 150 individuals (both red and gray color phases) were observed hibernating in the mine

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and in an early spring visit two years later (March, 1986) only 15 individuals were present. The presence of this species in Pike County represents a new county record. Mississippi myotis were previously reported from a mine located 17 km NW of Hot Springs, Garland County (Davis et al., 1955; Sealander and Young, 1955); however, it is believed that this mine has since been flooded by Lake Ouachita.

Myotis keenii (Merriam). Trogloxene. Although in fairly small numbers, this species has been found in 12 mines (Slimy, Shallow, Recreation, Walnut, Stinger, Heath, Golden One, Twin Upper, Pipistrelle, Big Ear, Candy, and Langley Hillside Upper). The largest hibernating aggregation consisted of 12 bats. The largest number during the remainder of the year was 57 females in Spring, 1985, in Big Ear Mine. Three of these bats were sacrificed and found to be pregnant; however, mines are not used as maternity colonies. When roosting, these bats are typically found solitarily in crevices near the entrances. *M. keenii* were recorded from the previously mentioned mine 17 km NW of Hot Springs, Garland County (Davis et al., 1955; Sealander and Young, 1955).

Myotis lucifugus (LeConte). Trogloxene. A single male was observed in Walnut Mine. This species was reported from the previously mentioned mine 17 km NW of Hot Springs, Garland County. McDaniel and Gardner (1977) reported that the little brown bat occurred in small numbers in Ozark caves.

Lasionycteris noctivagans (LeConte). Trogloxene. A single specimen was observed hibernating in the breezeway of Mercury One Mine on Lake Greeson, Pike County. The ambient temperature was 2°C. The specimen represents a new county record for this species. Typically a tree bat, this species has been documented from mines and caves (Barbour and Davis, 1969). In addition, Saugey et al. (1978) found one skull in an Ozark cave.

Pipistrellus subflavus (F. Cuvier). Trogloxene. The eastern pipistrelle is extremely widespread and abundant. It has been observed in every mine at all times of the year. Over a three year period, winter visits to Pipistrelle Mine have revealed 600-800 hibernating individuals in this 70 meter straight-shaft mine.

Order Rodentia
Family Cricetidae

Neotoma floridana (Ord). Trogloxene. Eastern woodrat nests were found around the entrances to Twin Upper, Twin Lower, and Candy mines.

Peromyscus attwateri Trogloxene. Brush mouse scat and a nest were found about 15 meters inside the entrance to Slimy Mine and a live mouse, with its nest, was observed in Twin Upper Mine.

Order Carnivora
Family Procyonidae

Procyon lotor (Linnaeus). Trogloxene. Raccoon tracks were found in the mud of Stinger Mine. Raccoons may use mines as refugia or feeding sites.

Family Ursidae

Ursus americanus Pallas. Trogloxene. Black bear were not actually observed by the authors, however, they have been observed utilizing several mines (L. Ateshire, Mena, Polk County, AR. pers. comm.).

DISCUSSION

Abandoned mines represent important ecological features of the Ouachita Mountains, in that at least 27 vertebrate taxa are utilizing the mines for some purpose. It is to be expected that several other species may also utilize the mines on a temporary basis, either as refugia or feeding sites. These results lend additional emphasis to the statement by Maser et al. (1979) that, "Unique habitats occupy a very small percent of the total forest land base, yet they are disproportionately important as wildlife habitats."

McDaniel and Gardner (1977) reported the occurrence of 53 vertebrate taxa utilizing Ozark caves; several of which were accidentals which we might also expect to find. Caves provide a more extensive cavernicolous habitat than do mines (most of the mines were straight or 'L' shaped

shafts extending 30-150 meters). However, the deep constant temperature zone of the mines was rather stable averaging between 8-11 °C, with a short variable temperature zone. In addition, many of the mines, through seepage, contained permanent pools or streams. All of the pools within the mines contained varying amounts of leaf litter. These characteristics may have contributed to 18 vertebrate taxa common to both Ozark caves (34% total taxa) and Ouachita abandoned mines (67% total taxa).

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SURVEY OF 1985 PERIODICAL CICADA (Homoptera: *Magicicada*) EMERGENCE SITES IN WASHINGTON COUNTY, ARKANSAS, WITH REFERENCE TO ECOLOGICAL IMPLICATIONS

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ABSTRACT

Systematic roadside surveys were conducted in June 1985 in Washington County, Arkansas, to locate areas where 13-year periodical cicadas had emerged during May. Although cicadas were found in a variety of upland and bottom land forest habitats, the present cicada distribution reflects the original forest and prairie pattern in the county, even though those boundaries are now largely lost. This suggests a high degree of philopatry whereby emergency areas have remained in the same area for the last 100 years. All present day emergence areas are within the White River drainage, suggesting that it was the main cicada dispersal route into northwestern Arkansas. It now probably marks the western limit of Brood XIX in northwestern Arkansas.

INTRODUCTION

Three species of periodical cicadas (Homoptera: *Magicicada*) emerge together in great numbers once every 13 years in southern parts of the United States. All periodical cicadas that emerge in a given year are considered members of the same brood (Marlatt, 1907) and year of emergence of each brood is one of the most highly predictable events in nature. The most extensive emergence involves cicadas of Brood XIX, which emerges from Virginia through the south to western Arkansas and southeastern Oklahoma (Marlatt, 1907; Simon, 1979). Brood XIX cicadas emerged in 1985 throughout most of Arkansas and are the focus of this report. (Brood XXIII cicadas also occur in Arkansas along Crowley's Ridge and are due to emerge in 1989.)

Although the emergence of periodical cicadas in Brood XIX occurs over a large area, the cicadas are patchily distributed within this range. In conjunction with research to study the effects of the cicada emergence on bird communities in northwestern Arkansas, we sought to locate specific emergence sites in 1984 (one year prior to emergence) to obtain baseline information on avian populations. We knew that Brood XIX would emerge in 1985, but we had no information concerning specific emergence sites in Washington and adjacent counties. Therefore, we had to rely on reports of others who had observed former periodical cicada emergences.

Surprisingly, we found no one who recalled details of the emergence in 1972. However, Lloyd O. Warren, Department of Entomology, University of Arkansas, was able to suggest several sites where periodical cicadas had emerged in 1959. One of the sites, near Durham, Arkansas, was visited during the emergence peak in 1959 by Jessie L. Lancaster and Robert Watson, who collected 6 specimens for the University of Arkansas Entomology Collection. Based on these specimens and Lancaster's and Watson's descriptions of high cicada densities at the Durham site, we selected that site for our study. Subsequently, we searched for oviposition scars on tree limbs made by periodical cicadas during previous emergences (White and Lloyd, 1979) and we found scars from both 1959 and 1972. Based on our finding, we began our research in 1984 and indeed, large numbers of cicadas emerged on that site in 1985.

Because of our difficulty in finding periodical cicada emergence sites, we decided that during the 1985 emergence we would survey Washington County and map emergence areas for use by future researchers. This paper is the result of that effort. In addition to identifying specific cicada sites and forest habitats, however, we discovered that the pattern of present-day sites has some interesting ecological implications concerning the location of former prairie areas. Our survey also showed that present cicada locations are confined to the White River drainage.

METHODS

The cicada survey routes were driven between 8-15 June 1985 (Figure 1), when periodical cicadas had emerged from the ground. After cicadas emerge, they molt into adult forms, and males aggregate in adjacent groups of trees and sing during daylight hours. Female cicadas are attracted to such "chorus centers", where mating occurs. Although cicadas may move short distances to congregate at choruses (Karban, 1981; Lloyd and Karban, 1983), choruses are always in immediate areas of periodical cicada emergences. Survey routes were travelled only in the middle portion of the day when cicada chorusing was maximal. Before driving a survey route, a known cicada site was visited to ascertain that conditions were appropriate for cicada chorusing. Frequent stops were made on the survey routes to listen for cicadas. Often all three species were heard (*Magicicada tredecassini*, *M. tredecim*, *M. tredecula*), frequently only two, sometimes only one. However, this aspect was not emphasized. Since the focus was on finding cicada sites regardless of species represented, details about the species present will not be mentioned.

DESCRIPTION OF PERIODICAL CICADA EMERGENCE SITES

The following is a list of periodical cicada emergence sites found in Washington County. Each site has been given a name which may or may not refer to an accepted local name. Detailed locations for each site are given, plus an overview of the forest habitat. Each cicada area is shown in Figure 2, located by site position. (Tree taxonomy and terminology is from Moore, 1972.)

1. Ten-mile rock: at West Fork, Arkansas, east of highway U.S. 71 in Sec. 4, T14N, R30W. The chorus was heard from the highway. This is an extensive upland forest area dominated by White Oak (*Quercus alba*) and Black Oak (*Q. velutina*) with many Winged Elms (*Ulmus alata*), some American Elm (*U. americana*), Shagbark Hickory (*Carya ovata*), Mockernut Hickory (*C. tomentosa*), Eastern Redcedar (*Juniperus virginiana*), and many Chinkapin Oaks (*Q. muhlenbergii*).
2. Tilly Willy Road: road that courses along east bank of the West Fork of the White River, east of the Fayetteville airport. Periodical cicada choruses were heard along both sides of this road where it crosses the NE corner of Sec. 9, SE corner of Sec. 4, and to the center of Sec. 3, T15N, R30W. This area is upland forest east of the road, bottom land forest west of the road. The upland is dominated by Black and White Oak, Shagbark and Black Hickory, with almost no cedars and very little elm, some White Ash (*Frax-*

Survey of 1985 Periodical Cicada (Homoptera: *Magicicada*) Emergence Sites in Washington County, Arkansas

inus americana). The predominant trees in the bottom land are American Sycamore (*Platanus occidentalis*), River Birch (*Betula nigra*), Black Willow (*Salix nigra*), Box Elder (*Acer negundo*), Silver Maple (*Acer saccharinum*), Hackberry (*Celtis occidentalis*) and White Ash.

3. Wilson Lake: chorusing cicadas surrounded a small reservoir named Wilson Lake south of Fayetteville, mostly in the SW half of Sec. 2, northern part of Sec. 11, and a portion of the NE part of Sec. 3, T15N, R30W. The forest around the lake is upland forest dominated by Black Oak, Post Oak (*Q. stellata*), Shagbark and Black Hickory, with a moderate number of Winged Elms and a few Eastern Redcedars in the understory.
4. Wilson Lake Road: along the north side of the road leading from Fayetteville to Wilson Lake, before the road crosses the West Fork of the White River. Includes SW and SE quarters of the NE quarter of Sec. 34 and the SW quarter of the NW quarter of Sec. 35, T16N, R30W. This upland forest area consists primarily of Post and Black Oak, Blackjack Oak (*Q. marilandica*), Winged Elm, Black Hickory, and a small number of cedars.
5. West Fork Crossing: along both sides of the road, mainly west of the bridge, where a road crosses the West Fork of the White River south of Fayetteville. The bridge is on the section line between Sections 35 and 36, T16N, R30W, and the cicada area extends along the road in the NE quarter of Sec. 35. This site is mostly bottom land forest along the river with a mixed variety of trees including Sycamore, Silver Maple, White Ash, Box Elder, River Birch, Hackberry and Black Oak. West of where the road turns north, the cicadas occupied upland forest containing Black Oak, Winged Elm, Post Oak, Black Hickory, with some Eastern Redcedar in the understory.
6. Black Oak, Arkansas: a site a little over a mile on the road NW of Black Oak community. The cicadas were on both sides of the road where another road joins the Black Oak road in the north-central part of Sec. 7, T15N, R29W. This is upland forest dominated by Black Oak, White Oak and Shagbark Hickory.
7. South of Elkins: just west of state highway 16 south of Elkins, slightly north of the center of Sec. 12, T15N, R29W. This is a densely overgrown old field dominated by Eastern Redcedar, Winged and American Elm, with Silver Maple along a creek; and is adjacent to extensive upland forest dominated by Black Oak, Post Oak, White Oak, and some Black Hickory, with cedar and Flowering Dogwood (*Cornus florida*) in the understory.
8. Brey Cave: an area of upland forest around the cave located SW of Mount Olive in the NW quarter of Sec. 8, T15N, R28W. The most common tree is Post Oak followed by Winged Elm, then Black Hickory, Eastern Redcedar and Black Oak.
9. White River Ford: the bottom land forest where the road fords the White River north of Durham at the NE edge of Sec. 18, T15N, R28W. Sycamore, River Birch, Silver Maple, American Elm, Hackberry, and Black Willow trees predominate.
10. Bridge North of Durham: an upland forest on a hillside south of the first bridge on state highway 16 NW of Durham. The site is SE of the creek in the NW corner of Sec. 19, T15N, R28W, and is almost all Post Oak in the overstory, but also has some Blackjack Oak and Shagbark and Black Hickory. The understory is Eastern Redcedar and Winged Elm.
11. Middle Fork Valley: just west of the road between Durham and the middle fork of the White River, slightly NW of the center of Sec. 26, T15N, R29W. This upland ravine forest is dominated by Black Oak, Post Oak and White Oak, and has Sycamore and Red Maple (*A. rubrum*) along a creek.
12. West of Durham: this cicada emergence site occupies the second ridge on the road leading westward from Durham. It is on both sides of the road where it crosses the boundary between Sections 25 and 26, and includes the adjacent corners of Sections 23 and 24, T15N, R29W. This extensive upland forest contains mainly White and Post Oak, Shagbark and Black Hickory, Red Maple, with Winged Elm and Flowering Dogwood in the understory.
13. Stewart's Place: along the road going west of Durham, mainly north of the road but also west and south of it in Sec. 25. The

site occupies the NW edge of Sec. 30, T15N, R28W, and most of the NE corner of Sec. 25, T15N, R29W. This is on the first ridge west of Durham and is mixed upland forest with Black, Post and White Oak, Eastern Redcedar, Winged Elm and Shagbark Hickory.

14. Cassidy's Place: our main cicada study area, NE of Durham across the White River. It occupies the western half of Sec. 20, T15N, R28W, and also along the White River in that section, dipping into the northern part of Sec. 29. This is an extensive upland forest of Post Oak, Eastern Redcedar, Shagbark Hickory and Black Oak. It also includes some bottom land forest along the river dominated by Sycamore, River Birch and Silver Maple.
15. West of Thompson: overlapping the county line, the site is SW of state highway 16 covering the common corner for Sections 33 and 34, T15N, R28W, and Sections 3 and 4, T14N, R28W. It is an area of upland forest composed of White and Post Oak, Southern Red (*Q. falcata*), Black Oak, and Shagbark Hickory.
16. East of Thompson: This area is over the line in Madison County on the east side of the White River in the SE corner of Sec. 34, T15N, R28W. It is covered by upland forest of Post and Black Oak, Southern Red and White Oak and Shagbark Hickory, with an understory of Winged elm; and also includes a strip of bottom land forest of Silver Maple, River Birch, Sycamore, Box Elder and Sweetgum (*Liquidambar styraciflua*) along the river.

In addition to cicada emergences in and near Washington County described above, we visited an active site in Carroll County NE of Eureka Springs along the road to Lake Leatherwood. Also, active cicada chorus centers were reported to us from Benton County in the vicinity of Molder Hollow, which is a major inlet on Beaver Lake in Sec. 24, T20N, R28W. There may have been many other cicada emergence sites in those two counties, but no systematic surveys were conducted there.

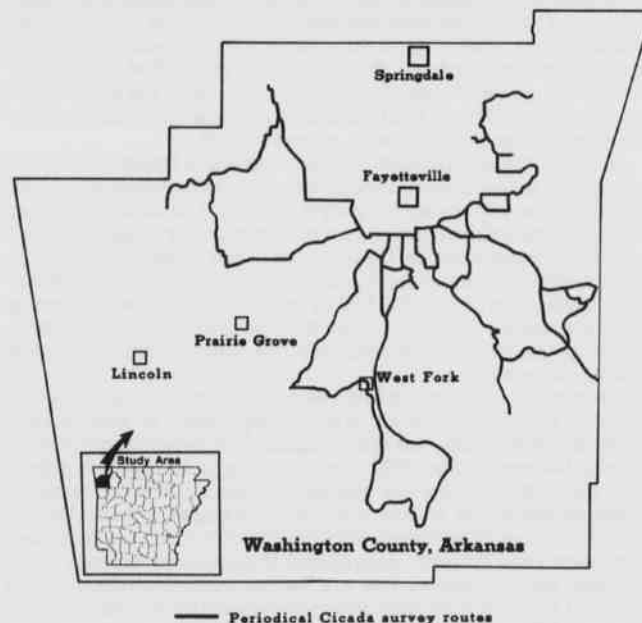


Figure 1. Outline of Washington County, Arkansas, showing the routes (solid lines) driven when conducting cicada site surveys.

DISCUSSION

Although survey routes radiated in all directions from Fayetteville (Figure 1), the 16 cicada emergence areas located were all positioned in the south and southeast part of Washington County (Figure 2), corresponding to that region of the county that is most heavily wooded. None of the present cicada positions in Washington County overlap

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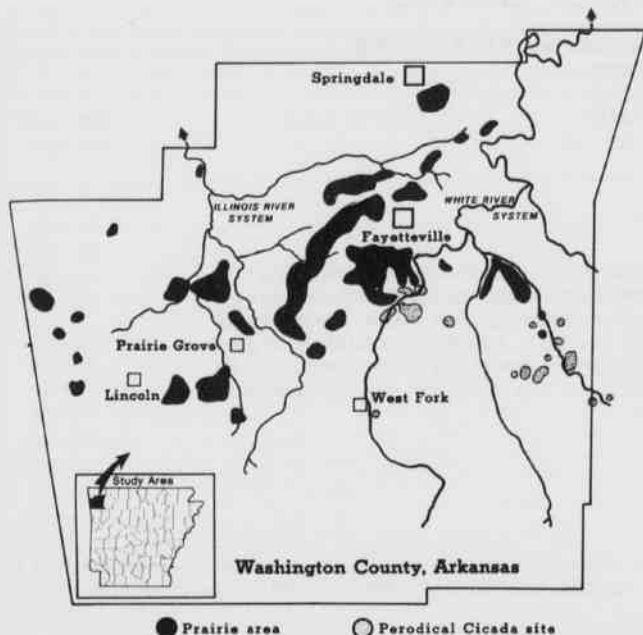


Figure 2. Map of Washington County, Arkansas, showing periodical cicada sites (stippled), original prairie areas (black), and the Illinois and White River drainage systems (thinner and wider solid lines, respectively).

areas of prairie grasslands (Figure 2) shown in a detailed map of Arkansas published by Langtree in 1866. Subsequent maps of Arkansas that detailed prairie areas were essentially the same as Langtree's (Sargent, 1884; Allred and Mitchell, 1955). Lesquereux (1860) corroborated the overall pattern shown on Langtree's map with his descriptions of the extensive prairie flatlands underlain by limestone in Benton and Washington counties. Lesquereux further commented that the area between the White River and Lee Creek had trees present, which includes the area occupied by periodical cicadas today (Figure 2).

Although forest stands have now spread across many of the former prairie areas in Washington County, the periodical cicadas apparently have not followed. Based on the present distribution pattern, we found no evidence that periodical cicadas exist in western Washington County near the Oklahoma border, as shown in the map published by Marlatt (1907). Rather, our results suggest that periodical cicadas have extended their range very little over the last century in Washington County and that their present distribution probably still marks the original forest areas. Several researchers have debated the dispersal capabilities of periodical cicadas (e.g., Karban, 1981; Lloyd et al., 1982; White et al., 1983). Our results suggest a large historical component influences the present distribution of periodical cicadas. Lack of apparent dispersal is no doubt due to the aggregative behavior and long generation time that 13-year periodical cicadas have. Even if the destruction of prairies began in 1866, there could have been only 10 generations of 13-year periodical cicadas in the 119 years since that date.

Several of the present cicada emergence sites are close to former prairie margins (Figure 2). This may represent the persistence of a former pattern resulting from a close ecological relationship. Female periodical cicadas seem to favor forest edge trees for oviposition and move toward forest edge habitats (e.g., Lloyd and White, 1976). The pattern of original prairies next to forest stands would produce relatively stable boundaries of forest edge, which apparently remain represented by the patterns of some cicada emergences.

Finally, we note that all the cicada emergences are positioned in the White River drainage in the eastern half of Washington County, and none are in the Illinois River drainage in the western half of the county. This situation also probably reflects a prairie and forest distribu-

tion. The Illinois River drainage widely embraces the prairie areas in Washington County, drains even more prairie areas in Benton County to the north, and then flows westward into Oklahoma. The White River drains extensive forest areas, and flows northward and eastward into forested areas of the Ozarks. The Illinois River flows into regions where 13-year periodical cicadas were virtually absent, the White River traverses a region where cicadas were abundant (Marlatt, 1907). Therefore, the forests adjacent to the White River could have served as a main avenue of cicada dispersal into northwestern Arkansas, thus providing the present distribution of cicada sites (Figure 2) are near branches of the White River. The White River drainage in fact may represent the western limit of Brood XIX of the periodical cicada in the United States, which is the most widespread of any 13-year brood, extending eastward to Virginia.

ACKNOWLEDGEMENT

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AGE AND GROWTH OF REDEAR SUNFISH, *LEPOMIS MICROLOPHUS* (GUNTHER), FROM BOB KIDD LAKE

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ABSTRACT

Total lengths (62-285mm) and body scales from 75 redear sunfish collected by electroshocking from Bob Kidd Lake during October and November 1985 were used for this study. The length-frequency distribution yielded five age groups, however, the body scale analysis revealed eight age groups. The total length — scale radius relationship was estimated as, $TL = 17.98 + 0.92 S_r$. Lengths attained at earlier ages were estimated by the Fraser-Lee method and the Bertalanffy growth model was fitted to the lengths for ages five through ten, and the resulting equation, $L_t = 295 [1 - \exp - 0.29 (t - 1.83)]$, estimated lengths similar to the back-calculated lengths ($r = 0.98$).

INTRODUCTION

The redear sunfish (*Lepomis microlophus*) is a large, hard-fighting panfish that can be harvested in great numbers at certain times of the year, and is a popular sport-fish in Arkansas and other states. Studies on growth are integral to sound management of redear populations and although numerous studies on redear growth have been conducted in other states (Finnell, 1954; King, 1955; Louder and Lewis, 1957; Schoffman, 1938; Swingle, 1965; Tharratt, 1966), none have been done in Arkansas. This paper describes the age and growth of redear sunfish from Bob Kidd Lake, Arkansas, and, to the best of the authors' knowledge, represents the first published study of redear age and growth in Arkansas.

STUDY AREA

Bob Kidd Creek was impounded in 1975 to create an 81 ha reservoir with an average depth of 4.2 m, and a maximum depth of 13.3 m. Bob Kidd Lake is located 5.4 km north of Prairie Grove on Arkansas State Highway 62, and is owned, operated, and managed by the Arkansas Game and Fish Commission. Six thousand redear fingerlings were stocked in Bob Kidd Lake on 20 September 1979, 6,800 fingerlings on 20 October 1980 and 5,000 yearlings on 23 October 1980 (Fourt, Pers. Comm.).

MATERIALS AND METHODS

During October and November 1985, 180 redear sunfish were collected with a boat-mounted 230 volt AC electroshocker. All redear were measured for total length to the nearest millimeter. A scale sample was removed from the body of each fish at the tip of the apposed left pectoral fin. Scales were mounted between two glass slides and photocopied at a magnification of 41X with a microfiche copy machine, as described by Kilambi and Galloway (1986). The scales that were too large for a 41X magnification were photocopied at 20X. These photocopies were used for all age and growth determinations. Scale measurements (mm) were recorded from the focus to each annulus, and to the right corner margin of the anterior field (scale radius). A subsample of 75 fish, representing all size groups, was used to determine the total length — scale radius relationship. The lengths of fish at previous ages were estimated by the Fraser-Lee method (Carlander, 1982), and the data were analyzed by the Bertalanffy growth model (Ricker, 1975)

$$L_t = L_{\infty} [1 - \exp - K (t - t_0)]$$

where, L_t = length at age t , L_{∞} = maximum attainable size, K = rate constant (coefficient of catabolism), and t_0 = age at which length is zero.

RESULTS AND DISCUSSION

The total length (TL) — scale radius (S_r) relationship for 75 redear sunfish, ranging in length from 62 to 285mm, was estimated as:

$$TL = 17.98 + 0.92 S_r; (r = 0.96)$$

Back-calculated lengths at earlier annuli, when plotted on a Walford graph, revealed a line that increased in slope for fish less than 160mm long, and then decreased for larger fish. This has been reported for centrarchids from the warmer parts of eastern North America (Ricker, 1975). The increased slope is often caused by selection for fast growing younger fish. A way to avoid this bias is to use lengths calculated from scale annuli of older fish to represent the younger ones (Ricker, 1975). Therefore, Fraser-Lee estimates of lengths at previous annuli from fish of ages 5-10 were fitted by the Bertalanffy growth equation as:

$$L_t = 295 [1 - \exp - 0.29 (t - 1.83)]$$

Analysis of the length-frequency distribution of all the 180 redear by the probability method (Harding, 1949) revealed five age groups (age group I, 61-100mm; age group II, 101-130mm; age group III, 131-160mm; age group IV, 161-200mm; the two large fish in an age group V). The scale analysis yielded eight age groups representing ages 1-6, 10, and 11 (Table 1). The length-frequency distribution also showed modal increases with increased fish length up to 160mm. The small sample size for fish over 160mm long, as well as the slow growth of older fish (causing overlap of age groups) made the length-frequency distribution unreliable for fish over 160mm. Age determinations by the scale analysis were verified for redear sunfish under 160mm long by the increase in the number of scale annuli with increase in fish length (Table 1) and agreement of age estimates by the scale annuli and length-frequency distribution. Hence, the scale analysis was considered to estimate correctly the ages of the larger redear sunfish. Furthermore, the lengths estimated by the Bertalanffy growth model and by back calculations using Fraser-Lee method (Table 2) were in agreement ($r = 0.98$) indicating the suitability of this model to describe growth of redear from the Bob Kidd Lake.

Comparison of growth of Bob Kidd Lake redear with the growth of redear from lakes in other states (Table 3) revealed a slightly slower growth rate in Bob Kidd Lake. Houser and Grinstead (1961) found that a reduction of the bluegill population in Rod and Gun Club Lake,

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Table 1. Age group frequencies in relation to length-frequency distribution of redear sunfish from Bob Kidd Lake.

Total length range (mm)	Number of annuli										
	1	2	3	4	5	6	7	8	9	10	11
61-70	5										
71-80		11									
81-90		11									
91-100		11	1								
101-110			7								
111-120			1								
121-130			2	1							
131-140				5							
141-150				6							
151-160				6	1						
161-170					1						
171-180					1						
181-190					1						
191-200					1	1					
261-270											1
281-290										1	
Total	5	33	11	18	5	1				1	1

Table 2. Average back-calculated lengths of redear sunfish from Bob Kidd Lake.

Age group	Number of fish	Total length (mm) at annulus										
		1	2	3	4	5	6	7	8	9	10	11
I	5	42										
II	11	51	74									
III	10	50	75	97								
IV	17	56	82	106	130							
V	5	49	90	116	139	159						
VI	1	62	95	116	141	162	175					
VII	0	--	--	--	--	--	--	--	--	--	--	--
VIII	0	--	--	--	--	--	--	--	--	--	--	--
IX	0	--	--	--	--	--	--	--	--	--	--	--
X	1	69	100	141	177	208	239	251	271	275	280	
XI	1	52	82	120	149	179	207	223	232	241	251	259
Weighted mean		53	78	107	135	168	202	237	251	258	266	259

Oklahoma, was followed by an increase in redear growth rate. The abundance of bluegill in an Alabama pond was found to depress the growth rate of redear (Elrod, 1971). We found bluegill to be more abundant than redear sunfish in Bob Kidd Lake. This could be responsible for the relatively low growth rate of redear sunfish in Bob Kidd Lake.

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Table 3. Comparison of growth rates of redear from Bob Kidd with growth rates of populations from other states.

Locality and Reference	1	2	3	4	5	6	7	8	9	10	11	age 6 and below
Bob Kidd L., AR (Present Study)	53	78	107	135	168	202	237	251	258	266	259	31
Sub-prison L., OK (Finnell, 1954)	49	89	119	155								35
Hiwassee L., OK (King, 1955)	66	117	170	208	240							38
Murphyboro L., IL (Louder and Lewis, 1957)	46	94	132	165	188	216	259					34
Reelfoot L., TN (Schoffman, 1939)	--	110	151	175	189	207						24
Folsom L., CA (Tharrett, 1962)	48	124	191	224								59
Spear L., IN (Ricker, 1955)	43	91	147	182	208							41
Harris L., FL (Freeman and Hight, 1953)	112	147	183	198	224	251	257	216				28
97 lakes, ponds, streams (Jenkins et al., 1955)	38	79	117	163	203	218						36

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RELATIONSHIP BETWEEN DIAMETER BREAST HIGH AND DIAMETER NEAR GROUND LINE FOR HARDWOOD SPECIES IN ARKANSAS

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ABSTRACT

The relationship of diameter breast high (DBH) and diameter near ground line (DNG) was investigated for three groups of Arkansas hardwoods from four physiographic regions in the state. The relationship between DBH and DNG did not vary significantly across species groups or physiographic regions. Equations of both linear and non-linear form were developed to estimate DBH from DNG. The relationships between DBH and DNG is used to estimate timber volume, growth, and value from residual stumps. The relationship is also useful in harvesting system design and cost estimation in operational forestry.

INTRODUCTION

Researchers have explored the relationship between diameter breast high (DBH) and diameter near ground line (DNG) (three to twelve inches, 8-30 cm.) for several reasons. The DBH-DNG relationship was established for seven southwestern species in order to estimate the standing volume of timber from residual stumps following timber theft (Hann, 1976). The same relationship was used to reconstruct growth and yield information for 17 southern species and Douglas Fir (McClure, 1968; Curtis and Arney, 1977; and Bylin, 1982). Lanford and Cunia (1971) investigated the relationship to provide harvesting engineers with information for the design of three shears. Kluender (1983) used the relationship to estimate total cost to fell trees in a harvesting operation. This relationship has not been established for hardwoods in Arkansas, but is needed.

The objective of the study was to determine the relationship between DBH and DNG for three groups of hardwood species in four physiographic regions in Arkansas.

METHODS

Description of Study Areas

Ozark Highlands — The study area is similar to much of the Ozark Mountains. The soil series is Clarksville-Gepp, a clayey, cherty soil, originating from several horizontally-laid zones of limestones (USDA, 1978). This formation gives rise to the typical North Arkansas benches between the rock layers. In most cases the soil depth and moisture is greater on the benches than on the rock ledge faces. The area extended around the slope on each of three benches (three elevations) on southern, southwestern and western aspects of Waugh Mountain. Most of this mountain is located on the Batesville Livestock and Forestry Experiment Station of the University of Arkansas, eight miles northwest of Batesville.

Coastal Plain — The Coastal Plain data were collected on the Teaching and Research Forest of the University of Arkansas at Monticello. Soils are of the Calloway Series and are somewhat poorly drained. Upper soil layers are silt loams and lower horizons are characterized by a wak fragipan of light brownish-gray mottled silty clay loam (USDA, 1976). Average slope of the area is zero to three percent.

Athens Plateau — The Athens Plateau study area was located eight miles northwest of Arkadelphia, AR, on land owned by The Ross Foundation. Soils in the area are of the Ouachita Mountain major soils group. Typical soil series on the site are Sherwood, Clebit, and Pickens (USDA, 1982). Generally, there is a moderately thick A horizon of topsoil that is well drained. Slopes of ten to fifteen percent are normal.

Ouachita Mountains — This study area is approximately 15 miles

northeast of Jesseville. The primary soil type in the Ouachita Mountain study area is of the Goldston-Rockland Association, typified by the Georgeville and Talledaga series (USDA, 1982). Generally, the sites are steeply inclined with deeply fractured rock formations that allow for adequate root penetration and moisture retention. Surface conditions are rough and stony with a relatively shallow topsoil layer.

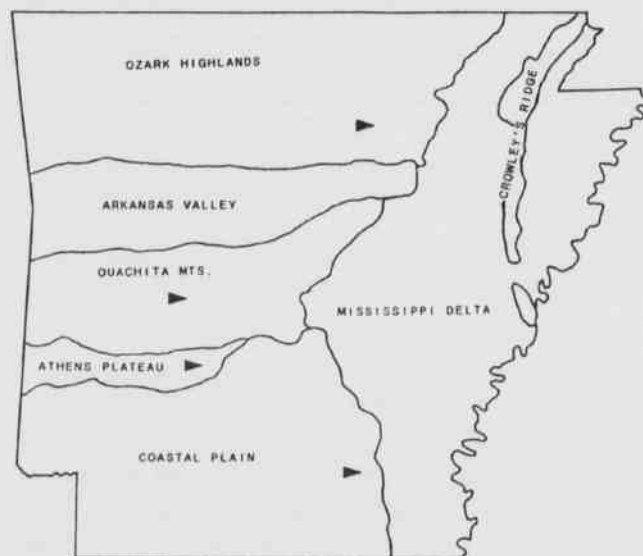


Figure 1. Physiographic regions of Arkansas showing study sites (▲).

Sampling Techniques

The sites and species group sampled typified the respective physiographic region and forest stands found there (Harlow et al., 1979) (Figure 1). The species within the three assigned species groups (red oak, white oak and mixed hardwoods) varied somewhat by region. For example, the dominant member of the white oak group at Batesville was post oak (*Q. stellata*) while the dominant member of the group at Monticello was white oak (*Q. alba*). Miscellaneous hardwoods were composed of primarily hickories (*Carya spp.*) at Batesville, sweet gum (*L. styraciflua*) and dogwood (*C. florida*) at Monticello and maples (*Acer spp.*) and hickories at Jesseville and Arkadelphia.

Samples were taken across contours to obtain a representative sam-

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ple within each stand. Also, each of the three species groups were sampled equally with measurements recorded for approximately 30 members each of the red oak, white oak and miscellaneous hardwood groups. Paired measurements for DBH and DNG were recorded for each tree, species group and physiographic region.

Paired observations of DBH and DNG were taken in each DBH class from one inch to the largest class found on the site to insure applicability of the developed equations over a complete range of tree diameters. DBH measurements were taken 4.5 feet (1.37 M) from ground level. DNG measurements were taken not lower than six inches (15 cm.) from the ground, and high enough to be above any fluting or exaggerated butt swell. No DNG measurements were taken above 12 inches (30 cm).

Statistical Analysis

Regression equations predicting DBH as a function of DNG were constructed in each of two different forms for each physiographic region-species group combination. The null hypothesis was that there was not a significant difference in tree form by species group and by physiographic region. The equation forms were:

$$DBH = a + b \times DNG$$

And,

$$DBH = a \times DNG^b$$

Where: DBH = diameter breast high
DNG = diameter near ground
a = a constant, and
b = the slope of the regression line.

The precedent for using simple linear regression estimation has been well established (McClure, 1968; Lanford and Cunia, 1971; Hann, 1976; Curtis and Arney, 1977; and Bylin, 1982). In order to have comparable results and to produce a set of equations of maximum utility to foresters, we used this commonly accepted form.

The non-linear form of estimation more closely approximates the true form of a tree. The relationship of DBH and DNG has been reported in this form in several places (McClure, 1968; Kira and Ogawa, 1969). Until the recent advent of calculators that would raise a number to a power, logarithmic conversions had to be used to adequately express a non-linear relationship. This problem greatly reduced the utility of non-linear forms for practitioners whose mathematical skills were rusty. The method we used to obtain the coefficients used a logarithmic transformation but the predictive equations are presented below in their non-linear form.

In order to test the hypothesis of difference in tree form (relationship of DBH and DNG) by species group and physiographic region we constructed a ratio of the estimated DBH (using the 12 developed regression equations) and DNG using a constant ten inch (25.4 cm) value for DNG. The constant DNG value was used to insure that the estimated DBH values were all based on the same level of the independent variable. These tree form ratios (DBH/DNG) were then investigated with an analysis of variance to determine if a significant difference existed by species group or physiographic region.

RESULTS AND DISCUSSION

The results of the analysis of variance tests showed that tree form as indicated by the ratio of estimated DBH and DNG set to ten inches did not vary significantly ($p = .05$) by species or by physiographic region. We therefore failed to reject the null hypothesis of no differences by species and physiographic region. However, in the means separation, using Duncan's test ($p = .05$), tree form did vary significantly between the Coastal Plain and the Ozark Highlands. We recognize that having failed to reject the null, the means separation is a relatively weak test. However, we do feel that the means separation test is picking up a slight difference in tree form based on the extremes of our observations. The composition of the species groups and the soil characteristics (primarily depth) differed most noticeably between these two physiographic regions. The results of testing consistency of tree form

lead us to pool the data for all species-groups and physiographic regions and rerun the regression analysis. Based on the means separation, we also grouped the data into two additional data sets for upland hardwood stands (Ozark Highlands, Athens Plateau and Ouachita Mountains) and low land hardwoods (Coastal Plain). Results of these regressions for the linear and non-linear forms of the equations are presented in Table 1.

Table 1. Regression equations for prediction of DBH from DNG for hardwoods in Arkansas and for upland and lowland hardwoods.

Physiographic Region	<u>Equation Parameters</u> ¹		R ²
	a	b	
Linear Form ²			
Statewide	-0.81 (-2.06)	0.86 (2.18)	.980
Upland	-0.65 (1.65)	0.83 (2.11)	.972
Coastal Plain	-0.56 (-1.41)	0.87 (2.20)	.990
Non-linear Form ³			
Statewide	0.54 (1.65)	1.07	.977
Upland	0.65 (1.66)	1.06	.971
Coastal Plain	0.71 (1.80)	1.06	.991

¹Table values are in inches, and (centimeters). For the non-linear equations, in conversion to metric form only the 'a' coefficient need be altered, since the slope is consistent regardless of units.

²Equations are in the form: $DBH = a + b \times DNG$

³Equations are in the form: $DBH = a \times DNG^b$

Our results may be applied to estimate individual tree or stand volumes, or the reconstruction of growth and yield data. For example, for timber theft valuation purposes, estimated DBH, from the equations, coupled with an estimate of the height, based on other trees in the area, can be used directed in the estimation of tree volume and hence, value. For rough growth and yield estimation a similar process is used. Stump DNG measurements can be estimated, with an allowance for bark thickness, at previous points in time by direct measurement of the appropriate inner rings. DBH at previous times can then be directly estimated and appropriate heights, as above, used in the estimation of previous tree volumes. With sufficient observations, this information can be extrapolated to stand level data.

Estimation of DNG from DBH can be achieved by recasting the equations with DNG as the dependent variable. This application is some times used in operational forestry when the average DBH of a stand is known but average DNG is needed. DNG, or stump diameter, is used to compute such values as average time to fell a tree or to calculate the force required to mechanically shear a standing tree, or estimate the amount of herbicide needed for tree injection (Yeiser and McLemore, 1984).

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TAGGING AND MARKING CRAWFISH (*Procambarus clarkii*) IN A POPULATION ESTIMATION STUDY

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ABSTRACT

Crawfish (*Procambarus clarkii*) were tagged with enumerated plastic streamers and released in 0.1-ha ponds to observe recapture frequency in stand-up traps. Also, crawfish were marked by a uropod punch, released and recaptured in 0.1-ha ponds for population estimation.

Survival of streamer-tagged crawfish in indoor tanks averaged 46.7% after 25 days, indicating that tagging caused stress leading to mortality, especially during molt. Recapture frequencies of tagged crawfish indicated sampling bias which obviated use of the tagging method in population assessments.

Short term (3-day) survival of marked crawfish (92%) and retention of the mark after molt indicated potential application in population assessment studies. Population estimates in two ponds were calculated using two methods: mark-recapture data and quadrant sampling. For both methods, crawfish were collected by seining. Population estimates using quadrant sampling averaged 25% lower than those using mark-recapture data. This discrepancy may have been due to escape during seining, which would lead to population under-estimation with quadrant sampling.

INTRODUCTION

Crawfish population assessments can be used as a management tool to indicate relative abundance, total biomass, growth rates, and other crawfish production parameters in various systems. Accurate population estimates allow the crawfish producer to approximate future harvesting times and yields, food input and other management requirements. Population estimation with certain crawfish species can be accomplished in deep, clear waters by visual observations (Capelli, 1975); population assessments in clear, shallow streams can be conducted using electro-fishing (Hopkins, 1967). In the southeastern United States, however, most crawfish (*Procambarus spp.*) culture occurs in open, shallow ponds in which some type of vegetation is available for crawfish forage. Under these conditions, small crawfish (<5 cm) are typically sampled by dipnet to obtain data on their relative abundance, and larger crawfish are commonly captured in traps (Huner, 1978).

In several studies, larger crawfish have been individually marked by clipping or excision of non-vital appendages (Hopkins, 1967; Romaine, 1974; Momot and Gowing, 1977). However, analysis of population assessment data for coolwater crawfish (*Orconectes spp.*) indicates that trapping may be biased, selecting for crawfish based on size, sex and breeding state, rather than reflecting true population densities (Capelli and Magnuson, 1975; Malley and Reynolds, 1979). In addition, trapping studies have shown that certain animals become "trap-shy" or "trap-happy", thereby biasing population estimates from recapture frequencies (Eberhardt, 1969).

Additional population assessment research will help provide valuable management and research methods in estimating crawfish populations in warmwater ponds. The dual purpose of this study was 1) to observe the recapture frequency of tagged crawfish (*P. clarkii*) in baited traps, using enumerated streamer tags to estimate populations and 2) to compare population estimates obtained with mark-recapture data and quadrant sampling data in two crawfish ponds, using crawfish collected by seine sampling.

METHODS AND MATERIALS

In May and June of 1984, plastic streamer Floy (Floy Tag and Manufacturing, Inc., Seattle, WA) shrimp tags, individually enumerated, were inserted in crawfish (*P. clarkii*) in a tag retention and recapture frequency study. Crawfish were collected from several ponds by sein-

ing with a 4.6-m net with 4-mm mesh. The seine was weighted at the lead line with a heavy chain to prevent the lead line from floating over the submerged rice stubble in each pond. Crawfish that were >80 mm total length, retained all appendages and demonstrated normal activity levels were selected for tagging. The 80 mm criteria was selected based on Huner's (1978) observation that crawfish of that size were fully vulnerable to trapping using 1.9-cm mesh traps.

Streamer tags were inserted in the crawfish according to the manufacturer's suggestions for use in shrimp. Each streamer was inserted into anterior abdominal muscle until equal portions of the streamer extended from each side of the abdominal segment. All tagged crawfish were observed for injury trauma for five minutes prior to use in the studies. Streamer tags were brown in color to approximate the exoskeleton color, thus reducing tagged crawfish losses due to predation. The tags have a sharply indented middle portion to reduce slippage of the tag through entry or exit holes. This method of tag insertion in shrimp has resulted in tag retention exceeding 1000 km of shrimp travel in open ocean conditions (Floy Tag and Manufacturing, Inc., personal communication).

In the indoor tag retention study, 30 crawfish were tagged and then held in indoor tanks for 25 days to observe retention and survival rates. These rates were factors of consideration during assessment of recapture frequencies in ponds.

In the (1984) pond study of recapture frequencies, forty (40) tagged crawfish were randomly dispersed in each of three 0.1-ha ponds. During the next 32 days, crawfish harvested from 1.9-cm (0.75-in) mesh double-funnel standup traps in each pond were closely observed for the presence of streamer tags. Tag numbers were recorded and all captured, tagged crawfish were returned immediately to their respective ponds and randomly dispersed. Untagged crawfish were not returned, using the assumption that recruitment approximated loss from capture. Six traps per pond (60 traps/ha) were harvested daily, with approximate 24-hour sets.

In the 1985 crawfish marking study, crawfish were randomly collected from two 0.1-ha ponds by the seining method described for 1984. On May 10 crawfish were marked by punching a hole (approximately 6-mm in diameter) with a paper punch in a uropod of each animal. As naturally-occurring injuries on uropods may occasionally be mistaken for clip marks, or the clip marks may not be observed (personal observation), the punch hole is advantageous in leaving a distinctive mark that is easily made. Wilder (1953) found that similar marks in lobsters were still recognizable after two molts, thus suggesting that punch marks

Tagging and Marking Crawfish (*Procambarus clarkii*) in a Population Estimation Study

would be sufficiently durable for short-term studies in crawfish. Minimum total length of crawfish marked was arbitrarily chosen at 70 mm as smaller crawfish often did not have uropods of sufficient area to leave an intact punch hole. The overall physical condition of crawfish selected for marking was identical to that of crawfish in the 1984 tagging study.

An indoor survival study was conducted to observe possible acute injury effects on crawfish marked by punch holes over a 72-hour period. Survival at 24 and 48 hours was not recorded so as not to disturb the marked crawfish. The post-marking observation period (3 days) was shorter than the post-tagging observation period (25 days), as the mark (in contrast to the tag) was regarded as relatively permanent and occurred on a non-vital appendage.

In the 1985 marking study in ponds, crawfish were collected by seining, marked and released by random dispersal into two 0.1-ha ponds on May 10 (Day 0). Seine samples were taken in each pond on May 13, 16 and 20 (Day 3, 6, and 10, respectively). These intervals were arbitrarily selected to allow marked crawfish to disperse themselves with the ponds. Each seine sample consisted of three seine sweeps, 27.9 m² (300 ft²) per sweep, at random quadrants in each pond. During sampling, crawfish with marks were recorded, and all other healthy crawfish larger than 70 mm were marked in a similar fashion. All crawfish were immediately and randomly dispersed in their respective ponds. Pond population assessments were calculated by two methods: 1) total counts on quadrant plots (Seber, 1973) and 2) analysis of marked crawfish recaptures, using the Peterson Weighted Mean estimate (Begon, 1979). The latter estimate, to reduce effects of recruitment and mortality, assumes that all individuals have an equal chance of capture, that marking has no effect on capture or death and that sampling periods are short in relation to total time (Begon, 1979).

Table 1. Survival of Crawfish Tagged with Plastic Streamers (N=30 per treatment)

Day	Tagged		Non-Tagged (Control)	
	No. Alive	Survival (%)	No. Alive	Survival (%)
0	30	100	30	100
1	29	96.7	30	100
2	29	96.7	29	96.7
3	29	96.7	29	96.7
7	28	93.3	27	90.0
14	25	83.3	26	86.7
21	21	70.0	25	83.3
25 ¹	14	46.7	22	73.3

¹Many Crawfish experienced a molt during Day 24.

RESULTS

1984 Tagging Study

Indoor Survival and Tag Retention — The results of the indoor tagging survival study are listed in Table 1. Survival of tagged crawfish over a 25-day period was 46.7%, compared to 73.3% survival of non-tagged (control) crawfish under similar conditions. One-third (7/21 = 33%) of the tagged crawfish that survived to Day 21 died prior to Day 25. A simultaneous molt by many crawfish on Day 24 appeared to cause most of the mortalities, as most dead tagged crawfish on Day 25 were found to be in the process of molting. Four of the 14 tagged crawfish alive on Day 25 were soft-shelled, indicating that streamer tagging can be relatively permanent and not necessarily lethal for crawfish. However, the stress of molting, perhaps combined with indoor conditions and streamer tagging, can lead to a high incidence of mortality. The only tag losses observed in the indoor study were from dead crawfish.

Recapture Frequency — The numbers of tagged (as well as untagged) crawfish that were captured (trapped) tended to increase with time between early May and June (Fig. 1), perhaps reflecting increased crawfish activity with increasing pond water temperatures. In Pond No. 32, most captured, tagged crawfish (39/69 = 57%) were trapped more than once (from Table 2 and Figure 1), indicating little or no negative effect of capture on trap re-entry in that pond. More tagged individuals

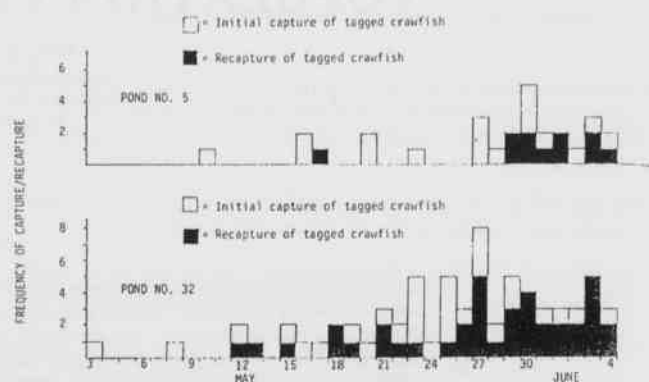


Figure 1. Capture/recapture frequencies of tagged crawfish in two 0.1-ha ponds, using traps.

Table 2. Capture frequency of Tagged Crawfish in Traps During May 3-June 4, 1984

Pond No.	Total no. of trapped crawfish (tagged and untagged)	Total no. of tagged crawfish trapped	No. of tagged individual crawfish trapped at least once	No. of tagged individual crawfish never trapped
3	1090	13	12	28
5	3621	28	17	23
32	2538	69	30	10
Totals	7249	110	59	61

entered traps in Pond No. 32 than in Pond No. 3 and 5 combined (30 vs 29), although total numbers of (tagged and untagged) crawfish captured during the study do not reflect a similar disparity among the ponds (Table 2). However, most tagged crawfish (61/120 = 51%) initially released into the three ponds were never observed to be recaptured.

1985 Marketing Study

Indoor Survival and Mark Retention — The survival of crawfish marked with punch holes, under indoor conditions, averaged 92% over 72 hours (data not included). This percentage compared favorably with non-marked (control) crawfish, which averaged 86% survival under similar conditions. Marked crawfish that had molted retained the mark. Marking appeared to have no adverse effect on crawfish survival during molt.

Population assessments — The pond area sampled by the three seine sweeps in each sample was 83.6 m² (900 ft²). As the total water area of each pond is 1067 m², 7.84% of the total pond area was swept during each sample period. Calculations based on the percentage of pond area seined should yield an under-estimate of total crawfish numbers (> 70 mm) in each pond, since this method assumes 100% capture in the seined area, and a certain percentage of crawfish will escape seining in burrows or depressions. Using total counts on quadrant

Table 3. Crawfish Population Estimates Utilizing Seine Sampling Area¹ in Two 0.1-Ha Ponds

Sampling Period	Pond No. 3		Pond No. 4	
	No. of seined crawfish	Pond population estimate	No. of seined crawfish	Pond population estimate
Day 0	119	1518	105	1339
Day 3	131	1671	65	829
Day 6	105	1339	68	867
Day 10	132	1684	82	1046
Average	121.8	1553	80	1020

¹In each case, seine sample area = 83.6 m², = 7.84% of total pond area.

Frank Meriweather

plots, based on the four seine samples in each pond, average population estimates (crawfish >70 mm) are 1553 for Pond No. 3 (C.V. = 8.7%) and 1020 for Pond No. 4 (C.V. = 10.7%) (Table 3).

The numbers of previously-marked ('old marks') and newly-marked crawfish in these ponds during these four seine sample periods are listed in Table 4. The Peterson Weighted Mean estimate of the crawfish population in Pond No. 3 is 1756 (C.V. = 15.3%), while the population estimate in Pond No. 4 is 1687 (C.V. = 21.2%). No significant differences ($P=0.05$) exist between pond population estimates derived from the quadrant-plot and mark-recapture methods.

Table 4. Seine Captures of Marked and Unmarked Crawfish in Two 0.1-Ha Ponds

Mark Type	Day	Pond No. 3	Pond No. 4
New Marks	0	119	105
Old Marks	3	9	5
New Marks	3	122	60
Old Marks	6	20	7
New Marks	6	85	61
Old Marks	10	15	11
Non-Marked	10	117	71
Total old marks		44	23
Total new marks		443	297

'New marks' and 'Non-Marked' signify previously uncaptured and unmarked crawfish.

'Old marks' signify recaptured marked crawfish.

DISCUSSION

The frequency of recapture of streamer-tagged crawfish in this study indicated that one or more basic assumptions required in the capture-recapture method of population assessment (Begon, 1979) may not have been met: 1) tags may have been lost during the study, 2) all individuals may not have had an equal chance of capture or 3) all individuals, whether tagged or not, may not have had an equal chance of dying. The indoor tagging survival experiment demonstrated that less than half of tagged crawfish survived to Day 25 under tank conditions, and that molting affected tagged crawfish survival. A high mortality rate was also observed for tagged brown shrimp in indoor tanks (Howe and Hoyt, 1982). Survival of tagged crawfish in ponds may be different from that in confined tanks. However, the increased movement of crawfish in ponds may also affect tag retention; for example, in open-water release of 27,324 tagged shrimp in Texas, only one tagged shrimp was recovered after one year, but 839 tags were found washed ashore within 10 days of release (Cody and Avent, 1980). The fact that 51% of tagged crawfish released into the three study ponds were never recognized as being caught, while 57% of captured tagged crawfish in Pond No. 32 were trapped more than once, also indicates that at least one of the three required assumptions in capture-recapture studies was not met. The tagged crawfish were perhaps differentially affected by mortality, were more trap-shy or trap-happy than crawfish not previously trapped, and/or tag loss occurred. Therefore, the tags were not considered suitable for population estimation studies, and no population assessments were conducted using data from the tagging study.

In conducting the marking (punch hole) study in ponds, there was no apparent violation of the assumptions required in mark-recapture; the mark was relatively permanent, did not appear to affect mortality, and animals were captured by random seining of quadrants rather than by trapping. Seber (1973) indicates that, in density estimates for closed populations using total counts on sample plots, 5-10% of the population area should be sampled. In this study 7.8% of the pond area was seined during each sample period, and the 10-day duration of the study appears adequately short to assume closed populations in the ponds.

Combined population estimates (for crawfish >70 mm) using quadrant sampling, of 1553 (Pond No. 3) and 1020 crawfish (Pond No. 4), average 25% lower than those obtained using the Peterson Weighted Mean estimate (1756 and 1687 crawfish, respectively). This discrepancy may be at least partially explained by crawfish escaping from the

seine. However, few crawfish were seen to escape to the side of the net during seining (the water was clear), and in each case the seine sweep was terminated at the pond bank, reducing loss by escape. Other crawfish may have escaped in burrows or depressions, the net having passed over them. Such loss of crawfish would decrease population estimates using quadrant sampling, but would not affect mark-recapture population estimates (assuming the mark does not affect the ability of crawfish to escape seining).

Based on these preliminary studies, the mark-recapture approach, utilizing a punch-hole mark, appears to be a fairly easy tool to approximate crawfish populations, at least in small ponds. The mark can be varied by using different uropods, allowing for a variety of assessment estimates. Based on research information to date, seining may have less inherent bias than trapping in assessing populations of larger crawfish. Streamer tags, as used in this study, do not appear to meet population assessment requirements, are more expensive and difficult to use, and therefore are not recommended for assessing crawfish populations in ponds.

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WOODY VEGETATION OF THE CRYSTAL MOUNTAINS REGION

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ABSTRACT

Arms-length rectangle transects and nested quadrats were used to sample overstory, understory and shrub layers on south-facing mountains, north-facing mountains and flat areas along Collier and Montgomery Creeks in Montgomery County, Arkansas. Data were collected and used to calculate importance values for trees and density values for shrubs. These data indicate that the shortleaf pine-oak forest type occurs on south-facing mountains while variants of white oak-black oak-northern red oak type occur on north-facing mountains and flat areas. Beech (*Fagus grandifolia* Var. *caroliniana* [Loud.] Fern and Rehd.) is common along Collier Creek and is completely absent from Montgomery Creek watershed. The presence of beech in the Collier watershed, may be due to reduced evaporation caused by less west to east surface air movement.

INTRODUCTION

Numerous studies have been made of special areas in Arkansas such as Devil's Den State Park (Bullington, 1962), Crowley's Ridge (Clark, 1977), Roth and Konecny prairies (Irving and Brenholts, 1977), Grassy lake (Huffman, 1974), Mississippi delta (Putnam and Bull, 1932) and the Black swamp (Fogleman, 1981). Many environmental inventories and impact statements have provided important information on vegetation in many river watersheds but in most of these studies lists of species have been prepared without showing community associations.

Literature reviews on the vegetation of Arkansas (Dale, 1963; Pell, 1980) list few reports of studies from the Ouachita Mountains Natural Division (Foti, 1974). Except for the study by Dale and Watts (1980) on the vegetation of Hot Springs National Park, information from this region of Arkansas is usually general and obtained from reconnaissance. A general description of Ouachita Mountain flora is given by Braun (1964).

The Crystal Mountains area has outstanding natural beauty of vegetation and terrain and has for many years provided the authors as well as many local residents with untold hours of pleasure. It is located at T3S, R24W and T3S, R25W in the Central Ouachita Mountains Subdivision of the Ouachita Mountains Natural Division (Foti, 1974). The sampling of plant communities was limited to Collier Creek and Montgomery Creek watersheds which are contiguous and separated by a divide located between Bear mountain and High Peak mountains. This region is greatly dissected by ravines between east-west mountains which rise 400 to 600 feet above creek channels.

The purpose of this study was to determine forest cover types, obtain information on the distribution of woody species and to compare the vegetation of similar areas of the Collier and Montgomery Creek watersheds.

METHODS

Norman and Caddo Gap Quadrangles (7.5 minute topographic maps, U.S. Department of the Interior Geological Survey) were used to select sites for three south-facing and three north-facing transects in each of the two watersheds (Collier Creek and Montgomery Creek). Each transect consisted of a continuous sequence of 2 x 25m arms-length rectangles (Penfound and Rice, 1957) from the base of a mountain to the top. Nested quadrats (Oosting, 1956; Phillips, 1959) were used to sample flat areas along streams (10 x 10 m for overstory and understory and 5 x 5 for shrubs) which were chosen by site inspection. During both

types of sampling procedures, overstory and understory trees were named and measured (dbh) as they were encountered in sample plots. For purposes of this study, overstory formed the canopy; understory trees were distinctly shorter than canopy but more than fifteen feet in height and shrubs were considered as woody plants in the four to fifteen foot height range.

Field data for overstory and understory trees were converted to relative frequency, relative density and relative basal area. The relative values were then summed for each species to produce an importance value (Curtis and McIntosh, 1951). Data from three transects were compiled to form a composite picture of vegetation on south-facing and north-facing mountains in each watershed. Likewise, data from three sites were used to form a composite of vegetation on low flats and high flats in the two watersheds.

RESULTS AND DISCUSSION

Arkansas lies entirely within the temperate deciduous forest biome (Oosting, 1956) and forest cover for the Ouachita Mountains Natural Division is generally designated as Shortleaf Pine — Upland Hardwoods (Lang and Stevens, 1942; Braun, 1964) with combinations of various types of oaks and hickories mixed with pine as determined by moisture conditions (Moore, 1972; Pell, 1984). Dale and Watts (1980) identified four types of forest cover in the Hot Springs National Park. These were designated as Upland Hardwood, Pine-Oak Hickory, Oak Hickory-Pine and Mixed Forest and occurrence depended primarily on slope and exposure.

Moore (1972) lists Shortleaf Pine-Oak-Hickory and White Oak-Red Oak-Black Oak types as important or common forest cover types for the Ouachita Mountains.

South Facing Mountains

Shortleaf Pine (*Pinus echinata*) is the most dominant species on south-facing mountains in both Collier and Montgomery Creek Watersheds (Table 1). This is indicated by high importance values in both overstory and understory as well as significant presence in the shrub stratum. Northern red oak (*Quercus rubra*), white oak (*Quercus alba*), black oak (*Quercus velutina*) and post oak (*Quercus stellata*) are important secondary species. These data place the forest cover type on south-facing mountains of both watersheds as Type 76 (Shortleaf Pine-Oak) described by White (1980). However, Dale and Watts (1980) separate this type into Pine-Oak Hickory if pine has an importance value of 160 or more and Oak Hickory-Pine if Pine has an importance value less than 160

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Table 1. Woody vegetation on south-facing mountains of Collier Creek and Montgomery Creek watersheds. Importance values are given for overstory (OS) and understory (US) species and density (#/ha) for shrubs (Sh).

SPECIES	COLLIER			MONTGOMERY		
	OS	US	Sh	OS	US	Sh
<i>Pinus echinata</i> Mill.	168.2	64.0	90	114.6	48.0	180
<i>Quercus rubra</i> L.	64.8	38.6	143	21.7	4.9	62
<i>Quercus alba</i> L.	32.6	36.2	52	60.4	37.6	21
<i>Quercus velutina</i> Lam.	-	-	-	32.7	18.1	10
<i>Quercus stellata</i> Wang.	3.6	7.7	-	27.4	33.8	-
<i>Carya tomentosa</i> Nutt.	16.5	19.0	138	-	25.2	72
<i>Carya texana</i> Buckl.	3.5	19.8	14	15.3	32.4	31
<i>Quercus marilandica</i> Muenchh.	7.5	27.7	33	5.1	24.6	36
<i>Nyssa sylvatica</i> Marsh.	-	55.2	329	11.9	37.2	477
<i>Quercus falcata</i> Michx.	-	-	-	5.8	-	-
<i>Robinia pseudoacacia</i> L.	-	-	24	5.3	5.9	-
<i>Tilia americana</i> L.	3.5	3.3	5	-	-	-
<i>Acer rubrum</i> L.	-	10.8	110	-	6.9	21
<i>Cornus florida</i> L.	-	3.9	19	-	10.6	41
<i>Ostrya virginiana</i> (Mill.) Koch.	-	-	10	-	9.1	26
<i>Liquidambar styraciflua</i> L.	-	2.3	19	-	3.6	41
<i>Amelanchier arborea</i> (Michx. f.) Fern.	-	2.6	43	-	-	21
<i>Castanea ozarkensis</i> Ashe.	-	-	-	-	2.2	5
<i>Prunus serotina</i> Ehrh.	-	2.1	5	-	-	15
<i>Celtis laevigata</i> Willd.	-	6.9	-	-	-	-
<i>Vaccinium arboreum</i> Marsh.	-	-	381	-	-	84.6
<i>Sassafras albidum</i> (Nutt.) Nees.	-	-	38	-	-	26
<i>Diospyros virginiana</i> L.	-	-	19	-	-	5
<i>Viburnum rufidulum</i> Raf.	-	-	14	-	-	10
<i>Ulmus alata</i> Michx.	-	-	14	-	-	15
<i>Vaccinium</i> sp.	-	-	-	-	-	139
<i>Rhus copallina</i> L.	-	-	14	-	-	21
<i>Rhus glabra</i> L.	-	-	-	-	-	51
<i>Crataegus</i> sp.	-	-	10	-	-	26
<i>Prunus americana</i> Marsh.	-	-	-	-	-	5
<i>Aralia spinosa</i> L.	-	-	10	-	-	-
<i>Ulmus rubra</i> Muhl.	-	-	5	-	-	-
<i>Fraxinus americana</i> L.	-	-	5	-	-	-

and the aggregate importance value of oaks and hickories is greater than that of pine. According to this designation, Pine-Oak Hickory type is present on south-facing mountains of Collier Creek watershed and Oak Hickory-Pine on south-facing Montgomery Creek mountains. When using data from transects, chance placement may easily account for either of these pine-oak types. Generally pine is concentrated at the middle region of these mountains but will fluctuate upward or downward according to steepness of slope. The importance values for shortleaf pine were 170, 195, 130 and 14, 179, 152, for the lower, middle and upper regions of Collier and Montgomery mountains respectively. Accordingly, white oak (*Q. alba*) is most important in both overstory and understory on the lower one-third, blackjack oak (*Q. marilandica*) reaches its greatest importance on the middle one-third and post oak (*Q. stellata*) on the upper one-third in these south-facing mountains.

North-facing Mountains

Dale and Watts (1980) considered an importance value of 75 or more to establish dominance for overstory species. Likewise, importance values of 25-74 indicated important secondary species. Due to greater diversity in understory species, an importance value of 50 or more should indicate dominance and 20-49 should designate important secondary species.

Northern red Oak (*Quercus rubra*) and white Oak (*Q. alba*) are overstory dominants on north-facing mountains (Table 2). Blackgum (*Nyssa sylvatica*) and mockernut hickory (*Carya tomentosa*) may in some areas attain the status of important secondary species. Northern red oak, white oak, and red maple (*Acer rubrum*) are dominant understory species as blackgum, mockernut hickory and red maple are important secondary species. The shrub stratum is dominated by young overstory and understory species as well as flowering dogwood (*Conrus florida*), hophornbeam (*Ostrya virginiana*), witch-hazel (*Hamamelis* sp.), azalea, (*Rhododendron* sp.) and basswood (*Tilia americana*).

Importance values computed separately for overstory species on lower, middle and upper regions of these north-facing mountains show northern red oak to be an important dominant in all three while white oak is more important at the middle region and blackgum becomes more

Table 2. Vegetation on north-facing mountains of Collier Creek and Montgomery Creek watersheds. Importance values are given for overstory (OS) and understory (US) species and density (#/ha) for shrubs (Sh).

SPECIES	COLLIER			MONTGOMERY		
	OS	US	Sh	OS	US	Sh
<i>Quercus rubra</i> L.	189.5	54.1	105	100.8	53.1	389
<i>Quercus alba</i> L.	61.6	51.8	133	105.7	84.0	106
<i>Nyssa sylvatica</i> Marsh.	13.8	35.5	571	43.4	37.7	856
<i>Carya tomentosa</i> Nutt.	-	32.6	190	28.0	39.6	172
<i>Acer rubrum</i> L.	13.5	67.0	286	5.2	42.1	889
<i>Liquidambar styraciflua</i> L.	10.5	3.2	24	5.3	8.4	39
* <i>Fagus grandifolia</i>	6.3	-	43	-	-	-
<i>Pinus echinata</i> Mill.	-	8.1	5	5.9	-	-
<i>Fraxinus americana</i> L.	-	-	24	5.3	-	150
<i>Robinia pseudoacacia</i> L.	4.8	8.2	14	-	-	-
<i>Cornus florida</i> L.	-	17.6	324	-	4.3	366
<i>Ostrya virginiana</i> (Mill.) Koch.	-	5.9	100	-	17.5	1039
<i>Magnolia acuminata</i> L.	-	-	-	-	7.5	28
<i>Magnolia tripetala</i> L.	-	-	-	-	4.3	139
<i>Amelanchier arborea</i> (Michx. f.) Fern.	-	4.5	19	-	-	367
<i>Carya texana</i> Buckl.	-	2.6	-	-	4.3	39
<i>Quercus stellata</i> Wang.	-	2.3	-	-	-	-
<i>Prunus serotina</i> Ehrh.	-	2.3	38	-	-	22
<i>Prunus americana</i> Marsh.	-	2.3	-	-	-	-
<i>Ulmus rubra</i> Muhl.	-	2.0	14	-	-	-
<i>Rhododendron</i> sp.	-	-	-	-	-	733
<i>Hamamelis</i> sp.	-	-	229	-	-	561
<i>Tilia americana</i> L.	-	-	100	-	-	306
<i>Asimina triloba</i> (L.) Dunal.	-	-	5	-	-	244
<i>Euonymus americanus</i> L.	-	-	-	-	-	178
<i>Hydrangea arborescens</i> L.	-	-	-	-	-	72
<i>Ilex vomitoria</i> Ait.	-	-	62	-	-	-
<i>Juniperus virginiana</i> L.	-	-	29	-	-	-
<i>Carpinus caroliniana</i> Walt.	-	-	-	-	-	33
<i>Rhamnus caroliniana</i> Walt.	-	-	-	-	-	22
<i>Ulmus alata</i> Michx.	-	-	24	-	-	-
<i>Ulmus americana</i> L.	-	-	-	-	-	17
<i>Aralia spinosa</i> L.	-	-	-	-	-	22
<i>Bumelia lanuginosa</i> (Michx.) Pers.	-	-	5	-	-	-
<i>Pinus strobus</i> L.	-	-	-	-	-	17
<i>Sassafras albidum</i> (Nutt.) Nees.	-	-	19	-	-	-
<i>Platanus occidentalis</i> L.	-	-	5	-	-	-
<i>Viburnum rufidulum</i> Raf.	-	-	5	-	-	-

* *Fagus grandifolia* Var. *caroliniana* (Loud.) Fern. and Rehd.

Table 3. Vegetation of low flat areas in Collier Creek and Montgomery Creek watersheds. Importance values are given for overstory (OS) and understory (US) species and density (#/ha) for shrubs (Sh).

SPECIES	COLLIER			MONTGOMERY		
	OS	US	Sh	OS	US	Sh
<i>Carya cordiformis</i> (Wang.) K. Koch	68.7	14.8	-	29.3	31.7	-
* <i>Fagus grandifolia</i>	49.3	37.1	400	-	-	-
<i>Quercus alba</i> L.	-	29.1	-	57.9	36.2	-
<i>Liquidambar styraciflua</i> L.	49.2	7.0	171	30.1	34.8	36
<i>Quercus rubra</i> L.	29.6	15.3	-	23.8	7.7	-
<i>Quercus muehlenbergii</i> Engelm.	22.3	-	-	30.7	6.7	-
<i>Platanus occidentalis</i> L.	21.7	-	-	24.1	-	-
<i>Nyssa sylvatica</i> Marsh.	17.2	8.2	-	43.0	-	291
<i>Acer rubrum</i> L.	14.0	24.7	57	7.6	-	-
<i>Fraxinus americana</i> L.	9.4	22.8	114	17.0	9.9	36
<i>Tilia americana</i> L.	-	9.6	171	19.0	9.9	764
<i>Juglans nigra</i> L.	-	-	-	9.6	-	-
<i>Ulmus rubra</i> Muhl.	9.4	-	-	-	-	-
<i>Ostrya virginiana</i> (Mill.) Koch.	9.1	27.8	57	-	54.1	800
<i>Carpinus caroliniana</i> Walt.	-	37.8	57	7.6	34.6	436
<i>Cornus florida</i> L.	-	23.5	286	-	-	581
<i>Cercis canadensis</i> L.	-	16.3	57	-	-	-
<i>Magnolia tripetala</i> L.	-	12.4	229	-	26.8	73
<i>Ulmus americana</i> L.	-	7.0	-	-	6.7	36
<i>Alnus rugosa</i> (DuRoi) Spreng.	-	7.0	171	-	-	255
<i>Carya tomentosa</i> Nutt.	-	-	-	-	21.4	73
<i>Morus rubra</i> L.	-	-	-	-	13.9	-
<i>Bumelia lanuginosa</i> (Michx.) Pers.	-	-	-	-	5.3	36
<i>Ilex opaca</i> Ait.	-	-	114	-	-	-
<i>Cornus Drummondii</i> Meyer	-	-	57	-	-	-
<i>Ulmus alata</i> Michx.	-	-	57	-	-	-
<i>Lindera Benzoin</i> (L.) Blume	-	-	57	-	-	-
<i>Asimina triloba</i> (L.) Dunal.	-	-	-	-	-	800

* *Fagus grandifolia* Var. *caroliniana* (Loud.) Fern. and Rehd.

Woody Vegetation of the Crystal Mountains Region

Table 4. Vegetation of high flat areas in Collier Creek and Montgomery Creek watersheds. Importance values are given for overstory (OS) and understory (US) species and density (#/ha) for shrubs (Sh).

	COLLIER			MONTGOMERY		
	OS	US	Sh	OS	US	Sh
<i>Quercus rubra</i> L.	106.9	18.1	-	26.0	-	-
<i>Quercus alba</i> L.	55.6	128.7	50	79.1	27.4	57
<i>Nyssa sylvatica</i> Marsh.	13.6	27.0	350	64.9	-	-
<i>Liquidambar styraciflua</i> L.	20.6	-	200	36.9	-	-
<i>Pinus echinata</i> Mill.	65.5	-	-	-	-	-
<i>Carya tomentosa</i> Nutt.	11.5	50.1	150	29.2	77.6	57
<i>Carya cordiformis</i> (Wang.) K. Koch	-	-	-	28.8	45.5	57
<i>Fraxinus americana</i> L.	10.4	-	50	15.7	19.1	571
* <i>Fagus grandifolia</i>	15.7	-	150	-	-	-
<i>Magnolia acuminata</i> L.	-	-	-	10.3	-	-
<i>Acer rubrum</i> L.	-	30.4	-	9.0	22.7	171
<i>Magnolia tripetala</i> L.	-	12.5	250	-	60.8	629
<i>Ostrya virginiana</i> (Mill.) Koch	-	11.5	50	-	-	1486
<i>Tilia americana</i> L.	-	8.8	150	-	-	286
<i>Cornus florida</i> L.	-	6.5	500	-	47.0	514
<i>Sassafras albidum</i> (Nutt.) Nees	-	6.5	50	-	-	-
<i>Hamamelis</i> sp.	-	-	150	-	-	114
<i>Vaccinium arboreum</i> Marsh.	-	-	100	-	-	-
<i>Rhamnus caroliniana</i> Walt.	-	-	50	-	-	-
<i>Bumelia lanuginosa</i> (Michx.) Pers.	-	-	50	-	-	-
<i>Prunus americana</i> Marsh.	-	-	50	-	-	-
<i>Euonymus americanus</i> L.	-	-	50	-	-	-
<i>Carpinus caroliniana</i> Walt.	-	-	-	-	-	228
<i>Asimina triloba</i> Dunal.	-	-	-	-	-	228
<i>Quercus muehlenbergii</i> Engelm.	-	-	-	-	-	114

* *Fagus grandifolia* Var. *caroliniana* (Loud.) Fern. and Rehd.

important on the upper region.

This cover type is classified as White Oak-Northern Red Oak, a variant of Type 52 (white oak-black-oak-northern red oak) which is probably climax in the Ozark-Ouachita highlands and highly variable in species composition of all strata (Sander, 1980).

Species composition on north-facing mountains of Collier and Montgomery Creek watersheds are very similar and differences are probably due to the great diversity and chance distribution in areas of this type. However, Eastern white pine (*Pinus strobus*) and cucumber magnolia (*Magnolia acuminata*) were not sampled or observed in Collier Creek watershed and beech (*Fagus grandifolia*) was not sampled or observed in Montgomery Creek watershed at any site (Tables 2, 3, and 4).

Flat Areas

Low flats (0-2 m above low water level) are subject to flooding but duration of flooding is usually short in the mountains. Overstory vegetation is diverse and does not show a dominant species in either watershed. Combinations of bitternut hickory (*Carya cordiformis*), beech (in Collier only), sweetgum (*Liquidambar styraciflua*), northern red oak, white oak, chinkapin oak (*Quercus muehlenbergii*) and blackgum may occur at different locations as important secondary species (Table 3). Any of these overstory species, hophornbeam (*Ostrya virginiana*), American hornbeam (*Carpinus caroliniana*) and umbrella magnolia (*Magnolia tripetala*) may be important secondary species in a diverse understory (Table 3). Any of these overstory and understory species and pawpaw (*Asimina triloba*), flowering dogwood, American basswood, blackgum and alder (*Alnus rugosa*) may be present in a well developed shrub layer.

The woody vegetation of these low flat areas are similar to the mixed forest types described by Dale and Watts (1980).

High flats (2-10 m above low water level) are seldom if ever flooded but receive runoff from mountain slopes. Collier high flats show one dominant species (Northern red oak) while Montgomery high flats have white oak as a dominant. In both cases here these two species are important secondary species when not dominant (Table 4). Various combinations of shortleaf pine, blackgum, sweetgum, mockernut hickory and bitternut hickory may be associated as important secondary species. These overstory species, red maple, and flowering dogwood are impor-

tant secondary species of the understory. In fact, umbrella magnolia and mockernut hickory are dominants in the Montgomery Creek watershed understory. The prolific shrub layer is mostly small overstory and understory species.

The forest cover type of these flat areas is modified northern red-oak-white oak (Type 52) where improved site conditions (moisture and soil) have increased diversity and decreased dominance. This is most easily seen in the species composition of high flats (Table 4). The vegetative cover of these two watersheds reflects the effects of decreasing moisture from the low flats which are the most mesic to high flats to north-facing mountain slopes to the most xeric south-facing mountains. Slope and exposure which greatly influence evaporation are responsible for different associations of species in the different areas.

Basically the forest cover types are the same in the Collier and Montgomery Creek Watersheds. Chance variations in species composition do occur within each watershed as well as between watersheds.

The most conspicuous difference is the presence of American beech (*Fagus grandifolia* Var. *caroliniana* [Loud.] Fern and Rehd.) in the Collier Creek watershed and its total absence from Montgomery Creek watershed. The sporadic occurrence of beech in the Ouachita Mountains is well known (Braun, 1964; Moore, 1972), and in this instance, it is common on low and high flats as well as precipitous slopes at low elevations along Collier Creek. It was not found to occur in these areas along Montgomery Creek even though they would appear to be environmentally similar. Harlow and Harrar (1968) state that beech is found on a wide variety of soil types but appears to be limited by moisture conditions particularly rapid surface drying. The ravines of Montgomery Creek are exposed to air movement from the west, southwest and northwest which could increase evaporation from soil and decrease relative humidity. Collier Creek ravines are not directly exposed to this prevailing air movement but are exposed to the south which would increase afternoon isolation. This slight difference in exposure could be controlling presence and absence of beech for it is well known that small difference in critical factors have profound effects near the edge of a species' range of distribution.

Eastern white pine (*Pinus strobus*) was sampled in a Montgomery north-facing mountain transect (Table 2). Scattered specimens ranging in size from seedlings to mature trees were observed in the Montgomery watershed, mostly on high flats. This species was not observed in Collier watershed. It was transplanted into the Montgomery watershed through a government project during the early 1900's (Personal communication from Bob McClane, a retired forester).

Other observed species of limited distribution which probably occur in both watersheds are filbert (*Corylus americana* Marsh.) along roadsides, Ozark chinkapin (*Castanea ozarkensis* Ashe.) on south-facing slopes and near top of mountains (Very limited), cucumber magnolia (*Magnolia acuminata* L.) which was very occasional on high flats and one small grove of leatherwood (*Dicra palustris* L.) on a well drained bank of Montgomery Creek.

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EFFECTS OF JUGLONE (5'-HYDROXY-1,4-NAPHTHOQUINONE) ON THE ALGAE *ANABAENA FLOS-AQUAE*, *NOSTOC* *COMMUNE* AND *SCENEDESMUS ACUMINATUS*

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ABSTRACT

Three species of algae, *Anabaena flos-aquae*, *Nostoc commune* and *Scenedesmus acuminatus* were selected for their sensitivity to juglone and studied for the effects of juglone concentrations of 10, 1, 0.5, 0.1 and 0.01 $\mu\text{g/ml}$ upon their growth. *A. flos-aquae* was most sensitive, with significant inhibition by the 0.5 $\mu\text{g/ml}$ concentration. *N. commune* was inhibited least, with significant inhibition only in the 10 $\mu\text{g/ml}$ concentration. *S. acuminatus* was found to be moderately inhibited at the 0.5 $\mu\text{g/ml}$ concentration. All species were found to be non-viable after 14 days exposure to 10 $\mu\text{g/ml}$ juglone.

Tests with 7 and 14 day old cells of *S. acuminatus* showed significant differences in growth. Seven day old cells used as inoculum were inhibited by all concentrations while 14 day old cells showed growth in excess of controls in three concentrations (0.5, 0.1 and 0.01 $\mu\text{g/ml}$). All studies with 14 day old cells showed slight, but not significant, increases in growth in the 0.01 $\mu\text{g/ml}$ concentration. These results suggest that juglone may enhance growth of some soil micro-organisms.

INTRODUCTION

The deleterious effect of the black walnut, *Juglans nigra*, upon higher plants has been known since ancient times. Many studies have shown that juglone, 5-hydroxy-1,4-naphthoquinone, is the compound responsible for inhibiting the growth of higher plants around the walnut tree (Reitveld, 1983; Funk et al., 1979). Juglone has also been studied as a fish toxicant (Marking, 1970), and has been found to be a depressant in other animals (Westfall et al., 1961). Studies by Koeppel (1972), Harmon and Crane (1974, 1976), Cobley et al. (1973), and Grossman et al. (1974) have established a mode of action for juglone as a respiratory inhibitor, specifically of NADH dehydrogenase. Studies by Van Duuren et al. (1978) demonstrated the substance to have potent tumor promoting properties. Investigations of micro-organisms have indicated that juglone may serve as a resistance factor to plant pathogens such as *Fusicladium effusum* (Hedin et al., 1979), Solkov et al. (1972) presented evidence of juglone inhibition for a variety of plant pathogens and other microbes. Krajci and Lynch (1977) used the antibiotic disc assay method to determine inhibition by crude walnut hull extracts and pure juglone against a broad spectrum of microbes including bacteria, algae and fungi. More recently, Dawson and others have demonstrated inhibitory effects on the symbiotic nitrogen-fixing micro-organisms *Rhizobium japonicum* strain 71 and *Frankia* Ar 13 (Dawson et al., 1981; Dawson and Seymour, 1983).

Although some work has been done with members of both Cyanophyceae and Chlorophyceae, those studies have neglected to assess either extremely low-level exposure or the possibility of growth enhancement at non-inhibitory concentrations. In addition, the low solubility of juglone in water has led to the use of organic solvents to provide a carrier for the substance. The purpose of this study was to examine the effects of juglone on two free-living soil algae (Cyanophyceae), and on different aged cultures of a sensitive green alga (Chlorophyceae). Water was used as the solvent for the juglone since it is the natural carrier of the substance.

MATERIALS AND METHODS

Algae were obtained from Richard C. Starr's collection at the University of Texas. Those selected were *Anabaena flos-aquae* (Lyng.) Breb. UTEX 1444; *Nostoc commune* Vaucher UTEX 584; *Scenedesmus acuminatus* (Lagerh.) Chodat UTEX 415; and *Chlorella pyrenoidosa* Chick UTEX 252. Preliminary studies showed *C. pyrenoidosa* to be unaffected by juglone at the concentrations tested so it was abandoned.

Juglone (90% pure) was obtained from Sigma Chemical Corporation. A saturated stock solution was made by dissolving juglone in approximately 1L of distilled water with constant stirring for 24 hours. Suspended solids were removed by filtration through a 0.45 μm filter (Millipore). Concentration was calculated by deducting the weight of undissolved solid from the original amount of juglone, correcting for purity and adjusting the volume to 1L. The saturated solution was found to contain 0.1032 g/l juglone.

Test organisms were cultured in 250 ml flasks containing 100 ml of Bristol's solution in a Lab-Line Environ-Shaker at 20°C, 100 rpm on a 12 hour day/night cycle, for 14 days prior to introduction to test conditions. In studies of *S. acuminatus*, the inoculum for one series was

Conc. ($\mu\text{g/ml}$)	Scenedesmus	Anabaena	Nostoc
10.0	-	-	-
1.0	+	-	+
0.5	+	+	+
0.1	+	+	+
0.01	+	+	+

(+) observable growth
(-) no observable growth

Table 1. Viability study (1 ml test culture removed from flasks at end of two week exposure to juglone, cultured 7 days on Bristol's medium solidified with 15 g/l agar, for microscopic examination used to verify negative results.

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allowed to grow for only 7 days. Ten ml aliquots of inoculum were transferred aseptically to flasks containing 80 ml Bristol's solution and 10, 1, 0.5, 0.1 or 0.01 ml of filter sterilized juglone. Volumes were adjusted to 100 ml for all concentrations. Controls contained 10 ml sterile distilled water. After 14 days incubation the cells were harvested by centrifugation in tared centrifuge tubes at 15,000 rpm for 30 min. Dry weights were obtained by drying at 65°C to constant weight (approximately 7 days).

At time of harvest, 1 ml aliquots of test cultures were pipetted onto Bristol's medium solidified with agar (15 g/l) in order to test for viability (Table 1). All cultures were tested for purity by streaking on nutrient agar plates at the time on inoculation.

Data for *S. acuminatus* and *N. commune* represent the means of three series of three repetitions each. Data for *A. flos-aquae* represent the means of four series of tests. Significance was determined by both linear regression and Fisher's Least Squares Determination of analysis of variance. All tests were done at the 0.05 level of significance.

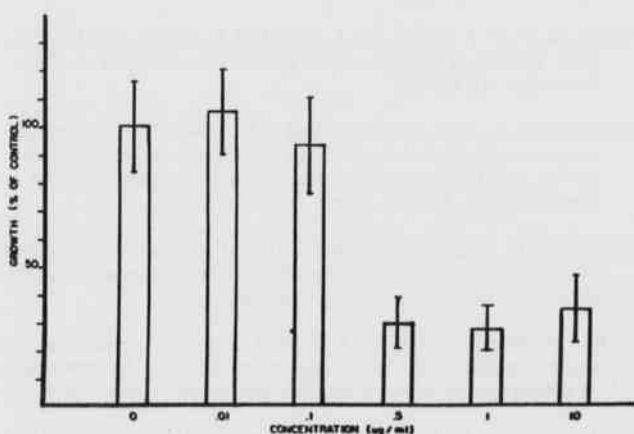


Figure 1. Effects of juglone on the growth (dry weight) of *Anabaena flos-aquae* shown as a percent of control (vertical line = standard deviation). Correlation = -0.8541 ; Significance = 0.0001 .

DATA AND RESULTS

The results of viability checks for all tests showed no growth in the 10 ug/ml concentration. *A. flos-aquae* showed no growth in the 1 ug/ml concentration. Analysis of dry weights showed a significant change between the 0.1 and 0.5 ug/ml concentrations, resulting in a bimodal distribution (Figure 1). The lower concentrations were grouped with the controls and the 10, 1 and 0.5 ug/ml tests were related. It is of interest to note the slight increase in growth associated with the 0.01 ug/ml concentration. While not significant, it nonetheless was seen in all experiments with the exception of *S. acuminatus* cultures initiated with 7 day old inocula. *N. commune* was significantly affected by only the 10 ug/ml concentration. All other data were within one standard deviation of the control. Once again there was a slight elevation in growth in the lowest concentrations of juglone (Figure 2).

The study of different inoculum ages of *S. acuminatus* displayed no significant difference between the two highest concentrations of juglone when adjusted for difference in initial inoculum weights (Figure 3). The 7 day old inoculum was inhibited in all concentrations of juglone. Significant inhibition occurred only in the 10, 1 and 0.5 ug/ml concentrations, with the 69% weight at 0.5 ug/ml being the only example of significant inhibition which differs from both the controls and the non-viable cultures. The 14 day inoculum showed growth above the level of controls in all but the 10 and 1 ug/ml concentration. There was again an increase in overall growth at 0.01 ug/ml juglone solution for the 14 day old inoculum, although the 7 day inoculum was significantly inhibited at this concentration. Results of viability checks indicated that only the 10 mg/ml solution was lethal.

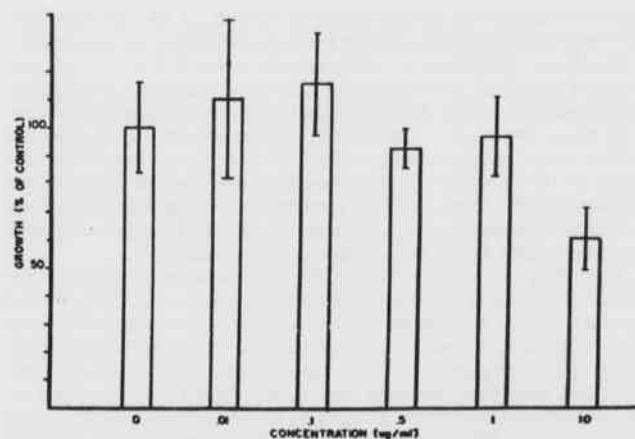


Figure 3. Effects of juglone on the growth (dry weight) of *Nostoc commune* shown as a percent of control (vertical line = standard deviation). Correlation = -0.5497 ; Significance = 0.0003 .

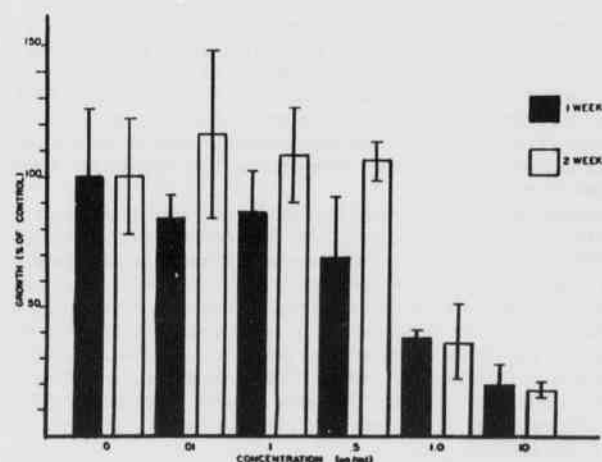


Figure 3. Effects of juglone on the growth (dry weight) of *Scenedesmus acuminatus* shown as a percent of control (vertical line = standard deviation). Comparison of 1 and 2 week old inocula adjusted for initial difference in inoculum dry weight. Correlation = -0.8585 ; Significance = 0.0001 for one week inoculum. Correlation = -0.7314 ; Significance = 0.0001 for two week inoculum.

DISCUSSION

Krajci and Lynch (1977) demonstrated the inhibition of several different bacteria, algae and fungi by juglone. The algae tested were *Calothrix flaccumbaciens*, *Anacystis* sp., *Bracteacoccus cinnabarinus*, *Coelastrum microsporum*, and *Anabaena variabilis*. Their results showed *A. variabilis* to be inhibited by juglone concentrations of 0.0625 mg/ml. Corresponding concentrations of 10 and 1 ug/ml used in this study significantly inhibited *A. flos-aquae*. Apparently, the two *Anabaena* species exhibited a similar sensitivity to juglone.

Although this is the first report of algal growth stimulation by juglone, others have reported similar results for higher plants. Funk et al. (1979) reported the stimulation of some coniferous seedlings at concentrations of juglone as low as 10^{-8} and 10^{-9} M. Reitveld (1983) also reported some increased growth in 10^{-5} and 10^{-6} M concentrations of juglone, but the increases were not significant. Data presented here indicate

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growth stimulation at concentrations of about 0.5×10^{-8} M for all test cultures except those inoculated with 7 day old cells of *S. acuminatus*.

Significant inhibition of algal growth below 0.5×10^{-5} M was observed only for *A. flos-aquae* and 7 day old inocula of *S. acuminatus*. Results of the other studies cited using approximately equivalent concentrations showed that the levels of juglone required to significantly inhibit other organisms, except *Fusicladium effusum*, were within the range of 10 - 1 ug/ml. Comparison with the work of Dawson and Seymour (1983) indicated that the symbiotic micro-organisms *Rhizobium* and *Frankia* reacted to the same concentrations of juglone as did those free-living algae found to be sensitive to the substance.

According to Langhans et al. (1976) *Fusicladium effusum* was inhibited by juglone at 0.1 mg/ml. Windham and Graves (1981) showed several different pathogenic isolates of *F. effusum* to be inhibited at 50 and 100 ug/ml concentrations. Since the species is pathogenic on mature trees, a higher level of resistance to the substance was expected.

Studies with *Candida utilis* have demonstrated juglone effects on mitochondrial activity to be affected by the growth phase of the culture (Cobley et al., 1973; Grossman et al., 1974). Their studies indicated the presence of an NADH dehydrogenase in inner mitochondrial membrane preparations which had variable sensitivity to juglone. Preparations from exponential phase cells were found to be equally sensitive to both ferricyanide and juglone inhibition; but late stationary phase cells were much more sensitive to ferricyanide than to juglone. These studies may provide an explanation for the variability noted in *Scenedesmus* cultures of different ages reported here. In general, the 0.01-0.5 ug/ml concentrations of juglone resulted in growth above the level of the control cultures when added to 14 day old cultures of *S. acuminatus*. When corresponding amounts of juglone were added to 7 day old inocula, inhibition was observed, with dry weights indicating growth of only 69-86% of controls. Growth of 69% in the 0.5 ug/ml concentration was significantly different from both controls and severely inhibited cells.

Because of the narrow range between lethal and non-inhibitory concentrations, determination of a lethal dose for 50% of the population (LD50) was not attempted. Cultures which proved to be non-viable had dry weights not significantly different from those which showed significant inhibition in both *A. flos-aquae* and *S. acuminatus*, with the above noted exception for the 7 day old *S. acuminatus*. For all other trials where no significant inhibition was noted, dry weights did not differ significantly from those of controls. Data from animal studies (Westfall et al., 1961) also noted that the range between depressant and lethal concentrations of juglone was so narrow as to make determination of an LD50 difficult.

It is possible to infer from these studies that seedlings of black walnut and related species may actually stimulate growth of some soil micro-organisms. Since both *Anabaena* and *Nostoc* are able to fix nitrogen, available soil nitrogen may be enhanced during early stages of growth. Co-cropping with leguminous plants has been shown to enhance the growth of walnut trees, although Dawson and Seymour (1983) demonstrated juglone inhibition of two symbionts responsible for nitrogen fixation in higher plants at toxin concentrations of 10^{-4} M. Their results indicated minor inhibition at concentrations of 10^{-5} and 10^{-6} M. Correlation of their study with the concentrations used in this study (0.5×10^{-4} to 0.5×10^{-7} M) showed that the blue-green algae used in this study were sensitive to the same levels of juglone. Additional study of both *Rhizobium* and *Frankia* to test for enhanced growth below 10^{-6} M concentrations would be of interest.

Reitveld (1983) stated that allelopathic effects of juglone upon other trees in mixed, even aged plantings did not become evident before 12-25 years, indicating a relatively slow accumulation of juglone in the soil. The results of this study suggest that during the period of juglone accumulation, concentrations may exist which actually stimulate the growth of soil micro-organisms. More study is needed concerning effects of low concentrations of juglone upon other beneficial soil microbes.

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CONTINUED DDT PERSISTENCE IN MISSISSIPPI RIVER DELTA STREAMS: A CASE STUDY

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ABSTRACT

Fish samples representative of several trophic levels were taken from the Wolf and Loosahatchie Rivers of western Tennessee during the early 1980s. Results indicate that DDT, with metabolites DDD and DDE, remains common in fish tissues in these areas and approaches the levels recommended as maxima for human consumption by the U.S. Food and Drug Administration. Samples of top carnivores and forage fishes, particularly the gizzard shad, *Dorosoma cepedianum*, commonly exceeded 500 ppb DDE. The results are discussed in light of sediment disturbing activities.

INTRODUCTION

The synthetic organochlorine insecticide DDT (dichlorodiphenyl trichloroethane) was discovered to be a remarkable residual insecticide at Basle, Switzerland in 1939 (Brown, 1978; EPA, 1976). In 1963, 155 million pounds of DDT were sold, of which approximately 39% (60 million pounds) were used in the continental United States. In a 1964 survey of 56 United States' rivers, 42% contained DDT (Weaver et al., 1965). In addition, several studies revealed egg-shell thinning in a number of raptors, especially fish-eaters, as well as deaths in amphibian and reptile populations attributable to DDT and metabolites, particularly DDE (Fleet et al., 1972; Ames, 1966; Brown, 1951). Use of the insecticide was suspended in the United States in 1972, although several thousand tons are still applied worldwide in insect and disease control programs (Brown, 1978). On cropland in the United States, DDT was often applied on highly erodible soils, and/or excessive slopes. The insecticide was displaced from croplands under those conditions to area streams and rivers, predominantly adsorbed to eroded soil particles (USDA-ARS and US EPA, 1975).

This report describes a portion of fish tissue analysis studies conducted in the Wolf and Loosahatchie River Basins of western Tennessee (Fig. 1) by federal, state, and local agencies during the 1978-1981 period (USDA-SCS, 1985; Sinclair and Higgs, 1980; Simco, 1979). These studies were used to determine the persistence of historically applied pesticides in the aquatic food chains of these river systems, particularly organochlorines such as DDT.

STUDY AREA

The study area is located in southwest Tennessee and northwest Mississippi. The drainage area of the Wolf River consists of about 520,200 acres (208,000 ha), while the Loosahatchie River drains about 474,600 acres (189,900 ha). The rivers are within the eastern half of the Gulf Coastal Plain physiographic area. The present land forms are the result of erosion which has dissected this plain. The valleys are well incised, and streams have moderately wide valley floors. The streams have detritic drainage patterns with rounded hills and ridges with moderately sloping valley walls. The Gulf Coastal Plain is further subdivided into the West Tennessee Uplands and the West Tennessee Plain. A small portion of the eastern end of the basin lies in the Uplands. This area is characterized by hilly to rolling topography and flat flood plains. Most of the basins are in the Plain which is gently rolling with small ridges and drainage divides.

The hilly topography, high rainfall index and inherent erosion characteristics of upland soils formed from these geologic formations contribute to excessive erosion rates. Sediment deposited in channels and on flood plain land range from silts driven from loess to fine and medium sand derived from underlying coastal plain formations. Flood plain soils are classed as recent geologic deposition of unconsolidated

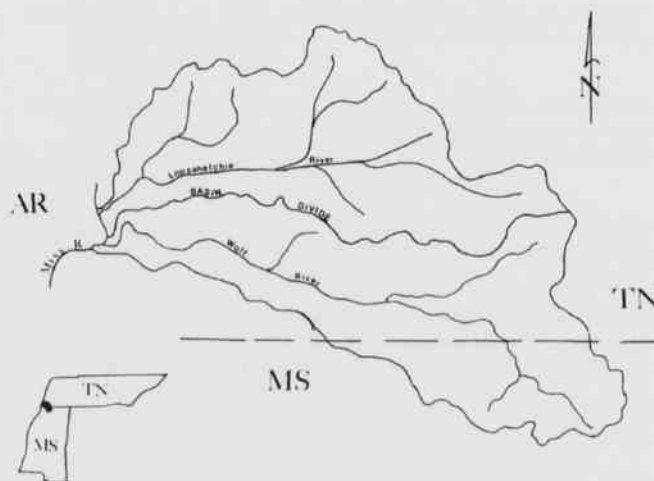


Figure 1. The study area of the Wolf and Loosahatchie River Basins of Western Tennessee and northern Mississippi.

silty, andy alluvium and colluvium. These soils may be highly unstable if stripped of protective vegetation and accompanying root systems (USDA-SCS, 1985) and serve as the vehicle for transport of adsorbed pesticide pollutants into surface waters (USDA-ARS and EPA, 1975).

METHODS AND MATERIALS

Fish samples were collected through use of fish toxicants (5% rotenone), standard minnow seines (4.5 m x 1.2 m x 0.3 cm and 6.1 m x 1.2 m x 0.3 cm) and a Coffelt electrofishing boat. Specimens were identified using Pflieger (1975), Douglas (1974), Buchanan (1973), and Cook (1959). Trophic level classifications followed information contained for each species in these references and are as follows; Category A = detritivores/omnivores (bottom feeders), Category B = herbivores (plant material/plankton feeders), Category C = lesser carnivores, and Category D = top carnivores. These are summarized in Table 1. Individual fish were prepared for analysis by removing edible portions (filets) from all fish regardless of size and freezing until delivery to the laboratory. No organs were included.

Laboratory analysis used gas chromatography electron capture detection as outlined in the Pesticide Analytical Manual, Vol. I and II (Food and Drug Administration, 1970 et seq.) and in accordance with established methodology (APHA, 1985). All laboratory analyses were done by Woodson-Tenent Laboratories, Inc., an affiliate of National Health Laboratories, Inc., 345 Adams Street, Memphis, Tennessee

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(Bassett, 1980, pers. comm.). Action levels referred to herein, follow Food and Drug Administration (1980) guidelines as established and revised according to the criteria specified in Title 21, *Code of Federal Regulations*, Parts 109 and 509.

Table 1. Fish species analyzed for pesticide residues by trophic categories from the Wolf and Loosahatchie river basins, Tennessee.

CATEGORY	DESCRIPTION	SPECIES INCORPORATED
A	Detritivores/omnivores (bottom feeders)	Common carp, <i>Cyprinus carpio</i> Bigmouth buffalo <i>Ictalurus bubalus</i> Smallmouth buffalo, <i>Ictalurus cyprinellus</i> Spotted sucker, <i>Minytrema melanops</i> Black bullhead, <i>Ictalurus melas</i>
B	Herbivores (plant-plankton feeders)	Gizzard shad, <i>Dorosoma cepedianum</i>
C	Lesser carnivores/omnivores (predators, opportunists)	White crappie, <i>Pomoxis annularis</i> Channel catfish, <i>Ictalurus punctatus</i> Blue catfish, <i>Ictalurus furcatus</i> Warmouth, <i>Lepomis gulosus</i> Largemouth bass (<9"), <i>Micropterus salmoides</i> Bluegill, <i>Lepomis macrochirus</i> Longear sunfish, <i>Lepomis megalotis</i> Green sunfish, <i>Lepomis cyanellus</i>
D	Top carnivores (fish eaters and decomposers)	Bowfin, <i>Amia calva</i> Flathead catfish, <i>Pylodictus olivaris</i> Spotted gar, <i>Lepisosteus oculatus</i> Largemouth bass (>9"), <i>Micropterus salmoides</i>

RESULTS

Concentrations of DDT and metabolites in the tissues of Wolf and Loosahatchie River fishes were summarized in Table 1 for upper reaches. Results from lower reach stations have been previously reported and are subject to the non-agricultural influences of the Memphis metropolitan area (Sinclair and Higgs, 1980; Simco, 1979).

In general, results display the bioaccumulation tendency of DDT and metabolites in the aquatic food chain in these systems (ARS, 1979; EPA, 1976), and support the conclusion of Macek and Korn (1970) that bioaccumulation occurs predominantly through the food chain rather than direct absorption (Johnson and Finley, 1980). Exceptions to this conclusion in these systems occurred in levels recorded for forage feeders (planktivores), predominantly gizzard shad, *Dorosoma cepedianum*, and in the metabolite concentrations in bottom feeders, *Minytrema melanops* and *Cyprinus carpio*. In the former case, DDE concentrations exceeded those noted in either detritivores or carnivores. In the latter case, DDT concentrations exceeded DDD concentrations, a reversal of the most commonly encountered situation due to the rapid uptake and degradation of DDT (Menzie, 1980; Addison and Willis, 1978; Johnson et al., 1971). However, DDT concentrations were typically higher than DDD concentrations during recent spring and summer sampling of the lower reaches of both of these systems (Simco, 1979).

DISCUSSION

In 118 American rivers surveyed in 1968, highest DDT concentrations were 316 ppm in Beaulieu River, Florida, and 840 ppm in Kansas River, Kansas (Lichtenberg et al., 1970). Since banning in 1972, several documented effects of DDT and metabolites in the aquatic environment have lessened or improved. There is not enough data to determine if the levels in Tennessee and Mid-South fishes are decreasing, however, the insecticide has remained in detectable concentrations in these areas. Highest levels were noted in the Wolf and Loosahatchie Rivers in the herbivores, predominantly gizzard shad, *Dorosoma cepedianum*. This species is planktivorous as an adult, taking the majority of its food by filter feeding (Pfleiger, 1975). Brown (1978) pointed out that many phytoplankton species were resistant to DDT at 15 ppm con-

Table 2. DDT and metabolite concentrations in fishes of the upper Wolf and Loosahatchie River Basins, Tennessee and Mississippi.

CATEGORY/TROPHIC LEVEL ¹	RESIDUE (ppb)			
	DDT	DDD	DDE	tDDT
A = Detritivores/Omnivores (bottom feeders)	85	63	370	518
B = Herbivores (plankton feeders)	<10	412	1085	1500 ²
C = Lower Carnivores (predators/opportunists)	<10	63	338	400 ²
D = Top Carnivores	<10	107	710	820 ²

¹See Table 1

²Estimated

centration, though growth decreased slightly at 0.1 ppm. Also, most (70%) of the *D. cepedianum* specimens used were in size classes > 7 inches (17.5 cm) and were too large to be considered prey for secondary consumers (Jenkins and Morais, 1976). Therefore, the bioconcentrations in *D. cepedianum* did not pass on through the food chain and was not reflected in pesticide concentrations in trophic category C (lesser carnivores).

Concentrations in the bottom feeders (trophic category A) revealed greater levels of DDT than DDD, a reversal of the trend seen at other trophic levels. One explanation for this may lie in the fact that within the sediments DDT and metabolites tend to concentrate in the top 2 cm or that area most disturbed or ingested by bottom feeders (Brown, 1978).

In conclusion, the study reveals that although concentrations do not exceed the 5 ppm action level of the Food and Drug Administration (1980), DDT remains in the sediments of major river courses and continues to enter aquatic food chains. Actions which disturb sediments, including normal feeding by bottom feeders, also resuspend DDT in the water column where it becomes available to other trophic levels (USA-COE, 1985; Yokley and Gooch, 1976). These systems have been altered in the past by both the channelization (deepening and widening with heavy equipment) and hand clearing of log jams, falling trees, etc.

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ELECTROCHEMISTRY OF DIHALOGENATED NICOTINIC ACIDS IN AQUEOUS AND APROTIC MEDIA

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ABSTRACT

The electrochemical reduction of several 2,5- and 5,6- dihalonicotinic acids have been studied in dimethyl sulfoxide as well as in aqueous buffers of different pH. The polarographic half-wave potentials for the reduction of these compounds in both media are reported here. The compounds appear to reduce at the carboxyl group. The presence of halogen atoms on the pyridine ring facilitates reduction.

INTRODUCTION

The synthesis and spectroscopic (IR and NMR) characterization of several 2,5- and 5,6- dihalonicotinic acids have been reported earlier (Setliff, 1970, 1972, 1973, 1976 and 1978). Because of the chemical similarity with vitamin B (niacin), these compounds are of important biological significance. Since biological activities of chemical agents are generally believed to occur via oxidation-reduction mechanism, it is essential that the redox properties of these compounds be determined in order to understand the molecular basis of such activities. No electrochemical studies of nicotinic acid and its halogen derivatives have yet been reported. We have therefore undertaken the task of determining the polarographic half-wave potentials for the reduction of these compounds in both protic and aprotic media. In this report, the results obtained in dimethyl sulfoxide and in aqueous buffers are presented.

EXPERIMENTAL

Reagents: Dimethyl sulfoxide (DMSO) and tetrabutylammonium perchlorate (TBAP) were of analytical grade (Fisher Chemicals) and were used without further purification. Aqueous buffers of various pH were prepared (Carmody, 1961) from analytical grade boric acid, citric acid and trisodium phosphate (Fisher Chemicals). The aqueous reaction media were 0.1M buffer solutions, whereas the aprotic medium was a solution of 0.1M TBAP in DMSO, which was dehydrated (commercial TBAP and DMSO contain water) prior to use by passing over basic alumina (Woelm).

Apparatus: The half-wave potentials were determined by Differential Pulse Polarography using a three-electrode polarographic analyzer (Model PAR 174A; Princeton Applied Research Corporation, Princeton, NJ). The cathode, the counter-electrode and the reference electrode were dropping mercury electrode (DME), platinum foil and saturated calomel electrode (SCE) respectively. In aprotic medium, however, a low-porosity calomel, filled with 0.40M tetraethylammonium chloride to adjust voltage to 0.00 volt vs. SCE, was used as reference to minimize water-leakage into the medium. The polarograms were recorded on an X-Y recorder (Model 2200 Omnigraphic; Houston Instruments, Austin, TX). The mercury drop-rate of the DME was controlled by a mechanical drop-timer (Princeton Applied Research Corporation). The temperature of the reaction medium was maintained at $25.0 \pm 0.1^\circ\text{C}$.

Procedure: Twenty ml of the solution was poured into the reaction vessel, purged with ultra-high purity argon for thirty minutes to remove dissolved oxygen and a differential pulse polarogram of the medium (background) was taken using the following conditions: Initial Potential = 0.00 volt vs. SCE, Potential Scan Rate = 5 mV/sec, Pulse

Amplitude = 25mV and Drop Time = 1.0 sec. During potential scan in the negative direction (reduction), the solution was quiescent and the argon flow was diverted above the solution to keep atmospheric oxygen and moisture away. To the solution, about five mg of a particular compound was then added, stirred to dissolve completely, and the polarogram was taken under the same condition as above. The procedure was repeated for other compounds.

RESULTS AND DISCUSSION

The technique of Differential Pulse Polarography (DPP) is superior to that of Direct Current Polarography (DCP) for the determination of half-wave potentials due to improvement of signal to noise ratio as a result of discrimination against capacitive current (Bond, 1984). Moreover, polarograms obtained by DPP show Gaussian peaks due to charge-transfer process, compared to sigmoidal curves in DCP, and can be evaluated more precisely. In DPP, the half-wave potential ($E_{1/2}$), which is characteristic of a particular electroactive compound and is a measure of its ability to be either oxidized or reduced, can be related to the peak potential (E_p) of the polarogram by the equation:

$$E_{1/2} = E_p \pm \Delta E/2$$

where ΔE = pulse amplitude and '+' and '-' signs refer to reduction and oxidation processes respectively.

Figure 1 shows typical polarograms obtained by DPP in DMSO for nicotinic acid and two of its dihalogenated derivatives, namely, 5-chloro-6-iodo- and 6-chloro-5-iodo- nicotinic acids. Each polarogram displays two distinct peaks, indicating that the compounds are undergoing reduction in two steps. A previous report (Lund, 1983) showed that in acetonitrile, an aprotic medium, the electrochemical reduction of pyridine ring is very difficult. The two peaks, therefore, can be attributed to reduction of the carboxyl group.

The half-wave potentials obtained for a number of dihalonicotinic acids in both protic and aprotic media are shown in Table 1. While each compound showed two peaks in DMSO, additional peaks were observed in aqueous media, especially at a lower pH. This may indicate that in aqueous media either the protonated nitrogen of the pyridine ring or halogen atoms on the ring are also reduced. The presence of halogen atoms on the ring also have profound effect on the half-wave potential for the reduction of carboxyl group (see Figure 1 and Table 1). Both in aqueous and aprotic media, the first $E_{1/2}$ is shifted to a more positive value, as compared to that of the unsubstituted nicotinic acid, indicating that halogen atoms facilitate reduction. This positive shift of $E_{1/2}$ can be explained in terms of counter-balancing inductive effect (-I) and resonance effect (+R) of aryl halogen substituents (Gould, 1959). Because of this opposing action, the net electron-withdrawing capacity of halogens is in the order: $\text{I} > \text{Br} > \text{Cl} > \text{F}$.

Electrochemistry of Dihalogenated Nicotinic Acids in Aqueous and Aprotic Media

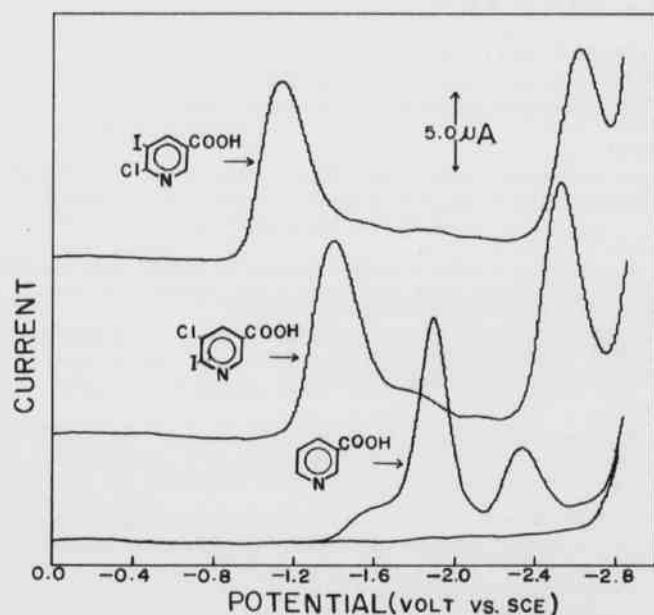


Figure 1. Differential Pulse Polarograms of nicotinic acid and its dihalogenated derivatives in 0.10M TBAP/DMSO. Conditions: scan rate = 5mV/sec, pulse amplitude = 25 mV, drop time = 1.0 sec. The bottom curve (flat) represents the background.

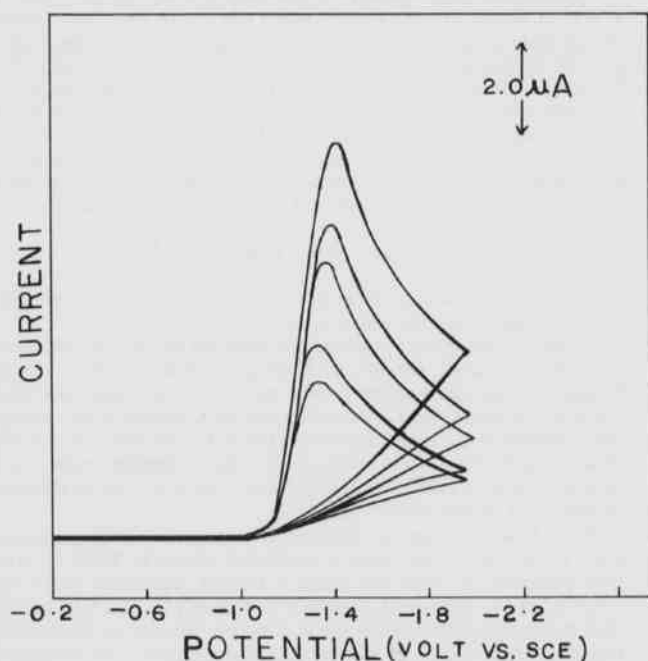


Figure 2. Cyclic Voltammograms of 5-Chloro-6-iodo-nicotinic acid in 0.10M TBAP/DMSO at potential scan rates of 10, 20, 50, 100 and 200 mV/sec. The peak height increases with scan rate.

I and Br at 5- and 6- positions of the pyridine ring therefore favor reduction of the carboxyl group. In DMSO, a negative shift of the second

Table 1. Half-Wave Potentials for Reduction of Some Dihalonicotinic Acids in DMSO and in Aqueous Buffers

Compound (Nicotinic Acid)	$E_{1/2}$ in DMSO (Volt vs. SCE)	$E_{1/2}$ in Water (Volt vs. SCE)		
		pH 2.0	pH 4.0	pH 6.0
Unsubstituted	-1.92 -2.36	-1.05 -1.14	-1.05 -1.13	-1.05 -1.22
5-chloro-6-iodo-	-1.38 -2.51	-0.32 -0.86 -1.09	-0.44 -1.21 N.D.	-0.61 -1.37 N.D.
6-chloro-5-iodo-	-1.14 -2.62	-0.69 -1.07 -1.16	-0.80 -0.90 -1.24	-1.01 -1.09 N.D.
2-chloro-5-iodo-	-1.57 -2.43	-0.83 -1.12	-1.11 -1.37	-1.33 -1.45
2-bromo-5-iodo-	-1.35 -2.43	-0.75 -1.08 -1.15	-0.93 -1.25 N.D.	-1.26 -1.61 N.D.
5-bromo-6-iodo-	-1.34 -2.47	-0.31 -0.85 -1.09	-0.43 -0.99 -1.19	-0.57 -1.38 N.D.
6-bromo-5-iodo-	-1.09 -2.53	-0.59 -0.66 -1.13	-0.72 -1.23 N.D.	-0.92 -1.14 N.D.
5,6-dibromo-	-1.50 -2.47	-0.60 -0.85 -1.09	-0.73 -0.99 -1.19	-1.03 -1.38 N.D.
2,5-dibromo-	-1.49 -2.49	-0.81 -0.93 -1.13	-1.01 -1.23 N.D.	-1.36 N.D. N.D.
2,5-dichloro-	-1.59 -2.44	-0.94 -1.11	-1.29 -1.51	-1.42 N.D.
5,6-dichloro-	-1.57 -2.41	-0.68 -0.85 -1.11	-0.86 -1.10 -1.23	-1.13 -1.23 -1.35

* Half-wave potentials are given in each column in sequence of First $E_{1/2}$, Second $E_{1/2}$ etc.

N.D. = The peak corresponding to the half-wave potential is in existence but is not clearly detectable.

$E_{1/2}$ was generally observed (see Table 1), indicating greater difficulty of further reduction of the compounds. The reason for such a shift is not clearly understood, although it appears that solvent (DMSO) molecules may play an important role.

Figure 2 shows typical cyclic voltammograms obtained for halogenated nicotinic acids in DMSO at various potential scan rates. The initial reduction of the compound is followed by a rapid chemical reaction (EC mechanism) of the product with solvent molecules. As a result, the product cannot be reoxidized back to the original compound during reverse scan. Similar behavior was also observed in aqueous media.

From Table 1, it is also obvious that the pH of the aqueous media has a profound effect on the relative ease of reduction of the carboxyl group. At lower pH, the half-wave potential shifts to the positive direction, showing the protons are involved in the reduction process. Similar proton-mediated reduction of isonicotinic acid has been reported earlier (Lund, 1963). In dry DMSO, however, the absence of protons dictates that the mechanism of reduction may be totally different from that in aqueous medium and most likely the reduction proceeds through a free-radical mechanism. The reaction products in two solvents may therefore be quite different. Caulometric analysis of the reduction processes in both media, followed by isolation and gas-chromatographic identification of the products, are now in progress in our laboratory to fully understand the mechanism of reduction of these biologically important compounds.

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OPTIMAL CONDITIONS FOR KINETIC STUDY OF SUCCINATE DEHYDROGENASE IN RAT LIVER

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ABSTRACT

Succinate dehydrogenase (SDH) commonly is assayed as a marker enzyme for mitochondrial activity. The literature presents numerous conditions for conducting this assay due to the fact that, it has been difficult to get sufficient reduction of the acceptor dye, 2,3,5-triphenyl-2H-tetrazolium chloride (TTC). This study was undertaken to optimize the SDH-catalyzed reduction of TTC dye by evaluation of a greater range of molar ratios of TTC to succinate and by further evaluation of additives reported as beneficial. Improvement in enzyme specific activity was achieved by liver perfusion via the left cardiac ventricle with homogenizing solution. Increase in TTC from 1 to 10 mM and further increase to 20 mM resulted in major improvement in color production. The greatest improvement in apparent activity was achieved by addition of 1 mM phenazine methosulfate, a hydrogen transfer mediator. Use of CaCl_2 , EDTA, Triton X-100, NaN_3 and KCN was not beneficial. The above modifications of the SDH assay resulted in greater sensitivity, the conduct of a greater number of assays with less tissue and the sacrifice of fewer animals.

INTRODUCTION

Succinate dehydrogenase (SDH) commonly is used as a marker enzyme for the mitochondrion because it is bound to the inner membrane of the mitochondrion. Frequently, its activity is used to assess tricarboxylic acid cycle activity as well as electron and hydrogen transfer to the electron transport system. The activity of SDH usually is measured spectrophotometrically by following the reduction of an artificial acceptor dye such as 2,3,5-triphenyl-2H-tetrazolium chloride (TTC).

Numerous conditions have been presented in the literature for conducting this assay, due to difficulty in obtaining sufficient dye reduction and adequate absorbance values when using reasonable amounts of enzyme. For determination of Michaelis-Menton constants for inhibited and uninhibited reactions catalyzed by SDH, it is important to obtain high absorbance values for the uninhibited reaction. Otherwise inhibitors may decrease the formation of reduced dye and absorbance values to such a point that instrumental error becomes too great to provide reliable measurements.

This study was initiated to optimize the SDH catalyzed reduction of TTC dye by evaluating a greater range of molar ratios of succinate to TTC dye and by further evaluation of additives mentioned in the literature. These include EDTA, a chelator, CaCl_2 , and Triton X-100, substances reputed to increase membrane permeability, KCN and NaN_3 , electron transport inhibitors, and phenazine methosulfate, a putative electron transfer mediator between FADH₂ and TTC.

This paper presents improvements in the assay that will increase the SDH catalyzed reduction of TTC, give high dye absorbance values for uninhibited reactions and adequate absorbance for inhibited reactions. This will facilitate future kinetic studies of SDH.

MATERIALS AND METHODS

Chemicals used in this study were obtained from 4 major chemical companies. 2,3,5-triphenyl-2H-tetrazolium chloride monohydrate (TTC) and sodium dithionite were obtained from Aldrich Chemical Company. Phenazine methosulfate, sodium azide, and sucrose were obtained from Sigma Chemical Company. Disodium succinate was obtained from National Biochemical Corporation. Sodium phosphate, ether, acetone, and potassium cyanide were obtained from Fisher Scientific Company. The necessary aqueous solutions were made with distilled, deionized water.

The animals, black-hooded derived rats, were housed in environmentally controlled conditions and were provided food and water ad libitum.

The animals were sacrificed by stunning and cervical dislocation or by etherization, and exsanguination. Exsanguination was achieved by perfusion with ice-cold homogenizing solution (.25 M sucrose) via left cardiac ventricle until the liver became more lightly colored.

The liver was excised, weighed, placed in a 0°-5°C solution of homogenizing fluid, diced and transferred to a prechilled homogenizing vessel. Homogenization was achieved by 5 passes of a teflon pestle into a glass vessel (size C Thomas). The homogenizer was powered by a Talboys Instrument Corporation Model 102 electric motor operated at full speed. The homogenate was maintained at less than 5°C during this procedure.

The homogenate was then placed in a refrigerated Sorvall RC2-B centrifuge and spun at 800 xG for 10 minutes. The supernatant (S1) was collected, diluted with 0.25 M sucrose and recentrifuged at 20,000 xG for 20 minutes to pellet the mitochondria. The supernatant (S2) was removed and the pellet (P2) was resuspended in .25 M sucrose in the ratio of 1-2 gm wet weight of liver to 1 ml sucrose. This suspension was centrifuged at 600 xG for 5 minutes to remove all large particles not resuspended in the earlier step. The supernatant (S3) was kept chilled for subsequent use.

If appropriate, the homogenate was sonicated using 10-second bursts at maximum power from an Ultrasonic System Model 1000 Insonator. During this procedure care was taken to maintain a temperature below 10°C, and following this procedure the homogenate was returned to 0-5°C.

A determination of the homogenate's protein concentration was conducted, using the Bio-Rad protein assay kit, with bovine serum albumin as the standard. Absorbance was measured at 595 nm.

Typical reaction tubes were prepared by the addition of 0.5 ml of 0.1 M phosphate buffer, 0.5 ml of succinate and 1.0 ml of TTC (Kun and Abood, 1949). The final concentrations of these solutions were 16.6 mM, 5-10 mM, and 1-10 mM, respectively. After prewarming these reagents and liver homogenate at 38°C in a Forma Scientific water bath/circulator, the reactions were initiated by addition of 1.0 ml of liver homogenate and mixing. The reactions were terminated 15-20 minutes later by addition of 7 ml of acetone. The tubes were then centrifuged at 3000 rpm for 5 minutes and the absorbance of the supernatant was determined at 490 nm.

The standard curve for TTC was obtained by combining increasing amounts of TTC from 30-300 ug with approximately 7 mg of dry sodium dithionite. The reaction proceeded for 5 minutes, then was terminated by acetone addition and the absorbance of the solution was measured at 490 nm.

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RESULTS

TTC Standard Curve

In setting up a standard curve for TTC, difficulty was encountered in obtaining linearity when a few crystals of sodium dithionite were used as specified in the literature (Kun and Abood, 1949). Four to 10 mg of reductant were found to be necessary to achieve full reduction of TTC dye (Figure 1). Less sodium dithionite caused incomplete reduction. Greater amounts of sodium dithionite caused less absorbance to be recorded and a change in the absorption spectra was noted.

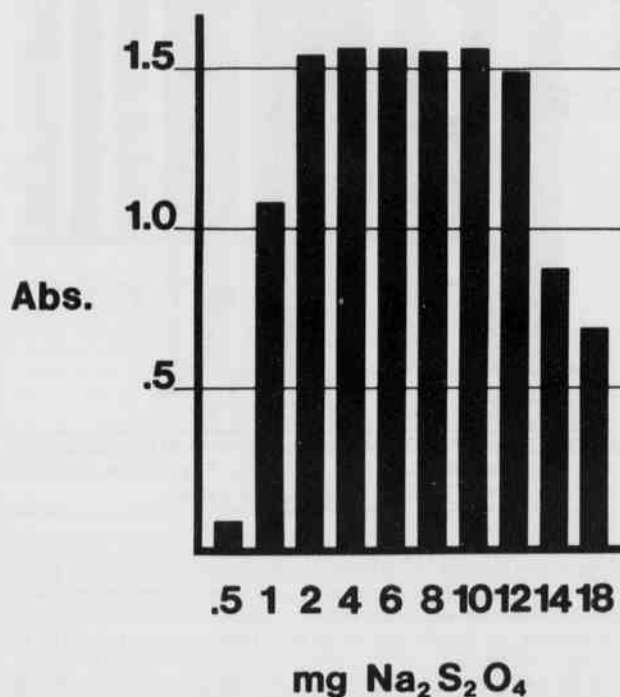
TTC Reduction

Figure 1. TTC reduction with Sodium Dithionite. Known weights of Sodium Dithionite were added to 3 ml aliquots containing 300 micrograms TTC. The solution was mixed, incubated for five minutes, and 7 ml acetone was added. Absorbance of the reduced TTC was then measured.

Test of Additives

EDTA at 1 mM (Melnick and Schiller, 1985), Triton X-100 at 0.1% (Tushurashvili et al., 1985), and CaCl₂ at 1-2 mM (Minatoguchi et al., 1984) are reported in the protocols of SDH assays in the literature. In the present system the above concentrations of EDTA and Triton X-100 caused decreases in dye reduction in the amounts of 32% and 91% respectively (Table 1). CaCl₂ was tested in TRIS buffer at the same pH as used above, because in phosphate buffer it forms a CaHPO₄ precipitate. 1-2 mM CaCl₂ caused decreases in dye reduction of 16% to 17%.

Test of Perfusion

Centrifugation of nonperfused liver homogenate resulted in a perceptible blood cell pellet following the first and second centrifugations, and the final mitochondrial suspension was darkly colored. Perfusion of the liver led to a decrease in the quantity of the blood cells in the first and second pellets and produced a more lightly colored mitochon-

Table 1. The effect of various chemicals on succinate dehydrogenase activity.

BUFFER	ADDITIVE	CONCENTRATION	% ACTIVITY
PHOSPHATE	NONE	—	100
PHOSPHATE	EDTA	1 mM	68
PHOSPHATE	TRITON X-100	0.1%	9
TRIS	NONE	—	100
TRIS	CaCl ₂	1 mM	83
TRIS	CaCl ₂	2 mM	84

ENZYME ACTIVITY WAS DETERMINED AT +20 MINUTES. THE REACTION CONTAINED 5 mM SUCCINATE, 1 mM TTC, 1.33 MG PROTEIN/ML AND BUFFER

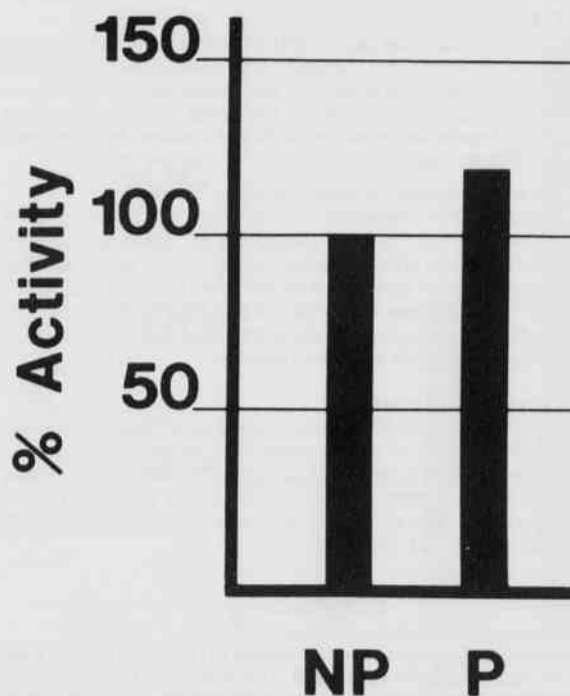
Perfusion Effects

Figure 2. Effect of Perfusion on Specific Activity of SDH. Enzyme activity was determined at +20 minutes. The reactions contained 5 mM succinate, 1 mM TTC, 1.33 mg protein, and buffer.

drial suspension. Perfusion led to a 19% increase in specific activity of SDH (Figure 2) and was used in all subsequent experiments.

Optimal Conditions for Kinetic Study of Succinate Dehydrogenase in Rat Liver

Test of Sonication

Sonication of the mitochondrial suspension was conducted to determine if some disruption of the mitochondrial membranes would lead to greater dye access to and reduction by SDH. Minor improvement in dye formation occurred following 10 to 20 seconds of sonication while extended sonication hampered product formation slightly (Table 2). Ten seconds of sonication was conducted in all subsequent experiments.

SONICATION TIME (SEC)	% ACTIVITY
0	100
10	104
20	103
30	97
40	99
50	94
60	90

ENZYME ACTIVITY WAS DETERMINED AT +20 MINUTES. THE REACTION CONTAINED 5 mM SUCCINATE, 1 mM TTC, 1.33 MG PROTEIN/ML AND BUFFER.

Test of TTC

The literature records the use of 10:1 or greater ratio of succinate to acceptor dye (Rondina, 1971; Futai, 1973). Tests of succinate to dye ratios up to 1:1 increased the amount of absorbance up to 278% (Figure 3A). Further increases of succinate to dye ratios up to 1:2 increased the amount of absorbance by another 48% and a plateau in absorbance was evident (Figure 3B).

Test of Electron Transport System Inhibitors

With regard to TTC reduction by SDH, the additive cyanide is reported to increase dye reduction (Nachlas et al., 1960; Minatoguchi et al., 1984), to have no effect (Kun and Abood, 1949), and to decrease reduction because of its action as a protein denaturant (Tsou, 1951). The present work demonstrated that cyanide and sodium azide, inhibitors of electron transport at cytochrome aa₃, caused decreases in dye reduction by as much as 95% (Table 3).

Test of Phenazine Methosulfate

PMS is mentioned in the literature as a mediator of hydrogen transfer between FAD and TTC. In these reports PMS usually is presented to the reaction in a ratio of 2 parts PMS to 1 part TTC (Futai, 1973; Massa et al., 1985). In the present work in which 10 mM TTC was used, a much smaller proportion of PMS, 1 mM, was found to improve TTC reduction by a factor of four (Figure 4).

DISCUSSION

The optional amount of sodium dithionite to reduce TTC for a standard curve was found to be 4-10 mg. It is interesting that many publications stated that a few crystals would be sufficient (Rendina, 1971; Hall and Hawkins, 1975). Too few crystals resulted in incomplete reduction and greater than 12 mg of sodium dithionite resulted in decreased color formation and a visible change in the absorption spectrum. This change in absorption suggests that an additional reaction may be involved that is not described in the literature.

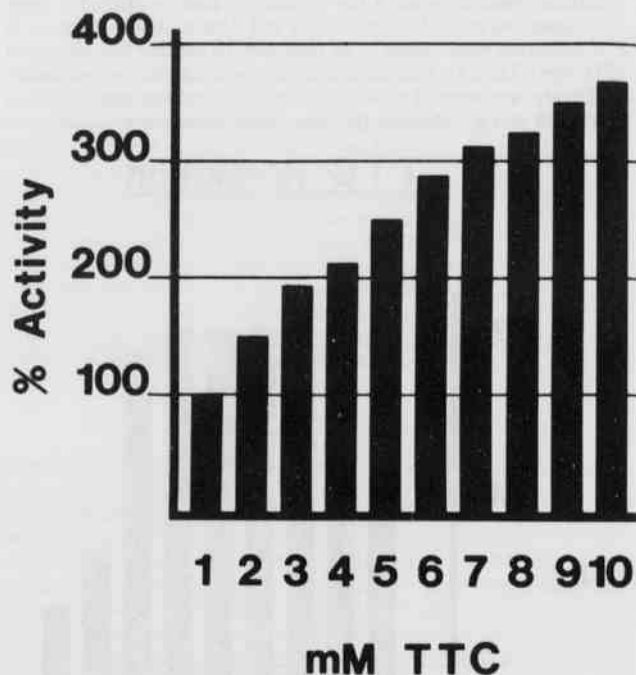
1-10 mM TTC Effect

Figure 3A. Effect of 1-10 mM TTC on Apparent SDH Activity. Enzyme activity was determined at +15 minutes. The reaction contained 10 mM succinate, 1.33 mg protein/ml, and buffer.

Contrary to findings in the literature, we found the detergent, Triton X-100, and CaCl₂ did not improve dye reduction. These reagents were reputed to increase the permeability of the outer membrane of the mitochondria, so that the dye would have better access to the SDH on the inner membrane.

The perfusion of the liver decreased the amount of intact and lysed blood cells found in the mitochondrial pellet and increased the specific activity of SDH by 19%. This rather time-consuming technique may continue to be selected for the above reasons but other modifications of the procedure gave such improvement in dye reduction that a 19% increase in specific activity may not be necessary.

Ten to 20 second sonication of the mitochondrial suspension gave very minor differences that were not different from control. But sonication was so easy to conduct and it may have improved access of dye to SDH, we found it worthwhile to continue.

The optimal amount of TTC to monitor the SDH reaction was found to be 20 mM. Unfortunately, the solubility limit of TTC is just greater than 30 mM, hence, the set up of this assay required 2 ml of 30 mM TTC in a reaction having a total volume of 3 ml. The remaining reagents were prepared at twice the typical concentration and were delivered in half the typical volume. Delivery of these smaller volumes and preparation of liver homogenate at twice the usual concentration was found to be less than desirable for routine work. Therefore, the reagent volumes described in the materials and methods section were used in all subsequent work. The amount of TTC achieved in the remaining assays was 10 mM. This provides almost 90% of the absorbance obtainable with 20 mM TTC.

Cyanide has been reported to improve the reduction of dye in the SDH reaction (Minatoguchi et al., 1984), to have no effect (Kun and

10 - 20 mM TTC Effect

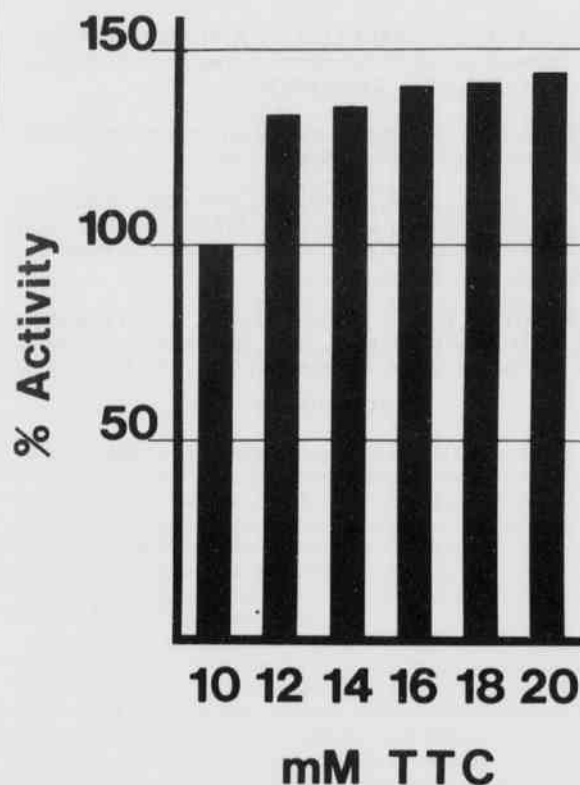


Figure 3B. Effect of 10-20 mM TTC on Apparent SDH Activity. Enzyme activity was determined at +20 minutes. The reaction contained 10 mM succinate, 1.33 mg protein/ml, and buffer.

Abood, 1949), and to harm the reaction due to its ability to denature protein (Singer and Kearney, 1957; Hatefi and Stiggal, 1976). Data herein demonstrate that when the reaction is run with 10 mM TTC, cyanide and the other tested ETS inhibitor, sodium azide, inhibited dye reduction. This and the EDTA chelation results, suggests that TTC may accept hydrogens from a number of sites that are fed by succinate metabolism and substantiates others findings (Nachlas et al., 1960).

The greatest improvement in dye reduction was brought about by the addition of 1 mM PMS. This agreed with the literature (Futai, 1973; Massa et al., 1985), but also indicated that the oft published ratio of 2:1 PMS to TTC is not important under the present conditions. The 1 mM PMS used here is in a 1:10 ratio to TTC.

It is thought that the future use of 10 mM TTC and 1 mM PMS will facilitate a greater number of assays to be conducted on less tissue and may then require use of fewer animals.

ACKNOWLEDGEMENTS

We would like to thank Mrs. Judy Carter for excellent clerical assistance, Drs. Jerry Manion, Arthur Hoyt, and John Choinski for advice, Dr. Derald Smith for laboratory space, Robert Saunders and Steve Thomas for photography, and the Chairman of the Department of Biology, Dr. Robert Wright, for funding this project.

Table 3. The effect of electron transport inhibitors on succinate dehydrogenase activity.

ADDITIVE	CONCENTRATION	% ACTIVITY
NONE	—	100
KCN	10^{-2} mM	50
KCN	10^{-1} mM	11
KCN	10^0 mM	13
KCN	10^{+1} mM	5
NaN_3	10^{-3} mM	95
NaN_3	10^{-2} mM	97
NaN_3	10^{-1} mM	95
NaN_3	10^0 mM	72
NaN_3	10^{+1} mM	51

ENZYME ACTIVITY WAS DETERMINED AT +15 MINUTES. THE REACTION CONTAINED 1 mM SUCCINATE, 10 mM TTC, 1.2 MG PROTEIN/ML AND BUFFER.

PMS Effect

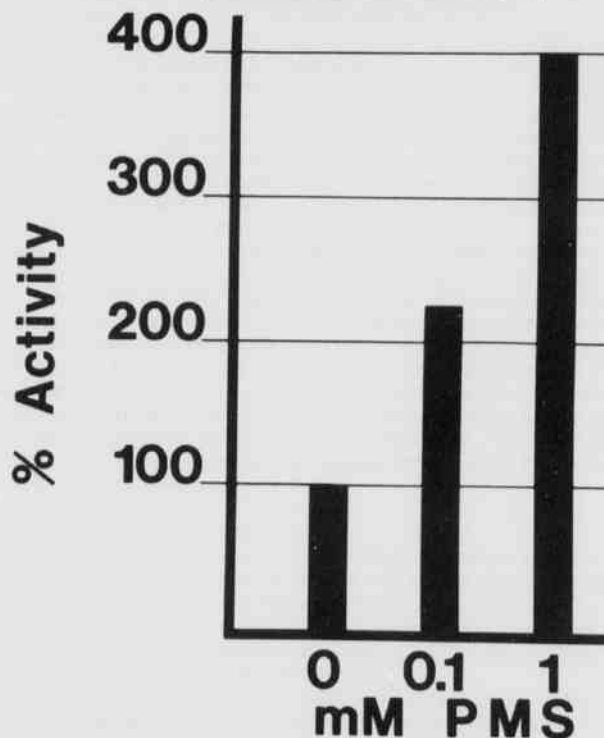


Figure 4. Effect of PMS on TTC Reduction. Enzyme activity was determined at +15 minutes. The reaction contained 1 mM succinate, 10 mM TTC, 1.2 mg protein/ml, and buffer.

Optimal Conditions for Kinetic Study of Succinate Dehydrogenase in Rat Liver

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DEPOSITIONAL HISTORY OF THE ST. JOE AND BOONE FORMATIONS IN NORTHERN ARKANSAS

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ABSTRACT

The Kinderhookian-Osagean (Lower Mississippian) St. Joe and Boone Limestone represent an unconformity bounded transgressive-regressive sequence widely distributed throughout the southern midcontinent. An irregular erosional surface developed on the Chattanooga Shale (Upper Devonian) or older strata. As Mississippian Seas transgressed, they deposited a thin interval of sandstone, shale, or the two together derived from these old beds. Carbonate deposition was initiated as grain-dominated, crinzoan-bryozoan packstones and grainstones, with subordinate wackestones, and is essentially chert free. These carbonates, referred to as the St. Joe Limestone, reflect a ramp across northern Arkansas that experienced condensed sedimentation and red coloration along its conditions reflected by carbonate mudstones, very fine-grained packstones and grainstones, and penecontemporaneous chert of the overlying lower Boone Formation. The upper Boone (Burlington-Keokuk equivalents) represents a regressive sequence that returned St. Joe-type, grain-dominated, lithologies with diagenetic chert replacement to the shelf. The regression terminated in a pronounced regional unconformity overlain by Meramecian or younger strata.

INTRODUCTION

Kinderhookian and Osagean rocks crop out on the southwestern flank of the Ozark dome in southwestern Missouri, northern Arkansas, and northeastern Oklahoma. The St. Joe and Boone Formations (and equivalent strata) form this Lower Mississippian sequence and develop the Springfield Plateau across this area. The Lower Mississippian interval consists of an unconformity-bounded carbonate package with the St. Joe being predominantly chert-free and the Boone consisting of chert-bearing carbonates (Fig. 1).

The principal area of study include portions of northern Arkansas extending from the Oklahoma-Arkansas border eastward as far as Stone County, Arkansas (Fig. 2). A total of nine surface section localities were sampled and described from this area. Additionally, data from 159 subsurface well logs were used to construct an isopachous map of the Boone Formation to illustrate thickness trends throughout the region. This investigation involves a detailed petrologic study of the St. Joe-Boone interval, resulting in the delineation of various carbonate facies which ultimately gives an insight into the depositional history of the sequence.

DEPOSITIONAL HISTORY

The Kinderhookian-Osagean (Lower Mississippian) St. Joe and Boone Formations were deposited on a broad carbonate ramp designated as the Burlington Shelf by Lane (1978). In northern Arkansas, these formations represent deposition on a ramp at the southern edge of this shelf that extended southward into siliceous sediments of the Marathon-Ouachita Trough.

The St. Joe and Boone Limestones represent an unconformity bounded, transgressive-regressive sequence. As Mississippian seas transgressed, an irregular erosional surface developed on rocks of Ordovician, Silurian, and Devonian age (Thompson and Fellows, 1970). The Bachelor Member of the St. Joe Formation represents the initial transgression of these seas and is generally recognized as a thin interval of greenish shale, a light-colored sandstone, or the two together derived from older strata (Post, 1982). Carbonate deposition was initiated as grain-dominated, crinzoan-bryozoan packstones, with subordinate grainstones and wackestones, and is essentially chert-free (Shanks, 1976) (Fig. 3). These carbonates, referred to as the St. Joe Limestone, were deposited in relatively shallow waters initially with gradual deepening represented by strata of the lower Boone. In some areas, this change is marked by carbonate mudstones and wackestones (Fig. 3). In other areas, such as the Buffalo River section, it is marked by an abrupt decrease in grain-size which can be attributed to the lack of mud in the area during this time (Figs. 3, 4). Moving up through the Boone interval many surges of grain movement produce repeated cycles of carbonate strata. These cycles are reflected by repetition of grain sizes, allochemical content, and facies throughout the Boone interval (Fig. 4). However, upper Boone strata generally represent shallower water conditions than do those of the lower Boone, reflecting a regressive sequence ending with uppermost Boone deposition. This regression terminated in a pronounced regional unconformity overlain by Meramecian or younger strata.

Shallow Versus Deep Carbonates

Similar lithologies may be found in shallow and deep water settings due primarily to transportation of relatively shallow water sediments into deeper water settings. Wilson (1975) notes the documentation of several limestone turbidite facies deposited in relatively deep water settings. However, several characteristics may be used to differentiate between shallow and deep water carbonates.

Certain sedimentary structures are indicative of shallow marine settings, for example, the presence of current structures such as ripple marks and low angle trough cross stratification. Although some current structures are known from both deep and shallow environments, current activity would be much more pronounced in shallow settings, where tidal and storm activity commonly effect bottom sediments. Mudcracks are also common indicators of shallow water deposition. Character of

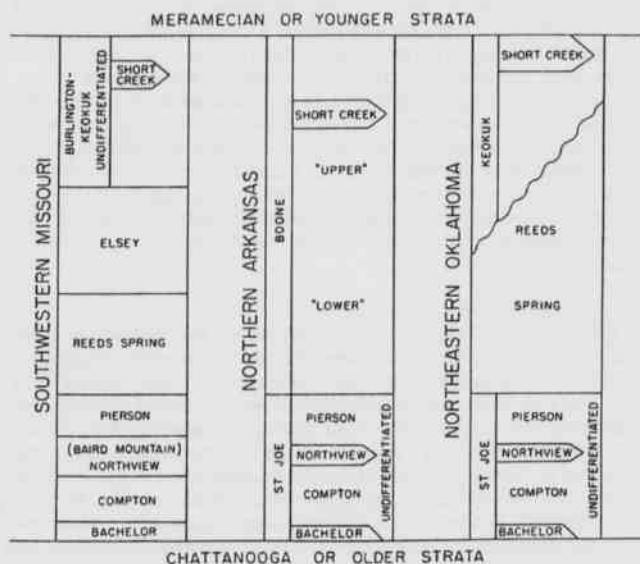


Figure 1. Stratigraphic nomenclature of Lower Mississippian rocks in Missouri, Oklahoma, and Arkansas.

Depositional History of the St. Joe and Boone Formations in Northern Arkansas

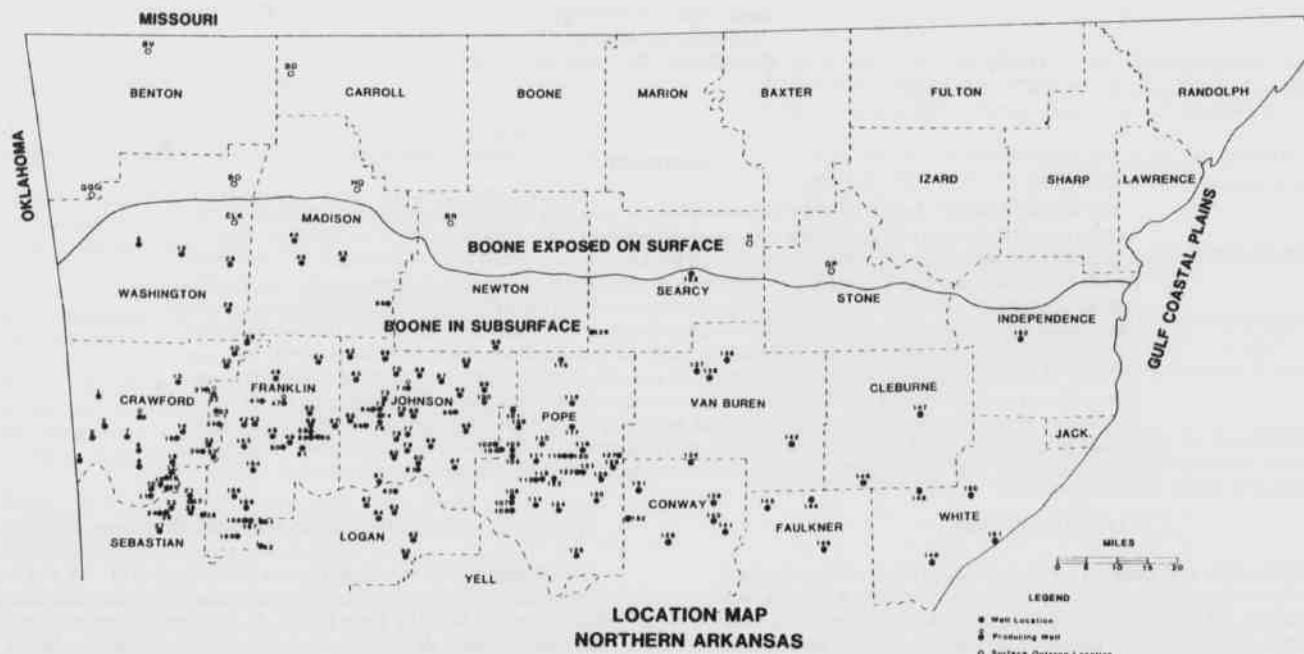


Figure 2. Location map of northern Arkansas showing section localities and subsurface well locations in study area.

individual grains is also an important indicator. Micritic envelopes surrounding grains and presence of moderate abrasion are indicative of high energy shallow water deposition. Presence or absence of certain allochemical constituents are significant. For instance, abundance of pellets, algal material, and/or shallow-water forams are all indicators of shallow water environments. Other indicators of shallow water deposition include abundance of burrowing and presence of trace fossils. Both of which are prevalent in quiet, shallow water settings. Another characteristic of quiet shallow water deposition is presence of primary dolomite, frequently associated with mudflats and stromatolites. Biohermal or mound-type buildups are also usually indicative of shallow water settings. However, the Waulsortian Mounds in lower Mississippian strata of Arkansas, Missouri, and Oklahoma are thought to be deep water (Manger and Thompson, 1982).

The mud-dominated facies of the lower Boone contains none of the characteristics of quiet, shallow-water environments. Mud cracks, algal stromatolites, bird's eye structures, and penecontemporaneous dolomite are all absent. Although some burrowing is present, it is not developed to the degree that would be expected in a lagoonal type setting. Moreover, there is a marked absence of distinctive shallow water fauna in all facies of the lower Boone. There are no foraminifers, algae or pellets. Micritic envelopes are not present, and there is an absence of current structures. Another important characteristic missing in the lower Boone is the development of mound-type or biohermal buildups. Manger and Thompson (1982) note the development of more than 40 Waulsortian mounds within the St. Joe interval in northeastern Oklahoma and southwestern Missouri. Harbaugh (1957) found apparent Waulsortian mound development in northeastern Oklahoma within the Keokuk interval (upper Boone equivalent).

In contrast, the upper Boone interval represents the return of relatively shallow-water conditions towards the top of the interval. At the Elkins and Huntsville Quarry sections, foraminifers and quartz sand grains are found scattered in samples taken near the top of the Boone interval. Also, apparent mud cracks are developed in one sample at the Elkins Section. Low angle cross-stratification is present within a ten foot bed near the top of the Buffalo River section. Oolitic grainstones (Short Creek Oolite) are developed sporadically in the upper Boone interval across northern Arkansas. Liner (1979) and Van den Heuvel (1979) noted

the present of oolites in three separate sections (Buffalo River, Hemmed-In-Hollow, and War Eagle).

Carbonate Depositional Cycles

The Boone Formation appears to be cyclic in some areas throughout much of its lower interval. Graded bedding is present, consisting of tightly packed bryozoan-crinoid packstones and grainstones exhibiting fining-upwards sequences.

At the Buffalo River section, these cycles are represented by the alternation of coarse-grained crinoidal grainstones and subordinate packstones with fine-grained bryozoan grainstones and packstones (Fig. 4). At another locality (Beav-O-Rama), a single crinoid bed exhibits this graded-bedding. This bed grades from a coarse crinoidal grainstone at the base to a very fine-grained bryozoan packstone at its top.

These cycles may be attributed to a combination of two possible origins. They may represent turbidity flows in which shallower water sediment is periodically brought into the deeper water setting (Fig. 5). In between these periods of active transport not much deposition occurs with only very fine-grained material setting out from the water column. These cycles may also be related to fluctuations in the early Mississippian shoreline where the orientation changed frequently in localized areas.

Condensed Sedimentation

Thompson and Fellows (1970) noted that St. Joe thickness in northeastern Oklahoma and southwestern Missouri was inversely proportional to the rate of sedimentation. Post (1982) reported that sections of St. Joe strata in northcentral Arkansas showed evidence of condensed sedimentation. Condensed sections produced a relatively high number of conodonts suggesting a slow rate of deposition. An isopachous map prepared by Gandl (1983) illustrates the thinning trend of St. Joe Strata across northern Arkansas and southwestern Missouri (Fig. 6).

In contrast, Boone strata in the same area is quite thick and yet contain less conodont zones than does the St. Joe, suggesting that the rate of sedimentation was higher. This could be attributed to a higher frequency of turbidite type transport to the area resulting in thicker sediment in less duration of time. Condensed sections may be present in the Boone farther to the south and east, where it dips into the subsur-

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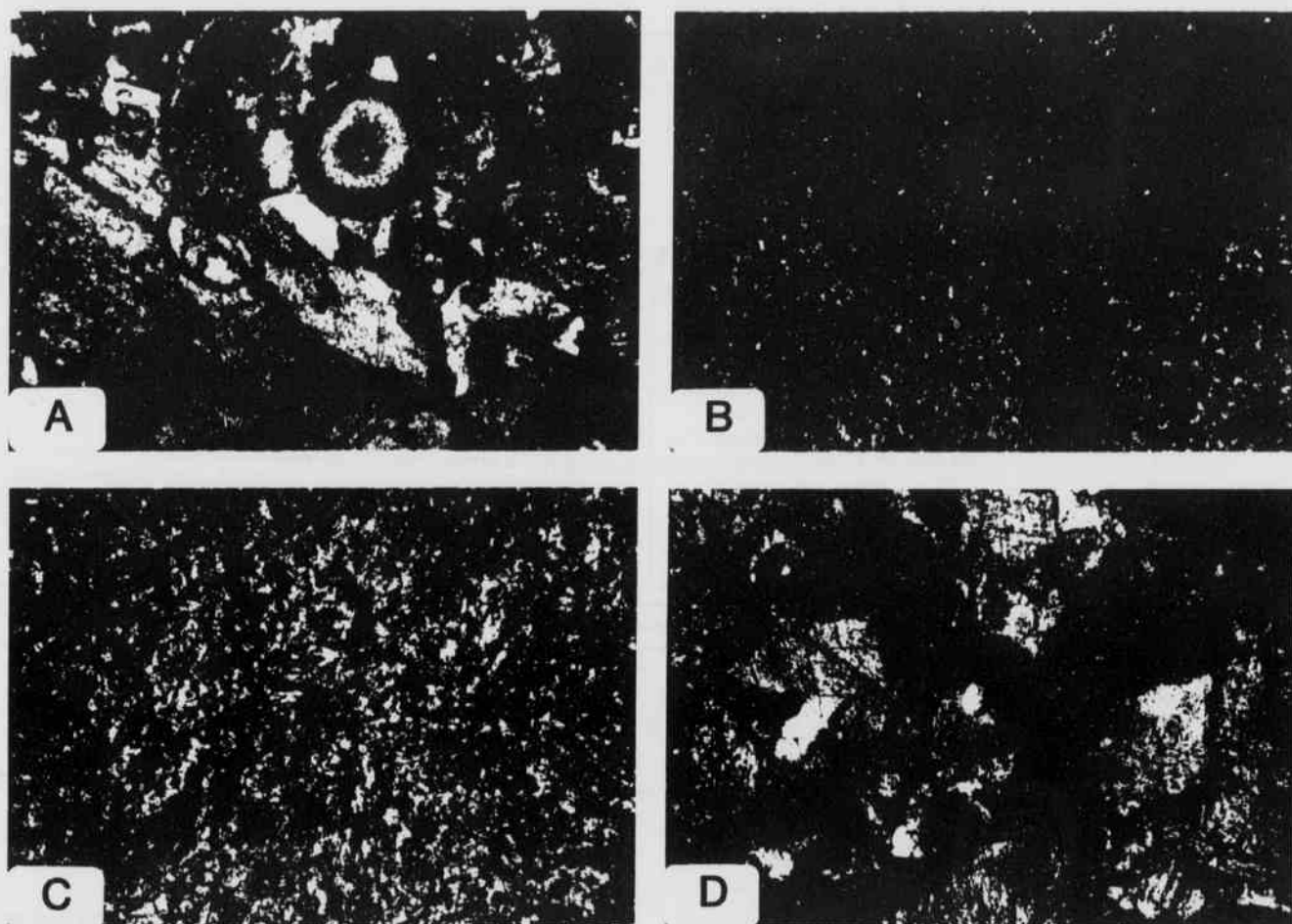


Figure 3. Photographic plate: A) photomicrograph of typical St. Joe lithology, crinoidal lime grainstone; B) photomicrograph of typical lower Boone lithology, lime mudstone; C) photomicrograph of typical lower Boone lithology, fine-grained bryozoan lime grainstone; D) photomicrograph of typical upper Boone lithology, crinozoan lime grainstone; all photographs 25X.

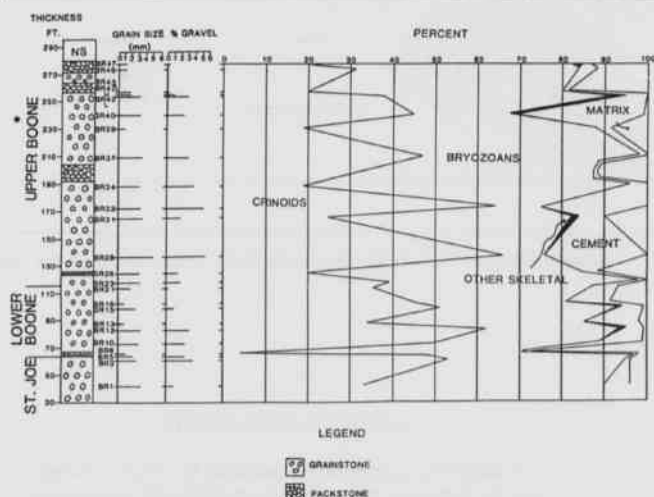


Figure 4. Grain size and modal analysis data of St. Joe-Boone samples at Buffalo River section.

face. A newly constructed isopach map of the Boone interval shows trends of thinning to the south and east (Fig. 7).

CONCLUSION

The Kinderhookian-Osagean (Lower Mississippian) St. Joe and Boone Limestone represent an unconformity bounded, transgressive-regressive sequence deposited on the southern edge of a broad carbonate platform known as the Burlington Shelf. In northern Arkansas, none of the St. Joe-Boone Strata was deposited in place. The sediment was transported down slope and deposited in deeper water conditions.

The Bachelor Member of the St. Joe Formation represents the initial transgression of the Mississippian seas and is everywhere approximately the same age suggesting rapid initial movement of these seas. Carbonate deposition was initiated as shallow-water grain-dominated lithologies and is represented by the St. Joe Limestone. These carbonates reflect a ramp across northern Arkansas that experienced condensed sedimentation eastward.

As the seas continued to transgress and greater water depths were achieved, different carbonate facies were deposited. These changing conditions are reflected by mud-supported carbonate, turbidite-type transported packstones and grainstones, and penecontemporaneous chert of the lower Boone. The upper Boone represents a general regressive sequence that returned St. Joe-type, grain-dominated shallow-

Depositional History of the St. Joe and Boone Formations in Northern Arkansas

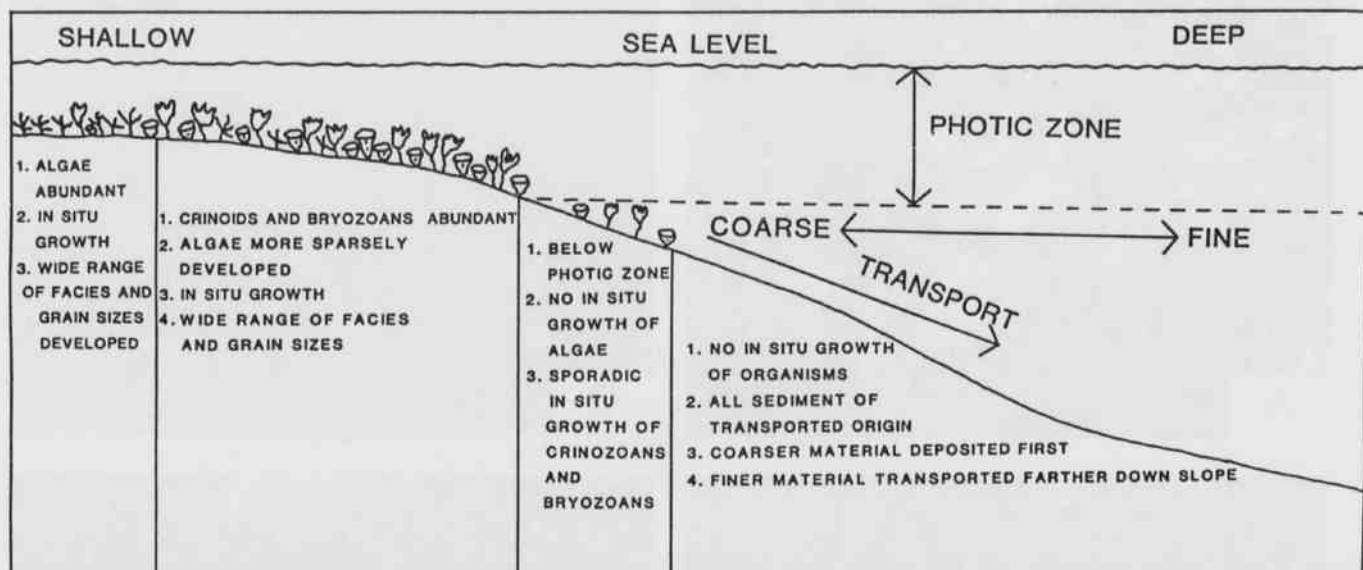


Figure 5. Generalized regional depositional setting of St. Joe-Boone interval.

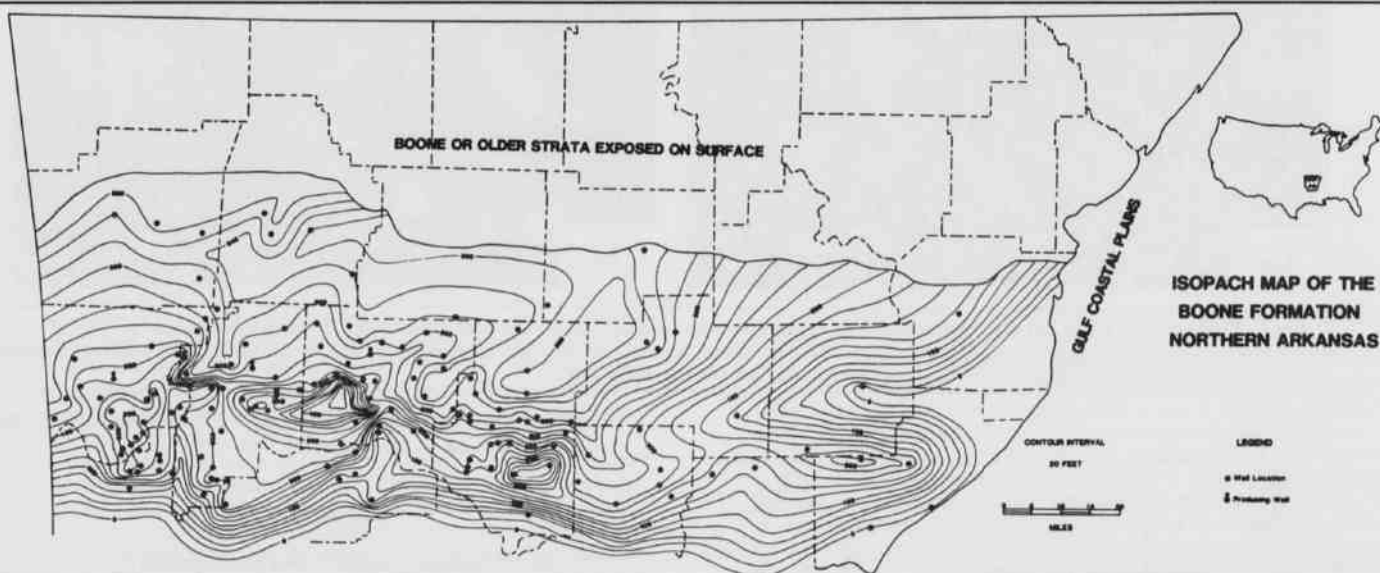


Figure 7. Isopachous Map of the Boone Formation.

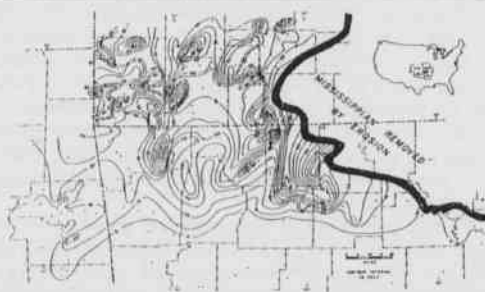


Figure 6. Isopachous Map of the St. Joe Formation (from Gandl, 1983).

water lithologies with later diagenetic chert replacement to the shelf.

ACKNOWLEDGEMENTS

I would like to express my thanks to Dr. Walter Manger for his direction and guidance through the completion of this project.

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THE BAT FAUNA OF SOUTHWEST ARKANSAS

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ABSTRACT

A systematic survey of the mammalian fauna of Southwest Arkansas has resulted in the accumulation of more than 200 records of bats from the 21 counties comprising the study area. The records reveal distributional patterns for 12 species of bats and represent a total of 68 new county records for this area of Arkansas.

INTRODUCTION

During the spring of 1981, a systematic survey of the mammalian fauna of Southwest Arkansas was begun. The composition of Arkansas' mammal population is relatively well known for some areas of the state; however, Southwest Arkansas is not one of these areas. Few collections have been made, and no systematic approach has been employed. Our study area comprised twenty-one counties, including all counties located south and/or west of, and including, Pulaski County. In this area of the state the habitat varies greatly as it ranges from the rolling hills and rocky out-croppings of the Ouachitas to the sandy flood plane found along the Arkansas-Louisiana border. The vegetation of the area is primarily an oak-hickory climax forest with pine lumber forests and large tracts of cultivated land. This area is also noted for its many lakes, ponds, and water-ways.

METHODS

To date, more than two hundred bat specimens have been collected from the various counties. The primary method of collection was with Japanese mist nets of varied lengths. Collections of this type usually occurred during the hours of darkness with the nets in place over creeks or ponds where bats might be expected to drink. On a few occasions, the nets were placed across suspected flyways or near known roosts. Numerous additional specimens were collected by hand from roosts. A few specimens were collected by shooting with .22 caliber rat shot or similar small gauge shot. Specimens, upon capture, were placed in convenient holding containers and tagged according to date, location and collector. The specimens were taken to the laboratory as soon as possible. Due to the limited amount of data previously available from this area, specimens caught in the wild were not released; however, only very small voucher samples were taken from roosts.

In addition to the collection of new data, we have incorporated the few published records and information supplied by the Arkansas Department of Health.

DISTRIBUTION OF NATURAL HISTORY NOTES OF THE BATS OF SOUTHWEST ARKANSAS

Nycticeius humeralis (Rafinesque). The evening bat is a small dark colored bat usually found in buildings and tree cavities (Barbour and Davis, 1969). Heath et al. (1983) previously reported this species from six counties in the study area: Pulaski, Garland, Montgomery, Polk, Clark and Hempstead. To these, we add ten additional counties: Saline, Hot Springs, Howard, Sevier, Little River, Miller, Nevada, Ouachita, Columbia, and Union. The evening bat is very common in the study

area, and is probably the bat most often associated with human activities.

Eptesicus fuscus (Palisot de Beavois). The big brown bat, as its name implies, is a large brown colored bat. It prefers to roost in protected structures. This species is sensitive to disturbance and will abandon a roost if repeatedly disturbed. (Barbour and Davis, 1969)

Prior to our study, *E. fuscus* had been reported only from Saline and Pike counties (Sealander, 1956). We have recorded this species from ten additional counties of Southwest Arkansas: Clark, Columbia, Howard, Lafayette, Little River, Montgomery, Nevada, Polk, Pulaski, and Sevier.

Lasiurus borealis (Muller). The red bat is slightly smaller than *E. fuscus* and appears dark red to reddish orange in color. This species is sexually dimorphic as the male is usually much brighter in color and smaller than the female. This bat prefers the dense foliage of trees as roosting sites, and, when at rest, it closely resembles a hanging dead leaf. The red bat has been reported by Sealander (1956) from Columbia, Garland, Ouachita, Pike, Pulaski, and Union counties in our study area. We have records of this species from fourteen counties, twelve of which represent new records: Calhoun, Clark, Dallas, Hempstead, Hot Springs, Howard, Lafayette, Little River, Miller, Nevada, Saline, and Sevier.

Lasiurus seminolus (Rhoads). The Seminole bat is similar to the red bat in size but can be distinguished by pelage having a rich cinnamon to mahogany color. Solitary by nature, this bat can be found roosting in large clumps of Spanish moss or similar material. Two previous records of this species exist for Southwest Arkansas. Heath et al. (1983) reported collection of this species in Polk County and Sealander and Hoiberg (1954) reported it from Ouachita County. We have collected Seminole bats from three additional counties of the study area: Grant, Little River, and Nevada.

Lasiurus cinereus (Palisot de Beauvois). The hoary bat is the largest bat occurring in Arkansas. Its color ranges from yellowish brown to mahogany with silver tipped hairs giving it the hoary appearance. This species also roosts in trees. It is a noted migrator, being the only species of bat to have been reported from the Hawaiian Islands (Barbour and Davis, 1969). We have accumulated no new records of this species. It has been previously reported by Heath et al. (1983) from Polk, Montgomery and Saline counties. Gregg (1937) reported a specimen from Garland County and Dillinger and Black (1940) reported the species from Pulaski County. The Dept. of Health has received specimens from Pulaski and Saline counties.

Pipistrellus subflavus (F. Cuvier). The eastern pipistrelle is a small bat pale yellow to nearly black in color. It is normally found in caves although it occasionally has been found in buildings and foliage (Barbour and Davis, 1969). Previous to this study, the eastern pipistrelle had been only reported from two counties of southwestern Arkansas: from a mine in Garland County (Sealander and Young, 1955) and from Ouachita County (Sealander, 1956). We have collected this species from

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ten counties in the study area, eight of which represent new records: Calhoun, Howard, Miller, Nevada, Ouachita, Pike, Pulaski, and Saline.

Lasionycteris noctivagans (Le Conte). The silver-haired bat, is a medium to large bat and is named for its fur which is normally dark with many silver tipped hairs. This is a solitary bat which prefers to roost in tree cavities, buildings, and rock crevices. Heath et al. (1983) reported the previous records of this species from Southwestern Arkansas: Polk and Pulaski counties. We have collected silver-haired bat from five additional counties of Southwestern Arkansas: Columbia, Howard, Little River, Saline and Sevier.

Myotis keenii (Merriam). Keen's myotis is one of the smaller bats found in Arkansas. It is brown in color and has relatively large ears. It normally roosts in tree cavities or rock crevices. This species was reported from Garland County by Sealander and Young (1955) and from Pike County by Miller and Allen (1928). We have collected additional specimens from Garland and Polk counties.

Myotis austroriparius (Rhoads). The southeastern myotis is larger than *M. keenii* and is russet to gray in color. This colonial bat can be found in small groups in caves, tunnels, buildings, and hollow trees. This bat resists entering deep hibernation and usually remains semi-active year-round (Barbour and Davis, 1969). Previously, Davis et al. (1955) had recorded this bat from Garland County only in Southwestern Arkansas. We have recorded this species from Columbia, Little River, and Pike counties as well.

Myotis lucifugus (LeConte). The little brown bat is medium sized with sleek glossy fur. It ranges from pale tan to dark brown in color. Like *M. austroriparius*, this species is colonial and is usually found in caves, buildings, and other sheltered locations (Barbour and Davis, 1969). The little brown bat has been reported from Garland County only in Southwestern Arkansas (Sealander, 1956).

Plecotus rafinesquii Lesson. The Eastern big-eared bat, named because of its noticeable large ears, is a medium sized bat usually grayish in color. Its nose is adorned by two large lumps on the dorsolateral surface. Big-eared bats can be found roosting singularly or in small groups in caves, buildings, and occasionally in hollow trees. The species is extremely alert to disturbance and is usually aware of an intruder well before the bat is within reach (Barbour and Davis, 1969).

Sealander (1979) reported records of big-eared bats from Miller and Sevier counties in Southwestern Arkansas. We have specimens from nine additional counties: Calhoun, Columbia, Dallas, Grant, Lafayette, Little River, Nevada, Ouachita, and Union.

Tadarida brasiliensis (I. Geoff. St-Hilaire). The Brazilian free-tailed bat is the only species of the family Molossidae found in Arkansas. As the name implies, the tail of this species is not enclosed within the uropatagium. *T. brasiliensis* is a medium sized bat and is dark brown to gray in color. This species is highly colonial and is found in large clusters in buildings and caves. It has been found occasionally within the foliage of trees. Barbour and Davis (1969).

Sealander and Price (1964) reported this species from Pulaski County. Saugey et al. (1983) provided an additional record of free-tailed bats

from Garland County. We have records of this species from eight counties of Southwest Arkansas, of which seven are new county records. The eight counties include Clark, Garland, Howard, Lafayette, Little River, Miller, Ouachita, and Sevier.

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UNIVERSITY OF ARKANSAS AT MONTICELLO'S 1985 SUMMER SCIENCE INSTITUTE: A REPORT AND AN OPINION

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ABSTRACT

The University of Arkansas at Monticello's 1985 Summer Science Institute was created to improve competence in science among on-the-job upper elementary school teachers (grades 4-6) in southeast Arkansas. Students received three weeks of solid introductory coursework in botany, chemistry, and geology. However, deficiencies in public school science education are extensive and deeply rooted and will not be seriously addressed by anything less than radical changes in teacher training and certification policies.

INTRODUCTION

The Teacher Education Improvement Consortium was organized and funded in 1984 by the Arkansas Department of Higher Education to address the problem of declining student achievement in science at the elementary and secondary levels. Three goals were identified:

- 1) to improve the scientific and mathematical competence of existing teachers, K-12;
- 2) to improve the professional attitudes and esprit de corps of existing teachers, K-12; and
- 3) to identify model teaching techniques from the institutes and in-services (see below) and disseminate that information.

The Consortium's action took the form of four Summer Science Institutes located on the four University of Arkansas campuses. The Institutes offered education in the sciences to elementary and secondary teachers, who in turn were to pass along what they had learned both to their students, and, later, to their colleagues in a series of "in-service peer-teaching" workshops.

In its analysis of science education at the secondary level, the Teacher Education Improvement Consortium (Goal Statement, unpublished document, distributed by TEIC, 1984) attributed declining student achievement, in part, to an excess of academic democracy:

Secondary school curricula have become homogenized, diluted and diffuse. With extensive student choice, students do not opt for the more rigorous classes in science and mathematics.

The problem of course begins in the lower grades (if not at home). A National Science Foundation study, published in 1978 (The Status of Pre-College Science, Mathematics, and Social Studies Educational Practices in U.S. Schools: an Overview and Summaries of Three Studies, Washington, D.C.: U.S. Government Printing Office), gave the following dire description of elementary science education in America:

Although we found a few elementary teachers with a strong interest and understanding of science, the number was insufficient to suggest that even half the nation's youngsters would have a single elementary school year in which their teacher could give science a substantial share of the curriculum and do a good job of teaching it.

And most recently, a study by the Southern Regional Education Board's Commission for Educational Quality (Improving Teacher Education: an Agenda for Higher Education and the Schools, SREB: Atlanta, 1985) placed the responsibility for inadequate teaching, in part,

on teacher education programs. That report bears the general message: more content, less pedagogy.

Elementary teachers should be broadly educated across all of the major academic divisions...They need breadth in their academic preparation. If they are to develop as scholars, they also need to delve into some academic subjects more deeply than they are likely to do if they limit themselves mostly to introductory courses.

That the inadequate teacher salaries offered by a tight-fisted and skeptical to simply apathetic public might be the principal cause of the disease and the unsatisfactory performance of many students, teachers, and teacher educators merely symptoms is too large an issue to take up here.

THE UAM SUMMER SCIENCE INSTITUTE

Faculty from UAM and the regional public schools, as well as representatives from the Southeast Arkansas Educational Cooperative, meeting as a Local Advisory Committee, chose to concentrate efforts on science teaching at the upper elementary level. In UAM's Summer Science Institute, 23 fourth through sixth grade teachers were given three weeks of introductory science coursework by three UAM faculty in their areas of expertise: biology (mostly botany), chemistry, and earth science or geology. Each subject received a week's treatment. Students attended lecture-laboratory sessions 6 hours a day, 5 days a week. During the academic year subsequent to the Summer Institute, each teacher was to present two "in-service" workshops to his or her colleagues at the local schools.

One of the most attractive features of the Science Institute grant was its generous budget. Local school teachers were recognized as professionals and received an honorarium of 500 dollars each. Additional funds permitted the purchase and distribution of supplies and lab materials. Teachers returned to their classrooms with books on the trees and wildflowers of Arkansas, mounted specimens of native trees, rocks, and minerals, and an assortment of common chemicals and chemistry glassware and small lab equipment. Several travelling chemistry boxes were stocked with pH meters, small electronic balances, and battery chargers, to be circulated among interested area science teachers by the Southeast Arkansas Educational Cooperative.

A syllabus summarizing science content of the UAM phase of the Institute is given below:

BIOLOGY/BOTANY:

Day 1: Scientific method; aims and methods of taxonomy; artificial and natural classification systems; construction of dichotomous keys.

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- Day 2: Observation, description, and drawing of flowering plant vegetative parts; identification of local trees; setting up a lab practical examination.
- Day 3: Observation, drawing, and description of flowering plant reproductive parts (flowers); pollination biology; wildflower identification.
- Day 4: Wildflower identification (continued) and specimen preparation; structure and dispersal of fruits and seeds; seed germination.
- Day 5: Flora and vegetation; habitats, plant communities and biomes; field trip to Warren Prairie, a unique saline soil prairie in southeast Arkansas.

CHEMISTRY:

- Day 1: Elements, simple substances, and their properties.
- Day 2: Chemical reactions.
- Day 3: Acids and bases.
- Day 4: Solutions and electrolytes.
- Day 5: Gases, polymers, crystals; miscellaneous topics.

EARTH SCIENCE:

- Day 1: Earth materials; properties of minerals.
- Day 2: Rock cycles—igneous and metamorphic rocks.
- Day 3: Sedimentary rocks.
- Day 4: Fossilization and fossils.
- Day 5: Field trip to Hot Springs area to collect minerals, rocks and fossils.

Teachers stuck closely to this schedule, and students received a solid introduction to the three disciplines.

CONCLUSIONS

Based on observations of in-service peer-teaching workshops, Institute faculty have concluded that one week is insufficient to provide the student with a core of knowledge from which to draw upon in the creation of educational science activities. The majority of in-service lessons observed has been superficial and, occasionally, misinformed. Upper elementary teachers and their students would have been better served by a concentrated three week course in a single scientific discipline.

Even more appropriate, I believe, would have been a more or less standard undergraduate introductory lab science course, perhaps modified for the upper elementary teaching major and open to post-baccalaureate teachers as well. I will repeat here an assertion from the Teacher Education Improvement Consortium's Goal Statement: "With extensive student choice, (high school) students do not opt for the more rigorous classes in science and mathematics." If we would have high school students take three rigorous science courses, why should we not demand the same of college students preparing for careers in upper elementary teaching? On the job, in grades 4-6, they will teach science from 3 to 5 days a week, unless they make a deliberate effort to avoid the subject.

It appears to me that we must equip at least upper elementary teachers with some degree of expertise in science. Whether we would have elementary science specialists or simply elementary teachers with a solid background in the sciences, the most straightforward way to have either on a permanent basis in our public schools would be to bring certain education students into the mainstream of undergraduate science preparation. The Southern Regional Education Board (1985) calls for elementary education students "to take some courses in academic disciplines at the upper level. Completion of an academic major is another way in which some elementary teachers, especially those who will teach older children, might obtain more depth in the undergraduate subject matter preparation."

One such academic program would be a 36 credit hour major in General Science with only a minor in Elementary Education. As elementary school science teachers, graduates would be comfortable enough with the processes of science to emphasize method rather than content alone, and knowledgeable and flexible enough to supplement the textbook with personal observations and local materials.

Although professional scientists might debate the proportions of biology, chemistry, geology, and physics in such a General Science major, I would suspect the proposal, in general, to meet with their approval. Why is there, then, no such emphasis on science content in elementary teacher training programs? Among several possible answers to a complex question, I would emphasize one: elementary teachers are certified to teach kindergarten through sixth grade, or first through sixth grade, or reading, or special education. No distinction is made between math and science and the language arts nor even between upper and lower elementary. Thus a teacher who has taken one 3-hour lecture course in biology, a physical science for elementary teachers course, and one or two other non-lab, general science classes to fulfill General Education requirements is considered qualified to teach science not only to four and five year old children but to twelve year olds as well. In this regard, the seven years of astounding intellectual growth, undergone by a child between kindergarten and sixth grade, is not reflected in elementary teacher education programs nor in certification procedures. Obviously, such ill-prepared and, in certain instances, disinterested elementary teachers can as easily stifle scientific curiosity as foster it.

State laws govern the certification of teachers. They are enacted by the Arkansas General Assembly and enforced by the Arkansas State Department of Education. They derive largely from the recommendations of public school and college teachers and administrators. I would strongly recommend consideration of the implementation of a single teaching certificate in upper elementary and junior high science and math.

I in no way wish to belittle the accomplishments of the UAM Summer Science Institute when I suggest that post-baccalaureate science training for upper elementary teachers be modeled after the science program here proposed for undergraduates. To teach good science, most teachers need to be exposed to the standard science coursework of the college curriculum. Three week mini-courses and science institutes may be politically desirable at certain times, but they carry serious drawbacks: they are administrative headaches; they are often sinecures in which the grading scale starts at B; and they are academically second best to real laboratory science courses.

THE RIVER OTTER IN ARKANSAS. IV. WINTER FOOD HABITS IN EASTERN ARKANSAS

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ABSTRACT

Stomachs and intestines of 89 river otters (*Lutra canadensis*) collected in eastern Arkansas during the trapping seasons (December-January) of 1978-1983 were examined for food remains. Fish (primarily centrarchids, catostomids, and clupeids) dominated the diet (71.2%). The next most abundant prey was crayfish (18.3% of the diet). Other foods included gray squirrel (*Sciurus carolinensis*), wood duck (*Aix sponsa*), snakes (*Thamnophis proximus*), frogs (Ranidae and Hylidae), and beetles (Coleoptera).

INTRODUCTION

Most studies examining food habits of river otters (*Lutra canadensis*) have been conducted in the northern or western regions of the United States (Greer, 1955; Grenfell, 1978; Hamilton, 1961; Knudsen and Hale, 1968; Lagler and Ostenson, 1942; Melquist and Hornocker, 1983; Ryder, 1955; Sheldon and Toll, 1964; Towell, 1974). In the southeastern United States, river otter food habits have been studied in Alabama and Georgia (Lauhachinda and Hill, 1977) and North Carolina (Wilson, 1959). Our study was undertaken to extend this coverage to the lower Mississippi River Region, specifically eastern Arkansas.

METHODS

Stomachs and intestines were removed from the carcasses of 89 river otters collected from furbuyers in eastern Arkansas during the regular December-January trapping seasons of 1978 through 1983. Contents of stomachs and intestines were placed in a small-meshed sieve and washed to locate and clean diagnostic prey remains. Stomachs and intestines were examined separately. Food remains that could not be readily identified were dried and stored for later analysis. Fish remains were usually identified to genus or species using scale characteristics (Sheldon and Toll, 1964). Scale samples from museum specimens were used as reference material.

For each otter, the minimum number of individuals per prey taxon was estimated from conservative interpretation of prey fragments. When a food item occurred in both the stomach and intestine, it was counted only once unless it could be determined that two individuals of the prey taxon indeed were present. Frequency of occurrence (%) was calculated by dividing the total number of individuals of a taxon by the total number of individuals in all prey taxa.

RESULTS AND DISCUSSION

Forty-three of the specimens contained no prey remains, but a total of 104 prey remains were recovered from the remaining 46 otters. Conservative interpretation of prey remains usually allowed only documentation of the presence of food items, but a few taxa were recorded more than once in some otters. The primary food type was fishes, which constituted 71% of the foods recovered, and was represented by nine families and at least 12 genera (Table 1). The dominant families were Centrarchidae, Catostomidae, and Clupeidae. Centrarchids were primarily sunfishes (*Lepomis* sp.). *Lepomis* occurred 13 times in 11 ot-

Table 1. Food items found in 89 river otters from eastern Arkansas, 1978-1983.

Prey	No. of occurrences	Frequency (%)
Pisces	74	71.2
Centrarchidae	17	16.3
<i>Lepomis</i>	13	12.5
<i>Micropterus</i>	2	1.9
<i>Pomoxis</i>	2	1.9
Catostomidae	13	12.5
<i>Moxostoma</i>	13	12.5
Cyprinidae	4	3.8
<i>Cyprinus carpio</i>	3	2.9
<i>Notemigonus chryssoleucus</i>	1	1.0
Amiidae	2	1.9
<i>Amia calva</i>	2	1.9
Clupeidae	10	9.6
<i>Dorosoma cepedianum</i>	10	9.6
Ictaluridae	5	4.8
<i>Ictalurus</i>	5	4.8
Cyprinodontidae	1	1.0
<i>Fundulus</i>	1	1.0
Poeciliidae	14	13.5
<i>Gambusia affinis</i>	14	13.5
Sciænidæ	1	1.0
<i>Aplocheilichthys grunniens</i>	1	1.0
Unidentified fish	7	6.7
Decapoda	19	18.3
Astacidae	19	18.3
Amphibia	3	2.9
Ranidae	2	1.9
<i>Rana</i>	2	1.9
Hylidae	1	1.0
<i>Hyla cinerea</i>	1	1.0
Reptilia	2	1.9
Colubridae	2	1.9
<i>Thamnophis proximus</i>	2	1.9
Aves	2	1.9
Anatidae	2	1.9
<i>Aix sponsa</i>	2	1.9
Coleoptera	2	1.9
Scarabaeidae	1	1.0
Hydrophilidae	1	1.0
Mammalia	1	1.0
Sciuridae	1	1.0
<i>Sciurus carolinensis</i>	1	1.0
Mollusca	1	1.0

ters. Seven otters contained a minimum of 10 clupeids. The large size of scales indicated that the clupeids were all gizzard shad (*Dorosoma cepedianum*). Size of remains also indicated that most of the catostomids and ictalurids were between 200-500 mm total length. Mosquitofish (*Gambusia affinis*) occurred 14 times, but all were in the stomach of one specimen so these small fishes were not considered to be important food items.

Sheldon and Toll (1964) believed that the availability of fishes to otters was affected by the abundance and agility of fish, the habitat of

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the fish species, time of day the otters fed, fish spawning periods, effects of ice in winter, and fishing methods of otters. Ryder (1955) noted that the fishes preyed upon by otters were taken in proportion to their abundance but in inverse proportion to the swimming ability of the fish. The dominance of fishes in the winter diet of eastern Arkansas otters may be partially due to retarded escape capabilities of fishes during cold weather. Centrarchids and catostomids have been identified as important or dominant prey in several other studies (Hamilton, 1961; Lagler and Ostenson, 1942; Lauhachinda and Hill, 1977; Sheldon and Toll, 1964; Wilson, 1959). Centrarchids are presumably preyed upon because they occupy relatively shallow and often muddy waters or weedy areas that may be of logistic advantage to otters (Sheldon and Toll, 1964). The habitats available to otters in the Mississippi Alluvial Plain of eastern Arkansas amply provide such habitat for these forage taxa.

Crayfishes (Astacidae) were important prey items, constituting about 18% of the items recovered. Ten otters contained crayfishes, and a minimum of 19 crayfishes were present in these specimens. Crayfishes were also important food items in Michigan (Lagler and Ostenson, 1942), Oregon (Toweill, 1974), and Alabama and Georgia (Lauhachinda and Hill, 1977). Most of the crayfish remains were found in the intestine. Other researchers have noted this in mustelids, and Sealander (1943) suggested that hard indigestible materials are passed quickly from the stomach in mink (*Mustela vison*). An abundance of water in eastern Arkansas during winter and spring make crayfish most available to otters in these seasons. During summer, when backwaters recede and crayfish return to their burrow systems, the occurrence of crayfish in otter diets likely declines.

Five percent of the food items were reptiles and amphibians (Table 1). Lauhachinda and Hill (1977) noted these foods in 5.4% of their sample of digestive tracts of otters from Alabama and Georgia. Because these organisms usually overwinter underground, we suspect that the frequency of occurrence of this class of prey increases during spring and summer. Both of the ribbon snakes (*Thamnophis proximus*) were recovered from one otter collected in Jackson County.

Only two birds, both wood ducks (*Aix sponsa*), were found in otters during our study. Birds are common in otter food habits studies (Greer, 1955; Knudsen and Hale, 1968; Lagler and Ostenson, 1942; Lauhachinda and Hill, 1977; Sheldon and Toll, 1964; Wilson, 1954) but they are not major prey taxa. However, Grenfell's (1978) study in the Suisun Marsh of central California indicated waterfowl were a major food. He suggested that predation on waterfowl was due to their abundance while using the marsh as a wintering ground in the Pacific Flyway. Concentrations of Mississippi Flyway waterfowl in eastern Arkansas may provide a similar opportunity for river otters. Mr. Wayne Bullard of Bullard Fur Company, Newport, Arkansas, told us of an otter he bought from a duck hunter who lost 2-3 mallards (*Anas platyrhynchos*) to otters. The otters swam from a hollow cypress (*Taxodium distichum*) and retrieved each of the ducks the hunter had shot, before the hunter finally shot one of the otters. Otters in the Mississippi Flyway probably use waterfowl in proportion to their local abundance during winter. Hunting activities (e.g., lost kills and cripples) may increase the availability of waterfowl.

Only one mammal, a gray squirrel (*Sciurus carolinensis*), was found in the sample. The entire squirrel was packed into the stomach of one otter. Similarly, mammals are not important food items of otters in other studies. Mammals identified previously as otter food include snowshoe hare, *Lepus americanus*, (Lagler and Ostenson, 1942) and muskrats, *Ondatra zibethicus*, (Lauhachinda and Hill, 1977; Wilson, 1954).

A few beetles were identified but apparently are not important foods due to infrequent occurrence and small size. Lagler and Ostenson (1942) and Lauhachinda and Hill (1977) believed arthropods were ingested accidentally, but Greer (1955), Hamilton (1961), and Knudsen and Hale (1968) believed insects were taken intentionally.

One mussel was identified from shell fragments in our study. Morejohn (1969) matched otter denitions with holes in mussel shells and suggested that otters fed on mussels. Molluscs have been reported (Lauhachinda and Hill, 1977; Sheldon and Toll, 1964; Toweill, 1974;

Wilson, 1954) but most of these were snails (Gastropoda). Because few hard remains would be present if an otter opened a mussel and ate the soft organism within, actual mussel consumption may be under-represented in our study. Mr. Wayne Bullard, of Bullard Fur Company of Newport, noted that otters pulled mussels out of a Jackson County creek to feed on them. The broken shells were reportedly left on the bank.

CONCLUSIONS

The winter diet of river otters in eastern Arkansas consists mostly of fish and is similar to the diet reported for other areas of the southeastern United States. Our sample is limited to the winter season and we have no quantitative assessment of the frequency of prey taxa in the otter's habitat. Still, our data support the view purported by others that river otters are opportunistic foragers, feeding on prey in direct proportion to their availability. Accurate assessment of foods eaten is difficult due to differing detectability of remains (e.g., mussels) and a lack of remains in several gastrointestinal tracts.

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HARVEST TRENDS OF THE BOBCAT (*FELIS RUFUS*) IN ARKANSAS

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ABSTRACT

Arkansas bobcat fur harvest records were examined in relation to forest cover, furbuyer distribution, and price. Availability of forest cover correlated with areas of greatest harvest, and a dynamic forest products industry in southern Arkansas is believed to support a greater density, and therefore greater harvest, of bobcats. Comparison of furbuyer distribution with harvest level among physiographic regions suggested that the fur industry in southern Arkansas could expand. Prices increased dramatically in the 1970's, and 94.5% of the variation in harvest level could be explained by price.

INTRODUCTION

The bobcat, *Felis rufus* (Schreber), is the most widely distributed felid in North America (Young, 1958; Cowan, 1971). This secretive mammal is seldom seen, and accurate assessments of its population have been difficult due to the expense of reliable field and laboratory studies. Attempts to assess status through fur harvest records are complicated by the effects of climatic changes, price fluctuations, varying harvest pressures, changes in trapping regulations, and accuracy of fur harvest reports from buyers.

As recently as the early 1970's, bobcats in Arkansas were trapped primarily for predator control (Jenkins, 1971; Fritts, 1973). The value of bobcat pelts during the 1960's and the early 1970's averaged less than \$3.25, but by 1978 the value averaged \$75.00 and the bobcat had been given furbearer status. This study is the initial phase of a comprehensive study of the biology of the bobcat in Arkansas.

MATERIALS AND METHODS

We analyzed 21 years (1959-1980) of bobcat fur harvest records compiled by the Arkansas Game and Fish Commission (AGFC). The accuracy of these records was questionable: buyers might report county of sale rather than county of provenance. If buyers consistently did this, a significant correlation between by-county harvest and number of furbuyers in counties of apparently high harvest should be evident. Turlison et al. (1981) examined harvest records for river otters (*Lutra canadensis*) and believed that they were sufficiently accurate to allow regional analyses of harvest. Because harvests of both otters and bobcats must be entered in a log book separate from other Arkansas furbearers, we felt that bobcat harvest records were equally accurate as those of otters.

The AGFC used the four major physiographic regions of Arkansas (Gulf Coastal Plain, Ozark Mountains, Ouachita Mountains, and Mississippi Alluvial Plain or Delta) to group bobcat harvest records. Some physiographic bias exists because the county boundaries of Holder (1951) were used to demarcate regions. Foti (1974, 1976) has shown that two or more regions may occur in certain counties. Still, the effect of this overlap is probably negligible when considering the status of regional or statewide populations.

Harvest records were used to test the hypothesis that, in response to habitat, more bobcats occur (and therefore are harvested) from specific regions. Bobcats prefer habitats with secondary succession, logged forests, or swampland areas with appreciable ecotone or rug-

gedness (Rollings, 1945; Pollack, 1951; Young, 1958; McCord, 1974; Berg, 1979; Miller and Speake, 1979), rather than cleared blocks. Regional harvests were compared to the amount of forested land remaining in each of the regions, as determined from a map of forested lands in Arkansas (Foti, 1976).

By-county harvest records were available for the seasons of 1977-78 through 1980-81. Assuming an even trapping pressure throughout the state, relative population densities might be estimated by locating areas of consistently high and low bobcat harvests. To facilitate comparisons between years with fluctuating harvest levels, all harvests were adjusted to represent 1000 animals and proportioned among the counties. Additionally, regional harvests were graphed in an attempt to discern trends in relative importance of regions as bobcat pelt producers.

It is unlikely that harvest pressure is even, but it could be argued that an index of relative trapping pressure (or population density) is linked to the number of furbuyers operating within an area; i.e., an equilibrium is attained between the resource (and its renewability) and the utilization of the resource. An area providing a large fur resource would probably support more buyers than an area of more limited resources. The mean furbuyer populace among regions was compared to elucidate this possible relationship.

Harvests are mainly indicative of market trends and, to a lesser extent, of species availability (Erickson and Sampson, 1978; Sampson, 1980). Bobcat harvests were minimal during most of the harvest seasons considered, due likely to low prices offered for pelts during pre-1976 seasons. Price was believed to have had a major influence on the dramatic harvest increase, and this assertion was tested by a linear regression analysis. Price was treated on a dollar for dollar annual basis because Erickson and Sampson (1978) found trapping effort to be more closely tied to observed market prices than fur prices adjusted for inflation.

RESULTS AND DISCUSSION

The acreage of forested lands in Arkansas has decreased rapidly in recent years, especially in the Mississippi Alluvial Plain (Holder, 1969). Planimeter measurements of relative forested acreages between regions indicated that 26% of the Mississippi Alluvial Plain was forested, in contrast to 57%, 66%, and 72% in the Gulf Coastal Plain, Ouachitas, and Ozarks, respectively.

Turlison (1983) presented maps of by-county bobcat harvests for trapping seasons 1977-78 through 1980-81. A map of the averages for the four years (Fig. 1) gives the most likely view of the harvest levels to be expected from a given county. Some counties fluctuated in reported

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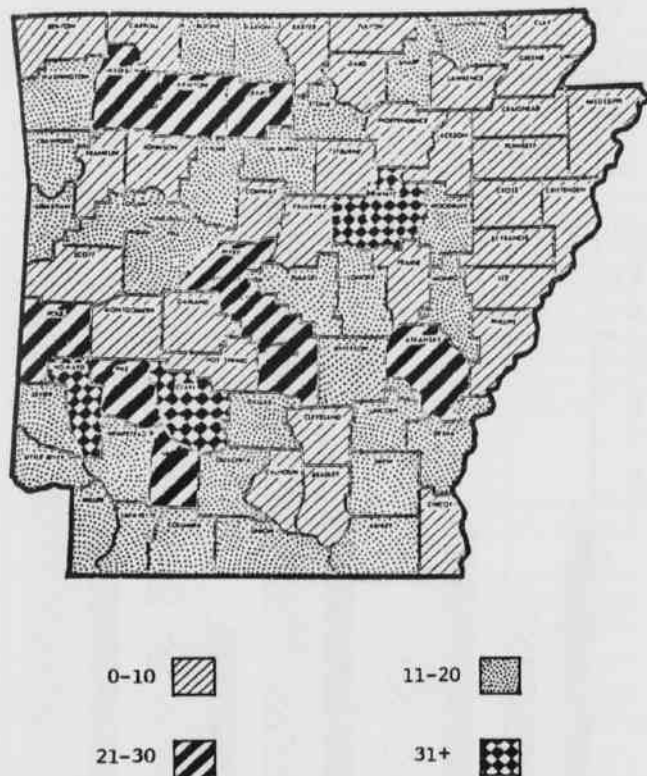


Figure 1. Mean bobcat harvests for trapping seasons 1977-78 through 1980-81. Reported harvest was adjusted to represent 1000 specimens and proportioned among counties.

harvest levels over the four-year period while others were stable. The Mississippi Alluvial Plain is the least forested region of the state (Foti, 1976). Forests of this region primarily occur in the White River National Wildlife Refuge and as narrow strips along portions of some rivers. Relatively few bobcats are harvested from that region (Fig. 1). Generally, regions of heaviest harvest in the Delta are from counties with the most forested habitat, specifically Desha, Arkansas, Lonoke, and Jefferson counties. An entire block of northeast Arkansas counties provides minimal bobcat harvests, probably due to habitat losses. Siegler (1971) believed that reforestation had promoted re-establishment of bobcats in parts of New England. Similarly, reforestation might be required to increase bobcat populations in the Mississippi Alluvial Plain of Arkansas.

The Gulf Coastal Plain and Ouachita Mountain regions of southwestern Arkansas support a large timber industry. Polk, Pike, Howard, Clark, and Nevada counties of these two regions consistently have the greatest bobcat harvest levels, are contiguous, have no geographic barriers to movement, and are located along the border between the regions. Assuming that harvest reports are reasonably indicative of bobcat population densities, this area provides optimal habitat for bobcats. Hall (1973) found areas of heavy undergrowth were important rest areas for Louisiana bobcats, and Miller and Speake (1979) believed that Alabama bobcats benefited from habitat modification created by logging and prescribed burning. Guenther (1980) found significant use of closed canopy habitats as mid-day refugia in Florida. In Missouri, Hamilton (1982) believed bobcats used brushy fields for their high density of prey, oak (*Quercus* sp.) regeneration areas for cover and hunting, and pine (*Pinus* sp.) regeneration areas for diurnal retreats in winter. Jenkins et al. (1979) reported that bobcats were common around well distributed clear-cut timber harvest areas. In the Gulf Coastal Plain and Ouachita Mountain regions of Arkansas, silvicultural practices have been used extensively by several forest resource industries. Although some pine plantations exist, much of the forested lands in

these regions is composed of a pine-hardwood mix (Foti, 1976). Pine and oak regeneration areas are common, and thickets of early successional undergrowth are numerous. Because previous habitat use studies consistently indicate that such habitats are preferred by bobcats, the consistently high harvests reported from these areas may be a function of relatively high bobcat density.

The Ozark Mountains normally provide an appreciable bobcat harvest, with a harvest nucleus in Madison, Newton, and Searcy counties. Although the Ozarks contain the largest relative acreage of forests in Arkansas, the lack of a dynamic wood products industry creating continual disturbance and regeneration probably results in a lower density of bobcats. The area of greatest harvest contains much of the Buffalo River, noted for its rugged terrain, and includes a vegetational distinction in the presence of shortleaf pine (*Pinus echinata*). Most of the rest of the Ozark forests are in climax oak-hickory (*Carya* sp.) (Foti, 1976). Berg (1979) found that bobcats used coniferous cover disproportionately to its relative abundance in Minnesota and McCord (1974) found that hardwoods were selected against as winter habitat in Massachusetts, possibly due to excessive cooling as compared to coniferous habitats. Hamilton (1982) found bobcats in the Missouri Ozarks increased their use of bluffs during winter, and suggested hardwoods might be selected against during winter because of increased energy demands of travelling in deep snow, increased wind, high radiation losses, and lower nighttime temperatures in such cover. Perhaps these factors also explain the distribution of the bobcat in the Arkansas Ozarks.

Figure 2 shows harvests by region for the years preceding the dramatic price increase, and Fig. 3 shows harvests subsequent to them. Through most of the 1960's and much of the 1970's, the primary source of bobcat pelts was the Ozark Mountains. Many people in the Ozarks own small farms with limited numbers of domestic animals. Real or feared depredation on domestic animals by bobcats often led to predator control efforts, and pelts from some of these specimens probably made it to the fur market in the Ozarks. Livestock depredation was likely less important in the Delta where loss of habitat reduced bobcat populations. Further, the value of a pelt during those years rendered bobcat trapping uneconomical, and specimens were regarded as trophies rather than sources of income. Therefore, early trapping records for bobcats are especially poor indicators of density.

As pelt prices became more attractive in the mid-1970's, harvests in all regions increased rapidly (Fig. 2). Regional harvests remained relatively proportional until the 1976-77 season (Fig. 3), when the Ozarks had an increase of almost 4X the harvest of the previous season (approximately 1000 specimen increase). The great increase in take from the Ozarks probably reflects a tremendous increase in trapping pressure due to pelt price. Mean pelt price increased from \$36.60 to \$52.81 between 1975-76 and 1976-77. Harvest records from the subsequent trapping seasons suggested a decline in the relative contribution of the Ozarks to Arkansas bobcat harvest. Whether this decline represents a true drop in the importance of the Ozarks due to over-exploitation or simply gains in the relative importance of other regions is unclear. However, it seems plausible that the uncharacteristically heavy harvest in the Ozarks in 1976-77 reduced populations and affected subsequent harvests through reduced density. By the 1979-80 season, the Ozarks again led in bobcat pelt production. Whether this means the population had recovered or that the other regions had been equally affected by increased pressure remains for speculation.

The average number of furbuyers during the five seasons from 1976-77 through 1980-81 indicated more buyers in the Delta (69) and Ozarks (63) than in the Ouachitas (35) and Gulf Coastal Plain (27). During the same period, the mean number of furbearer pelts harvested was 44,329 for the Gulf Coastal Plain, 48,340 for the Ouachitas, 72,858 for the Ozarks, and 111,253 for the Delta. Assuming the number of furbuyers operating in an area indicates the capacity of the fur resource to support them, it appears that the Delta and Ozarks provide the greater resource. The mean number of pelts per buyer was estimated from these figures and it was assumed that the minimum value represented the minimum pelt production under which a buyer could gainfully operate. However, further analysis required that the nature of the harvest be the same among regions, which was not true. Harvest figures in the

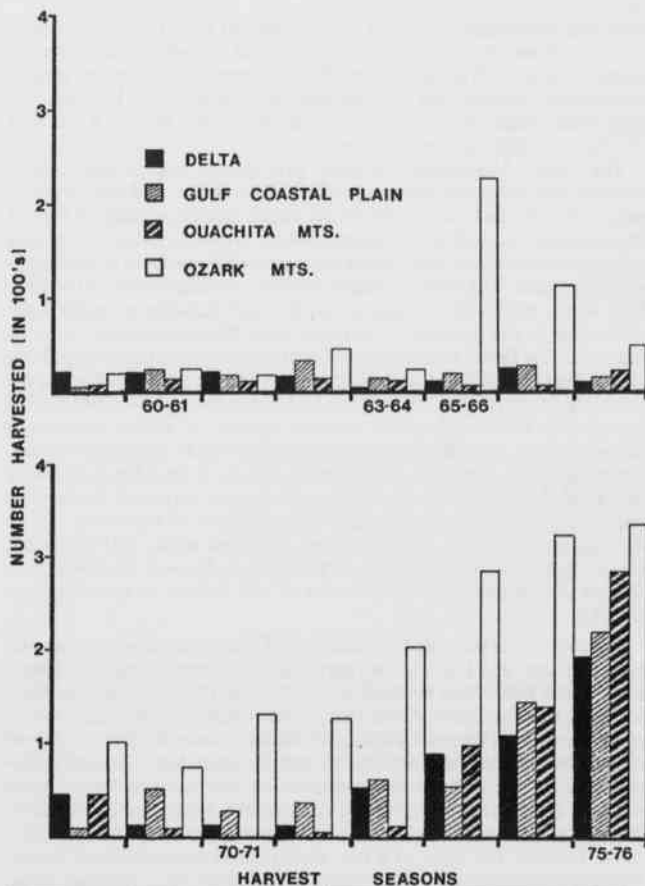
Harvest Trends of the Bobcat (*Felis rufus*) in Arkansas

Figure 2. Regional bobcat harvests in Arkansas, 1959-60 through 1975-76.

Delta were biased upwards by disproportionate occurrence of mink (*Mustela vison*) and muskrat (*Ondatra zibethicus*). Furs of greater value are more commonly bought in non-deltaic regions — specifically bobcat and gray fox (*Urocyon cinereoargenteus*). Although more animals are harvested in the Delta, the species composition and average pelt value is different, making the Delta unsuitable as a base for comparison with other regions. The Ozarks support one of the largest buyer populations and have the second largest harvest, and buyers in the Ozarks average the lowest number of pelts among regions. Further, the Ozarks are similar to the Ouachitas and Gulf Coastal Plain in average pelt value and species composition of the harvest. The Ozarks, then, best meet requirements for the minimum conditions for buyer operation, and can be used as a base for comparison.

If business in the Ozarks is profitable and the resource is not over-exploited, the Ouachitas and Gulf Coastal Plain can withstand additional trapping pressure, assuming the fur resource is equally available among these regions. Comparison of age structures of bobcats from these regions supports this opinion (Turnlison, 1983). If this is true, bobcat density in the Ouachitas and Coastal Plain may be under-represented by harvest figures. The low number of buyers in the Coastal Plain and Ouachitas likely do not indicate that the fur resource is limited. Rather, the lack of buyers in many counties of these regions may tend to decrease trapping pressure due to the distance prospective trappers must travel to sell their catch. Further, several buyers from the southern Ouachitas and western Gulf Coastal Plain make weekly circuits to buy fur in the middle and eastern Gulf Coastal Plain. This suggests that there is room for an expanded trapping industry in southern Arkansas, and that densities of bobcats in the Ozarks as inferred from harvest records are not comparable to those inferred from harvest records from southern Arkansas.

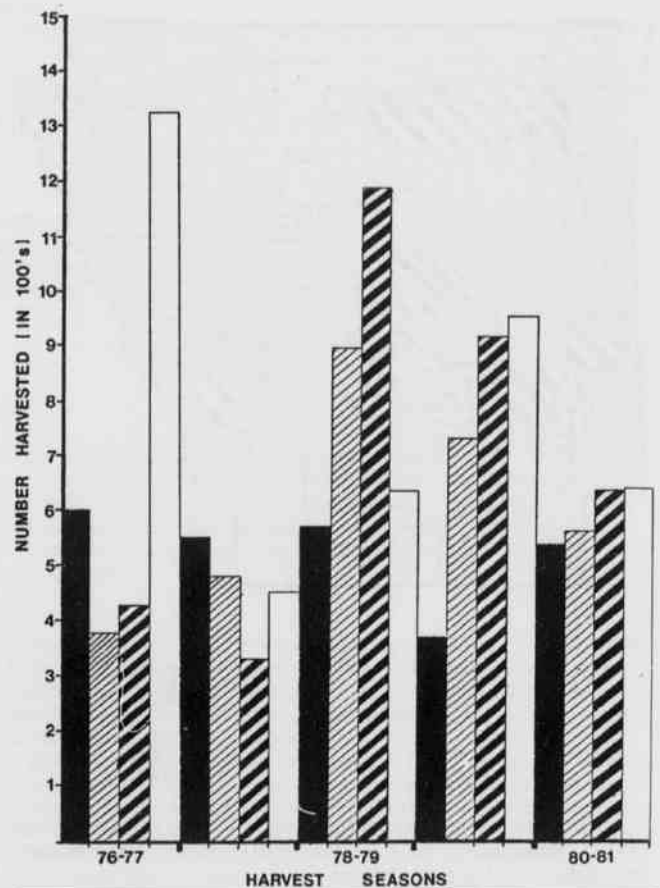


Figure 3. Regional bobcat harvests in Arkansas, 1976-77 through 1980-81. Legend as in Figure 2.

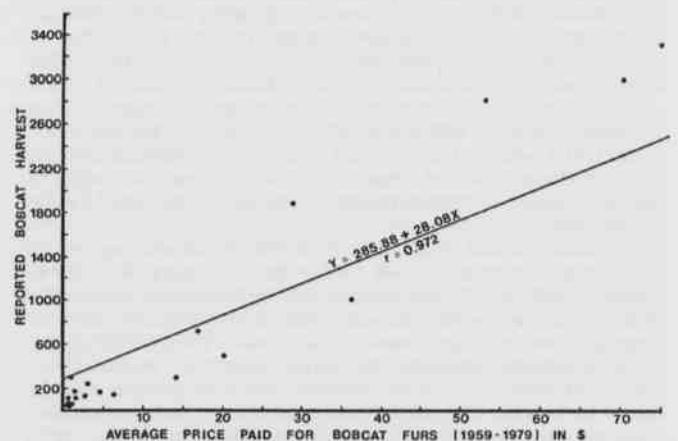


Figure 4. A regression of price on harvest levels of Arkansas bobcats for seasons 1959-60 through 1979-80.

Ford (1971) first expressed the opinion that bans on trade in certain endangered spotted cats would have an effect on the use of bobcat fur. The effect was increased prices for pelts, with concomitant increases in harvest pressure. In Arkansas, the mean price of \$75 during the 1978-79 season resulted in the highest bobcat take (3278) in Arkansas history. Harvests declined during the next two years, partially in response to lower prices which were brought about by court battles over export

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of bobcat pelts; buyers were afraid they could not export the pelts so were less willing to buy them, and trappers reduced their efforts to catch bobcats. Therefore, the declining trend in harvests may not be attributed to population declines from over-harvest, but rather is due to extrinsic effects of politics.

Linear regression analysis of average pelt price and harvest level (Fig. 4) suggested an average of 28 more bobcats were taken for each dollar increment in pelt value. Harvest level was highly correlated with price ($r=0.972$), and the regression model explained 94.5% of the variation. Because so much variation is explained by the price model, it is difficult to see that much information on densities can be gained through analysis of harvest records. Statistically, only about 5.5% of the yearly harvest variation could be attributed to density. As has been shown earlier, there is little evidence in the data that supports the contention that population level or density is reflected in harvest figures. Still, harvest figures provide insight into population status and allow researchers and managers to direct their approach by identifying potential problems.

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COMPARISON OF THE SYMBIOTIC FAUNA OF THE FAMILY PLETHODONTIDAE IN THE OUACHITA MOUNTAINS OF WESTERN ARKANSAS

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ABSTRACT

During the spring of 1985, 101 salamanders representing six host species (29 *Plethodon ouachitae*, 25 *P. caddoensis*, 6 *P. fourchensis*, 23 *P. serratus*, 13 *Desmognathus brimleyorum*, and 5 *P. glutinosus glutinosus*) were collected from six localities in three counties in Arkansas (Polk, Scott, and Montgomery) and examined for symbionts. With the exception of *Hannemania dunni*, all symbionts recovered from the first five species listed constitute new host records, and the endoparasitic fauna in all species establish new locality records. Examinations revealed one or more species of parasites in 82% of the hosts. Eight species of symbionts (3 nematode, 1 trematode, 1 cestode, 1 protozoan, 1 arthropod, and 1 cystacanth acanthocephalon) were recovered. Conclusions are based on the three host species examined in the largest numbers. *Thelandros magnavulvularis* and *H. dunni* were the most commonly occurring parasites, found in five and four host species respectively. *Cepedietta michiganensis* was restricted to *P. ouachitae* and *Brachycoelium storeriae* to *P. caddoensis*. *Hannemania dunni* was absent in *P. serratus*.

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INTRODUCTION

In general, surveys of the parasitic fauna of Plethodontid salamanders have been isolated studies with small samplings of hosts. The most comprehensive survey was conducted in North Carolina by Rankin (1937). He examined 297 individuals of the genus *Desmognathus* and 32 specimens of the genus *Eurycea*. Rankin's study represents one of the most extensive surveys of the genus *Plethodon*; examinations included 74 *P. cinereus*, 119 *P. glutinosus*, 18 *P. metcalfi*, and 3 *P. yonahlossee*. Working in the Smoky Mountains, Powders (1967) collected 392 specimens of *P. glutinosus* and 988 of *P. jordani*. His examinations concentrated solely on two parasites, *Brachycoelium* and *Cepedietta michiganensis*. All of the diagnosed symbionts we recovered from *P. glutinosus glutinosus* have been reported in that host species by these authors. General surveys and ecological studies of Arkansas salamander parasites are limited. Saltarelli (1977) examined 100 individuals of the genus *Eurycea* in northwestern Arkansas. Rosen and Manis (1976) examined 259 amphibian hosts, but only 14 were plethodontid salamanders.

This study is intended to provide a description and comparison of the parasitic fauna of three species of woodland salamanders (Family Plethodontidae): *Plethodon ouachitae*, *P. serratus*, and *P. caddoensis*. Two other terrestrial species, *P. glutinosus glutinosus* and *P. fourchensis*, and one aquatic species, *Desmognathus brimleyorum*, were examined in insufficient numbers to generate reliable comparison data. However, the data for the three latter species constitute new documentation and suggest certain relationships between the hosts and their symbionts. Table 1 lists the hosts examined as well as their sex and age distribution.

Specimens were collected at six sites in three counties during April and May, 1985. These collection sites were located on the Rich, Caddo, and Fourche mountain ranges of the western Ouachitas. According to Conant, the ranges of five of the six salamander species examined are restricted to specific regions of the Ouachita Mountains. The range of *P. glutinosus* extends throughout most of the eastern half of the United States. *Plethodon ouachitae*, *P. caddoensis*, and *P. fourchensis* represent allopatric species, while the three remaining species are sympatric with each other and the allopatric species mentioned above. Specimens of *P. serratus* and *D. brimleyorum* were collected from the same localities as the three allopatric species.

Table 1. Number of hosts examined.

HOST	TOTAL	MALES	FEMALES	JUVENILES
<i>P. ouachitae</i> (P.O.)	29	13	16	0
<i>P. caddoensis</i> (P.C.)	25	8	17	0
<i>P. serratus</i> (P.S.)	23	9	12	2
<i>P. glutinosus glutinosus</i> (P.G.G.)	5	1	4	0
<i>P. fourchensis</i> (P.F.)	6	3	1	2
<i>D. brimleyorum</i> (D.B.)	13	5	6	2
NUMBER OF HOSTS EXAMINED	101	39	56	6

MATERIALS AND METHODS

All specimens were collected under flat rocks and logs except *D. brimleyorum*, which was found in mountain spring run-offs. Specimens were immediately transported to the laboratory in styrofoam chests containing moist leaves and snails. The salamanders were then stored in a refrigerator at 7°C to slow body metabolism and prevent shedding of intestinal parasites. Examinations were completed within 72 hours. Specimens were dispatched in a hot water bath and all internal organs (excluding gonads) were removed through a mid-ventral incision. The intestine was divided linearly and examined in three equal sections. The distribution of chiggers in the integument was mapped on host cards. All examinations were done using a binocular dissecting microscope.

Nematodes were fixed with hot Looss' solution prior to evaporation and temporary mounting in glycerine. Cestodes were straightened by placing them in tap (hypotonic) water in a refrigerator for 24 hours prior to fixing with AFA. They were subsequently stained with Semichon's acetocarmine. Trematodes were flattened under a cover slip and fixed by drawing AFA underneath using porous paper. They were then stained with alum cochineal. The immature acanthocephalon and the protozoa were fixed in AFA, stained with alum cochineal, and mounted whole. Some protozoa found in the gall bladder were fixed *in situ* and later sectioned, mounted, and stained using hematoxylin and eosin. Chiggers were excised and fixed in 70% ethanol and subsequently mounted in CMCP-9AB. With the exception of nematodes and chiggers, all parasites were mounted in Permount. Voucher specimens were prepared for the U.S. National Museum.

Douglas A. Winter, Wojciech M. Zawada, and Arthur A. Johnson

RESULTS AND DISCUSSION

One or more of eight species of symbionts were found to infect 83 (82%) of 101 salamanders of the family Plethodontidae. *Plethodon ouachitae* (100%), *D. brimleyorum* (100%), *P. caddoensis* (92%), and *P. fourchensis* (83%) were the most heavily parasitized hosts, while *P. serratus* (48%) and *P. glutinosus glutinosus* (40%) exhibited the lowest prevalence. The most striking difference in intensity was recorded for *H. dunni* in *P. ouachitae* and *P. caddoensis* (Table 2).

The diversity of parasites was greatest in *P. ouachitae* and *D. brimleyorum*, as 6 of the 8 symbiont species were encountered in these hosts. Despite the small sample size, *P. fourchensis* also exhibited high diversity (5 of 8 symbiont species). *Plethodon glutinosus glutinosus*, *P. serratus*, and *P. caddoensis* harbored 2, 4, and 5 symbiont species respectively (Table 2). Our data suggest that each allopatric salamander species has as many or more symbiont species than the common sympatric species (Table 3).

With one exception, all endoparasites were restricted to either the intestine or the gall bladder. The acanthocephalon was found in the coelom.

Table 2. Prevalance and (mean intensity) of each symbiont.

SPECIES	P.O.	P.C.	P.S.	P.G.G.	P.F.	D.B.
PROTOZOA						
<i>C. michiganensis</i>	48(113)	-----	-----	20(465)	33(286)	-----
TREMATODA						
<i>B. storeriae</i>	-----	20(4.2)	-----	-----	17(7.0)	-----
CESTODA						
Nematotaeniidae	21(1.8)	8(1.5)	26(4.3)	-----	17(8.0)	15(4.0)
NEMATODA						
<i>T. magnavulvularis</i>	14(1.0)	12(1.0)	22(1.0)	-----	33(1.0)	77(4.6)
<i>O. euryceae</i>	38(3.6)	68(3.6)	9(2.0)	-----	-----	15(2.0)
<i>Oxysomatium</i> sp.	3(1.0)	-----	4(1.0)	-----	-----	8(1.0)
Unidentified immature Oxysomatium	14(1.8)	-----	-----	20(4.0)	-----	-----
ACARINA						
<i>H. dunni</i>	100(20)	80(6.2)	-----	-----	17(6.0)	77(21)
ACANTHOCEPHALA	-----	-----	-----	-----	-----	8(1.0)
TOTAL SPECIES	6	5	4	2	5	6

TREMATODA

Brachycoelium storeriae Harwood, 1932

The only trematode species recovered in this study was *Brachycoelium storeriae*, which was collected from the anterior third of the small intestine of *P. caddoensis* and *P. fourchensis*. It infected 5 (20%) of 25 *P. caddoensis* and 1 (17%) of 6 *P. fourchensis* examined. The average number of flukes per infected host was 4.2 and 7.0 respectively; the range varied from 1 to 15 flukes per host.

There has been much controversy surrounding the assignment of species in the genus *Brachycoelium*. Rankin (1938) reduced all North American species of this genus to the single species *B. salamandrae*. In contrast, Parker (1941) and Cheng (1958) recognized 7 and 10 distinct species of *Brachycoelium* respectively. More recently, Cheng and Chase (1961) and Couch (1966) proposed that 13 species represent the genus. Despite slight differences in size, we have concluded that all our specimens most closely resemble *B. storeriae* as described by Harwood (1932).

NEMATODA

Thelandros magnavulvularis (Rankin, 1937) Schad, 1960

This nematode was recovered from all host species, excluding *P. glutinosus glutinosus*, and was restricted to the posterior third of the intestine. *Desmognathus brimleyorum* was most heavily parasitized, with a prevalence of 77%; the four other infected species exhibited markedly lower prevalences and intensities of infection (Table 2). Although this

Table 3. Comparison of the prevalence of symbionts of the three allopatric species with that of their common sympatric species.

SPECIES	<i>Plethodon serratus</i>		
	Rich Mtn. (12)	Caddo Mtn. (7)	Fourche Mtn. (4)
CESTODA			
Nematotaeniidae	25	--	75
NEMATODA			
<i>T. magnavulvularis</i>	33	29	--
<i>O. euryceae</i>	17	--	--
<i>Oxysomatium</i> sp.	--	14	--
ACARINA			
<i>H. dunni</i>	100	80	17

* NUMBER OF HOST EXAMINED

nematode ranged from 1 to 19 parasites per infected host, only 4 (17%) of 24 infected hosts had more than two specimens. Only two male specimens of *T. magnavulvularis* were recovered, both from *D. brimleyorum*. This is similar to the experience of other investigators. However, most females were observed shedding fertile eggs during recovery, which may indicate that males are short-lived.

Ozwardocruzia euryceae Reiber, Byrd, and Parker, 1940

This trichostrongyloid nematode is found in the anterior third of the intestine. It has been reported in only three species of the genus *Eurycea* (Saltarelli, 1977); therefore, new host records are established for *P. ouachitae*, *P. caddoensis*, *P. serratus*, and *D. brimleyorum*. It was most prevalent in *P. caddoensis*, infecting 17 (68%) of 25 hosts. Infections varied from 1 to 12 specimens per host with an average of 3.6.

Oxysomatium sp.

A total of three specimens (1 male and 2 females) was recovered, two from *P. ouachitae* and *D. brimleyorum* at Rich Mountain, and one from *P. serratus* at Caddo Mountain. Fischthal (1955) reported *O. americana* in *F. fuscus*, and Landewe (1963) found *Oxysomatium* sp. in *P. cinereus*. The species designation of our specimens is uncertain at this point. Unpublished work (Johnson) has shown *Ambystoma maculatum* in this region to be more commonly infected with *Oxysomatium*.

CESTODA: Nematotaeniidae

Representatives of the family Nematotaeniidae were recovered from the anterior two-thirds of the intestine of all host species excluding *P. glutinosus*. *Plethodon serratus* exhibited the highest prevalence of infection (26%), with an average of 4.3 specimens per host. The other host species infected by nematotaeniids exhibited prevalences ranging from 8-21% and intensities ranging from 1.5 to 8. The average number of tapeworms per infected host was 4.4.

Immature forms of Nematotaeniidae were collected from all host species except *P. glutinosus glutinosus* and *D. brimleyorum*. This was the only cestode form represented in *P. caddoensis*, although the infections exhibited low prevalence (8%) and low intensity (1.5). *Plethodon ouachitae*, *P. serratus*, and *P. fourchensis* were the host species in which both mature and immature nematotaeniids were found.

Cylindrotaenia americana is the most frequently reported nematotaeniid in *Desmognathus* and *Plethodon*. This cestode has been

Comparison of the Symbiotic Fauna of the Family Plethodontidae in the Ouachita Mountains of Western Arkansas

recovered by Dunbar and Moore (1979) from *D. monticola*, *D. ochrophaeus*, *P. glutinosus*, *P. richmondi*, and *P. cinereus*. Rankin (1937) reported a proteocephalid cestode, *Crepidobothrium cryptobranchi*, from these two genera.

Our specimens have almost all of the morphological characteristics of the family Nematotaeniidae, including the four unarmed suckers, cylindrical body, and distinct posterior segmentation. However, the four recorded genera representing this family also exhibit two or more parauterine organs. Our specimens quite vividly show a progression of eggs from a degenerating uterus into a single parauterine organ in each succeeding posterior segment. Because these specimens do not fit into other families characterized by a single parauterine organ, we have tentatively placed them in the family Nematotaeniidae pending further identification.

PROTOZOA

Cepedietta michiganensis Woodhead, 1928

Cepedietta (= *Haptophrya*) *michiganensis*, a large ciliate (1.1 - 1.6 mm), was recovered from the gall bladder and intestine of *P. ouachitae*. In this host, intestinal infections never occurred in the absence of parasites in the gall bladder. However, one individual from *P. glutinosus* and *P. fourchensis* exhibited extremely large infections (> 450) of the intestine but not the gall bladder. The ciliates from the two different organs could not be distinguished morphologically. In gall bladder sections, the protozoans appeared to be randomly distributed and were not attached to the epithelium. Although these organisms could be found throughout the intestine, they were concentrated in the anterior third.

Cepedietta michiganensis undergoes asexual reproduction by binary fission. Powders (1967) reported chains of up to seven individuals. Woodhead (1928) and Puytorac (1963) state that chains of six are the maximum and occur rarely. We observed a maximum of only two individuals in tandem.

ACARINA

Hannemania dunni Sambon, 1928

This ectoparasite was first reported in *P. ouachitae* by Dunn and Heinze (1933). Pope and Pope (1951) confirmed this observation and reported a prevalence of 83% and an average of 10-15 per infected host. The latter authors also note the absence of this parasite from *P. glutinosus* taken from the same locations on Rich Mountain. Large infestations of *H. dunni* were recorded for *P. ouachitae* and *P. fourchensis* by Duncan and Highton (1979). They also reported variable infestations in *P. caddoensis* and very rare occurrences on the sympatric *P. serratus*. Our observations as to host distribution conform well to those recorded by the above authors.

Hannemania dunni was recovered from all species except *P. serratus* and *P. glutinosus*. Although only 17% of *P. fourchensis* were infected, chiggers were recovered from at least 77% of the hosts of the other infected species. The most prevalent infection occurred in *P. ouachitae*, in which 100% of the hosts were infected with an average of 20 chiggers.

The average number and distribution of *H. dunni* appeared to be species dependent. In all infected species, this parasite was usually dorsal in location. In *P. ouachitae*, an average of 20 chiggers was distributed primarily on the appendages and on the mid-body region to a lesser extent (Fig. 1). *Desmognathus brimleyorum* also displayed a high intensity of infection of *H. dunni*. An average of 21 chiggers was distributed almost entirely on the feet of this host. In a few individuals, severe infestation of the appendages resulted in tissue destruction and loss of toes. This host also seemed to have more chiggers located ventrally in comparison with other host species (Fig. 2). In *P. caddoensis*, an average of 6 chiggers was randomly distributed over the entire body, but absent in the feet (Fig. 3).

CONCLUSIONS

No information concerning the endosymbionts of five of the six host species we examined has been published previously. Thus, our study provides new documentation of eight species of symbionts in six species of plethodontid salamanders from the Ouachita Mountains of western

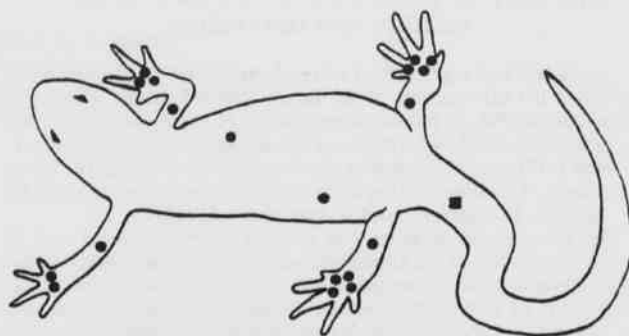


Figure 1. Average number and distribution of *Hannemania dunni* in *Plethodon ouachitae*.

Legend:
• represents one chigger on dorsal surface
■ represents one chigger on ventral surface

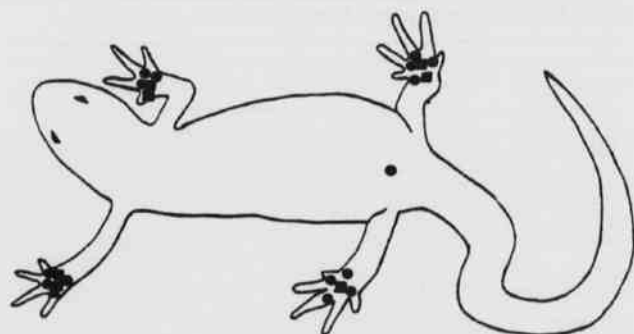


Figure 2. Average number and distribution of *Hannemania dunni* in *Desmognathus brimleyorum*.

Legend:
• represents one chigger on dorsal surface
■ represents one chigger on ventral surface.

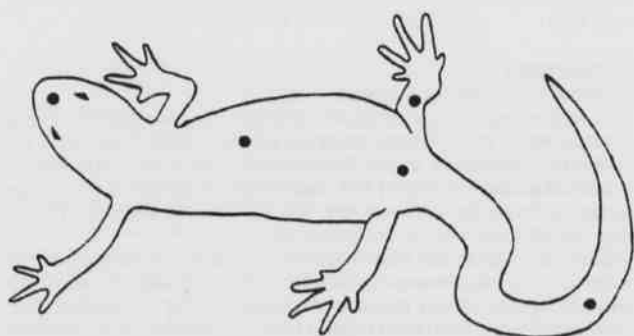


Figure 3. Average number and distribution of *Hannemania dunni* in *Plethodon caddoensis*.

Legend:
• represents one chigger on dorsal surface

Arkansas. Furthermore, all endosymbiont recoveries represent new locality and host records.

With the exception of *T. magnavulvularis*, which was found in the posterior third of the intestine, and the acanthocephalon in the coelom, all endoparasites were collected from the anterior two-thirds of the intestine. Data regarding the single ectoparasite species recovered con-

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firm the work done by others and provide further quantification of the distribution of the chiggers on the infected hosts. Two sympatric species lacked these symbionts.

The three allopatric species exhibited both higher prevalences and intensities of infection in comparison with their common sympatric species, *P. serratus*. These data indicate that, evolutionarily, the allopatric species probably did not acquire their symbionts from this sympatric host.

Comparison of the three host species examined in the largest numbers, two allopatric and one sympatric, shows exclusive infections of certain symbionts. *Brachycoelium storeriae* and *C. michiganensis* were restricted to *P. caddoensis* and *P. ouachitae* respectively, and *H. dunni* was limited to the two allopatric species. The common symbionts of these three major hosts were the nematodes *T. magnavulvularis* and *O. euryceae* and the nematotaeniid cestode.

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GENERAL NOTES

SPIDERS COLLECTED IN SOUTHEAST ARKANSAS USING PITFALL TRAPS PLACED IN PINE-HARDWOOD FORESTS THAT RECEIVED VARIOUS FORESTRY TREATMENTS — A PRELIMINARY LIST

Very little collecting of spiders has been done in Arkansas using pitfall traps, (Heiss, Spiders collected from pitfall traps in Newton and Union County, Arkansas, unpublished Master's thesis, Univ. Ark., Fayetteville, 1977). Due to the fact that the investigators must leave the traps in place for an extended period of time, most individuals who research large areas of the state are unable to suitably use this procedure; however, this study was conducted over only a two county area with one of the investigators on site for the entire period that the research was initiated. Since pitfall trap investigations have not occurred previously in nonagricultural areas of Arkansas, it is believed that this study will elucidate not only differences of spider fauna under various forestry practices but also will allow for comparisons and correlations of fauna in agricultural vs. nonagricultural areas.

Spiders were trapped in 1984 using pitfall traps with rain covers. Each trap consisted of a 1 qt. metal oil can, open at both ends to form a cylinder and buried open end up and level with the surface of the ground. A 16 oz. plastic drinking cup was placed into the cylinder. The cup held the preservative — 5 fl. oz. of a 1:1 mixture of antifreeze and water. The cup was easily removed and the contents collected without disturbing the ground around the trap. A 1 ft. square rain lid, held 1 in. over the cup, reduced the amount of rain entering the trap. Traps were emptied weekly and the spiders sorted by forest treatment and then placed in 80% ethyl alcohol. The weekly catches from all traps within each treatment were pooled for storage.

The Drew County treatments consisted of 9 pine-hardwood stands (mostly loblolly and shortleaf pines mixed with oaks, hickories, and sweetgum). Three stands were clearcut and site prepared in the summer of 1981, then planted in January to produce an evenaged stand of loblolly pine. Three stands were selectively harvested in the summer of 1981 to produce an all aged stand of loblolly pine. The 3 remaining stands were not cut and served as checks. Twenty traps were randomly placed in each treatment on an established 1-chain (66 ft.) grid. Traps were sampled from May 11 through October 31.

The Bradley County treatments included 3 study areas. Study area one was in a forest type of mixed pine-hardwoods that included three 15-20 ac. clear-cuts, each site prepared in 1982 using a different procedure, but replanted in 1983 to loblolly pines. The 3 treatments included: Sheer, rake and windrow in January; Drum-chop in September; and Hexazinone herbicide applied in May 1983 using a spot gun to place 4 spots of chemical around each pine seedling. An adjacent stand served as the check. Fifteen traps were placed in each treatment on a transect, with a 66 ft. trap spacing. Traps were sampled from June 6 through October 31.

Study area two consisted of a 50 ac. clearcut sprayed in May of 1983 with hexazinone and broadcast burned in July, then replanted in March of 1984 with loblolly pine. An adjacent stand of mostly mixed hardwoods was the check. Twenty traps were placed in each stand on a transect, with a 66 ft. trap spacing. Traps were sampled from June 6 through October 31.

Study area three was a 40 ac. 7-year-old evenaged loblolly pine plantation treated with hexazinone by air in 1983 to release the pine samplings from the hardwood competition. An adjacent unsprayed area of the plantation served as the check. Fifteen traps were placed in each treatment on a transect, with a 33 ft. trap spacing. Traps were sampled from June 20 through October 31.

Thousands of spiders were collected, with ground inhabiting spiders such as those belonging to the families Gnaphosidae and Lycosidae being the most numerous. For this preliminary report 10 families and 65 species of spiders have been listed from the 2,039 spiders identified.

They are as follows:

Taxa	Numbers Drew County	Identified Bradley County	Taxa	Numbers Drew County	Identified Bradley County
AGLENIDAE			LYCOSIDAE		
<i>Agelenopsis pennsylvanica</i> (C.L. Koch)	1		<i>Allocaeca funerea</i> (Hentz)	9	
<i>Coras medicinalis</i> (Hentz)	1		<i>Lycosa anteleucana</i> Montgomery	5	8
ANYPHAENIDAE			<i>Lycosa aspersa</i> Hentz	29	3
<i>Anypaena celer</i> (Hentz)	1		<i>Lycosa carolinensis</i> Walckenaer	5	10
ARANEIDAE			<i>Lycosa frondicola</i> Emerton	1	1
<i>Eustala anastera</i> (Walckenaer)	1		<i>Lycosa gulosa</i> Walckenaer	83	
<i>Neoscona arabesca</i> (Walckenaer)	1		<i>Lycosa helluo</i> Walckenaer	24	18
CLUBIONIDAE			<i>Lycosa lenta</i> Hentz	4	1
<i>Castianeira amoena</i> (C.L. Koch)	2		<i>Lycosa punctulata</i> Hentz	34	18
<i>Castianeira descripta</i> (Hentz)	2		<i>Lycosa rabida</i> Walckenaer	120	40
<i>Clubiona excepta</i> (C.L. Koch)	4		<i>Lycosa riparia</i> Hentz	4	1
<i>Clubiona obesa</i> Hentz	1		<i>Pardosa distincta</i> Blackwell	47	
<i>Marcellina piscatoria</i> (Hentz)	1		<i>Pirata insularis</i> Emerton	60	
<i>Micaria longipes</i> Emerton	1		<i>Pirata maculatus</i> Emerton	1	
<i>Strotarchus piscatoria</i> (Hentz)	2		<i>Pirata piratica</i> (Clerck)	1	1
GNAPHOSIDAE			<i>Schizocosa avida</i> Walckenaer	60	
<i>Callilepis pluto</i> (Banks)	28	27	<i>Schizocosa bilineata</i> (Emerton)	49	1
<i>Callilepis imbecillis</i> (Keyserling)	1	1	<i>Schizocosa crassipes</i> Walckenaer	1	
<i>Cesonia bilineata</i> Hentz	1	2	<i>Schizocosa ocreata</i> Emerton	13	1
<i>Drassylus creolus</i> Chamberlin and Gertsch	4	5	<i>Schizocosa saltatrix</i> Hentz	18	1
<i>Drassylus depressus</i> Emerton	64	45	<i>Tarentula aculeata</i> (Clerck)	1	
<i>Drassylus aprilius</i> (Banks)	7	1	<i>Trabea aurantiaca</i> (Emerton)	1	
<i>Drassylus covensis</i> Exline	10		<i>Trochosa terricola</i> (Thorell)	2	1
<i>Drassylus virginianus</i> Chamberlin	5		PISAURIDAE		
<i>Drassodes neglectus</i> (Keyserling)	1		<i>Dolomedes vittatus</i> Walckenaer	1	
<i>Gnaphosa sericata</i> (C.L. Koch)	224	52	SALTICIDAE		
<i>Gnaphosa muscorum</i> (C.L. Koch)	1		<i>Habrocestrum pulex</i> (Hentz)	2	
<i>Herpyllus vasifer</i> (Walckenaer)	1		<i>Metaphidippus exiguus</i> (Banks)	1	
<i>Lithophyllus temporarius</i> Chamberlin	2	2	<i>Neon nelli</i> Pockham	1	
<i>Psecilochroa capulata</i> Walckenaer	1	1	THOMISIDAE		
<i>Rachodassus exlineae</i> Platnick and Shadak	101	46	<i>Misumenops asperatus</i> Hentz	228	
<i>Synaphosus paludis</i> (Chamberlin and Gertsch)	11	5	<i>Misumenops celer</i> Hentz	1	
<i>Zelotes duplex</i> Chamberlin	44	20	<i>Misumenops oblongus</i> Keyserling	2	
<i>Zelotes hentzi</i> Barrows	362	17	<i>Misumenops deserti</i> Schick	2	
<i>Zelotes rusticus</i> (C.L. Koch)	11		ZORIDAE		
<i>Zelotes subterraneus</i> (C.L. Koch)	1		<i>Zora pumila</i> (Hentz)	1	
HAHNIIDAE					
<i>Neotantista agilis</i> (Keyserling)	1				

General Notes

The spider fauna collected are what we would have expected. Gnaphosids (ground spiders), Lycosids (wolf spiders), Thomisids (crab spiders), and Salticids (jumping spiders) are the families most likely to be wandering, hunting, ambushing, and stalking prey on the ground. Therefore, these spiders are more likely to fall into traps than other families of spiders that make webs or trap prey.

Fewer spiders have been identified from the Bradley County collection than from the Drew County collection which may account for the discrepancy in numbers reported for that county as compared with Drew County. The practices carried out in both treatments were also very different.

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POPULATION DECLINE OF THE ENDANGERED INDIANA BAT, *Myotis sodalis*, IN ARKANSAS

The Indiana bat, *Myotis sodalis*, is one of three Arkansas bat taxa listed as endangered (specifically, in danger of extinction throughout all or a significant portion of its range) by both the U.S. Fish and Wildlife Service and the Arkansas Game and Fish Commission. Other Arkansas bats also listed as endangered are the gray bat (*Myotis grisescens*) and the Ozark big-eared bat (*Plecotus townsendii ingens*).

The range of *M. sodalis* extends across the eastern United States from Oklahoma, Iowa, and Wisconsin east to Vermont and south to north-western Florida. Distribution is associated with major Karst regions and areas north of such regions (Hall, 1962). The present total population is estimated to number approximately 500,000, of which more than 85% hibernate at only six locations; two caves and a mine in Missouri, two caves in Indiana, and a cave in Kentucky. In Arkansas, Indiana bats are found primarily in the Ozark Mountain region, the only area of the state where caves are numerous.

Indiana bats hibernate in large dense clusters of up to several thousand individuals, in sections of the hibernaculum where temperatures average 3-6° C and having relative humidities of 66-95% (Barbour and Davis, 1969). In Arkansas, most Indiana bats have been found hibernating where temperatures were slightly warmer, ca. 8-10° C. Surface temperatures of large clusters taken with an infrared thermometer were usually within $\pm 0.5^\circ$ C of the temperature of the cave wall or ceiling near clusters. These bats hibernate from October to April, depending on climatic conditions. Density in clusters is usually about 3,200 bats per m²; however, in one instance, we found as many as 5,000 bats per m² in a tight cluster in an Arkansas hibernaculum in late February.

Females depart hibernacula before males and arrive at summer maternity roosts in mid May (Humphrey et al., 1977). They raise their single young, born during June, under the exfoliating bark of trees in wooded riparian habitats. During September they depart for autumn swarming caves (Cope and Humphrey, 1977; Humphrey et al., 1977). The summer roost of adult *M. sodalis* is apparently in the vicinity of hibernacula, but where most spend the day is not known (Hall, 1962; LaVal et al., 1977).

Until 1974, little was known concerning the summer habitat and ecology of this bat. In 1974, the first known maternity colony was discovered, under the loose bark of a dead bitternut hickory tree in east central Indiana (Humphrey et al., 1977). The colony, numbering about 50 individuals, also utilized an alternate roost, located under the bark of a living shagbark hickory tree. The total foraging range of the colony consisted of a linear strip along 0.82 km of a creek. Further, foraging habitat was confined to air space from 2 m to approximately 30 m high, near the foliage of riparian and floodplain trees (Humphrey et al., 1977).

During the summers of 1977 and 1978, two additional maternity colonies were discovered, both also in east central Indiana (Cope and Seerley, 1977; Cope et al., 1978a). The two colonies had maximum estimated populations of 100 and 91 respectively, including females and young. Indiana bats were also captured at four additional locations in the same area, but outside the known range of the two maternity colonies. Habitat in the area was similar to that described for the first maternity colony discovered in 1974 (Humphrey et al., 1977). The foraging area of one of the two colonies was found to extend along approximately 1.2 km of stream.

Summer foraging habitat of maternity colonies is in mature riparian forest. Interestingly, Indiana bats have not been observed foraging over cleared portions of streams or over fields away from trees (Cope et al., 1974; Humphrey et al., 1977). In flying to a foraging area, Indiana bats apparently will not fly over open country or open water (Cope et al., 1978a).

Much of what is currently known about summer habitat and ecology of this species is included in the publication of Humphrey et al. (1977), and in unpublished reports by Cope et al. (1978a, 1978b). During recent years additional evidence has accumulated indicating that, during summer, *M. sodalis* are widely dispersed in suitable habitat throughout a large portion of their range. LaVal and LaVal (1980) reported mist netting lactating females and juveniles at 10 locations scattered over northern Missouri and cited a personal communication from J. Bowles indicating similar data from Iowa. Others have also reported capturing females and/or young during summer in Missouri (Easterla and Watkins, 1969), Illinois (Kessler and Turner, 1979, 1980), and Kentucky (Kessler et al., 1981; and Harvey and Kennedy, 1980, 1981).

Our attempts to locate summer colonies of Indiana bats in Arkansas by netting at several locations in various habitat types resulted in failure to capture female bats. Males, however, were netted at some cave entrances. In addition, several (as many as 10 per cave) male *M. sodalis* were observed in Arkansas Ozark caves during summer. It is likely that female Indiana bats from Arkansas hibernacula migrate northward in summer to maternity roost sites located to the north of the Ozark Mountains.

Between early August and mid-September, Indiana bats arrive in the vicinity of their hibernacula where they engage in swarming and copulation. Swarming continues into mid to late October. During this time fat reserves are built up for hibernation. In Missouri, Indiana bats were found to feed primarily on moths (LaVal and LaVal, 1980). Paradiso and Greenhall (1967) reported a longevity record of 13 yr 10 mo for this species.

Hibernating bats leave little evidence of their past numbers, thus it is difficult to calculate a realistic estimate of population decline for this species. It is likely that the Indiana bat population in Arkansas was never as high as reported from other areas. However, we do know that at least 10 Arkansas caves that previously housed hibernating colonies of Indiana bats are no longer inhabited by this species. We also know that one Newton County cave, that only a few years ago contained 7,000 hibernating Indiana bats, now houses less than 200.

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Harvey (1980) and Harvey et al. (1979) reported that the largest known Arkansas Indiana bat hibernating colony numbered less than 2,000 individuals. That colony has since decreased to fewer than 200 bats. However, Harvey et al. (1981) reported locating an additional Indiana bat hibernating colony that, in February 1981, numbered ca. 5,000 individuals. That colony had decreased to only ca. 1,850 bats, when last checked during the winter of 1984-85.

Currently, we know of only six Arkansas caves where more than 30 individuals can be found hibernating in winter. The present Arkansas population (ca. 2,630) represents a 54% decline for this species since 1981 and is probably only a very small percentage of the numbers that previously hibernated in Arkansas caves. One of the six hibernation caves, located on Buffalo National River lands, has been fenced by the National Park Service to protect Indiana bats and gray bats that hibernate in the cave. Three additional Indiana bat hibernation caves located on Ozark National Forest lands have been closed (warning/interpretive signs) to the public to protect bat colonies. Hopefully, protection of these caves will result in an increase in bat populations at these caves. However, it is unlikely that other caves, previously inhabited by Indiana bats but now abandoned, will be recolonized by this species.

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USEFULNESS OF MICROFICHE READER/PRINTER FOR STUDYING FISH SCALES

Age assessment of fish is important in fisheries management because age data are used in estimations of growth, mortality and survival rates, and population structures. A variety of projectors have been used to study fish scales (Dauble and Gray, 1977; Phillips, 1974; Phillips and Webster, 1960; Wright and Kolb, 1970). When determining the age of fish by the scale method, the accuracy increases when there is agreement between two or more readers. It is, thus, desirable for the readers to analyse the same scale, and photographs of fish scales can make this possible.

A desk-top microfiche reader/printer (Minolta Reader/Printer RP 405) was used in analysing snakehead (*Ophicephalus striatus*) and largemouth bass (*Micropterus salmoides*) scales. For comparison, scale impressions on plastic slides and dry mounted or unmounted scales were placed between the glass plates of the microfiche film carrier. These glass plates flatten even a badly warped plastic slide or a fish scale, making it possible to obtain a focused image of the entire scale. The reader/printer has a wide range of interchangeable lenses providing a spectrum of magnifications useful for small to large fish scales.

The scale image can be projected, studied and measured from a vertical screen (30.5 x 30.5 cm), the brightness and sharpness being adjustable. Photographing the scales is a simple and fast procedure once a well focused scale image is projected, the polarity can be set at positive or negative, the exposure adjusted and the photocopy is made. The photocopy is returned within seconds and the brightness or exposure time can be adjusted and another copy made if the quality of the first copy is unsatisfactory. The cost of each photograph is minimal (ten cents per copy at the University of Arkansas).

Good quality photocopies were made for both snakehead, a tropical fish from Sri Lanka, and the largemouth bass from Crystal Lake, Arkansas (Figs. 1 and 2). The process of making plastic scale impressions is tedious and time consuming. Different size scales require different temperatures, pressing times or pressures. This makes it difficult to get a good impression and scales can be ruined in the process. Cleaned, dry mounted and unmounted scales can be used with the microfiche reader/printer and photocopies obtained as well (Figs. 1B and 2B).

The scales from older largemouth bass can be thicker in areas towards the foci. This makes it difficult to get even illumination across the dry mounted scale, though focusing is not a problem. It can be circumvented by taking two or more photocopies at different illumination settings and all the annuli can be identified. This procedure is certainly the least time consuming, however, good quality plastic impression slides of scales from an older fish are preferable so that all the annuli can be seen on one photocopy.

Many academic institutions and public libraries have microfiche reader/printers available. This instrument has many advantages over the conventional scale projectors. Plastic impression slides as well as dry mounted or unmounted scales can be viewed on the screen and photographed. The photographs and the microfiche reader both make it possible to compare a number of different scales for general patterns of annuli formation. In situations where multi-reader scale evaluation is warranted, specific photocopies could be used to insure that all the readers were evaluating the same scales.

We express our sincere appreciation to Jaya L. Kilambi for drawing our attention to the microfiche reader/prinder and to Mr. Stephen J. Chism of the Audio-Visual Department of Mullins Library, University of Arkansas, for making the machine available to us when needed.

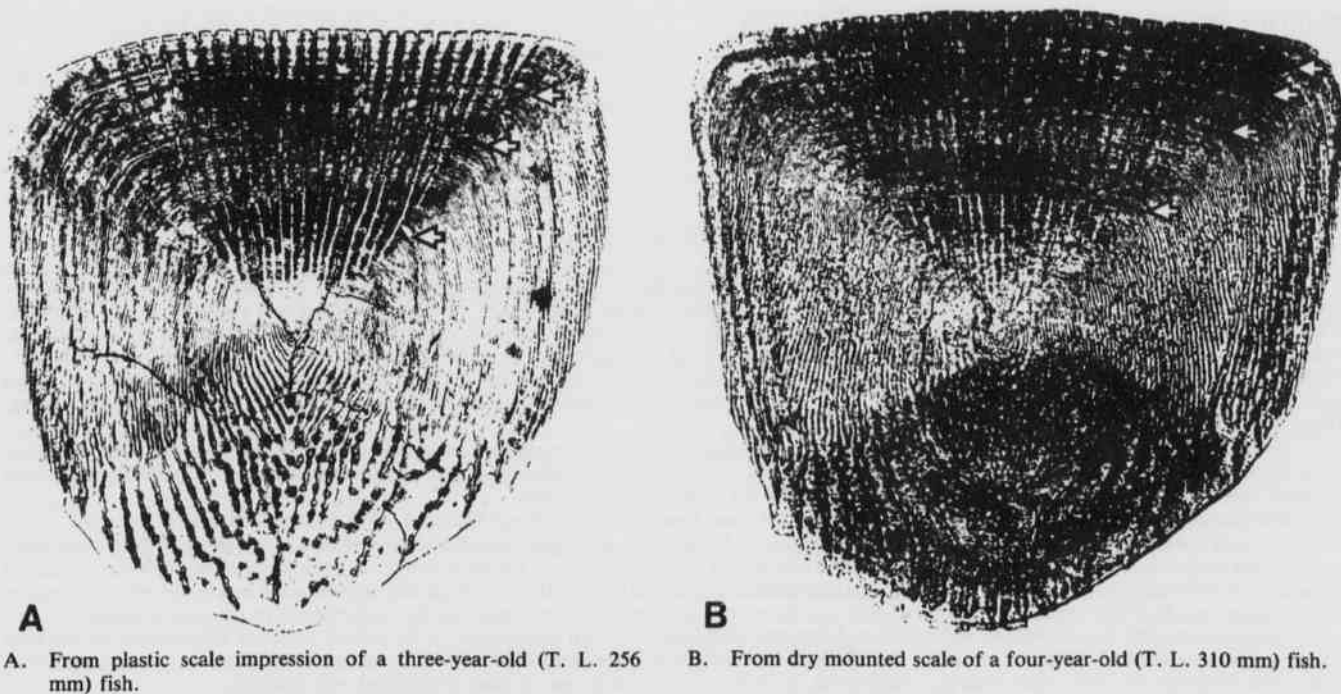


Figure 1. Photocopies of scales of snakehead from Sri Lanka.

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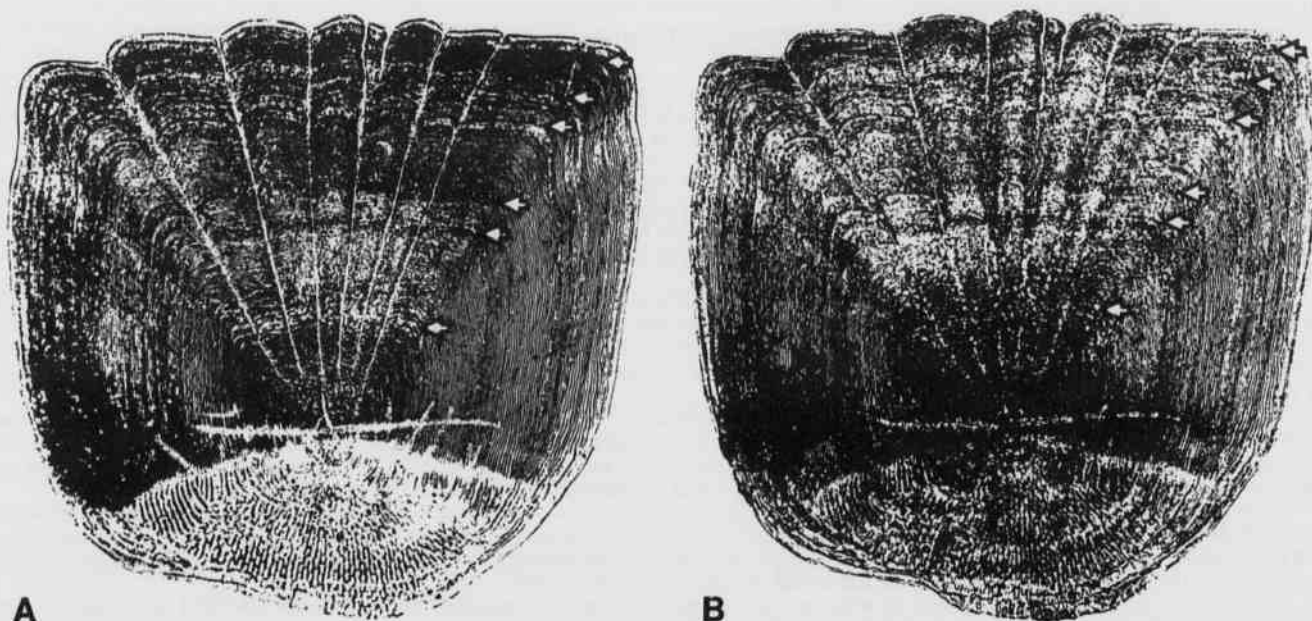


Figure 2. Photocopies from plastic scale impression (A) and dry unmounted scale (B) of a six-year-old (T.L. 393 mm) largemouth bass from Crystal Lake, Arkansas.

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A FOREST DATA BASE FOR ARKANSAS

The forest-derived resources of Arkansas form the largest single group of natural resources in the State. The timber, water, and wildlife of the forest form much of the basis for our wealth as a state. Our forests, directly or indirectly, provide Arkansas with recreational opportunities, jobs and many of the products that we need for shelter. The watersheds of our forests provide Arkansas with high quality water to maintain life, to irrigate our crops, for recreation and provide avenues for transportation. The economic importance of the forest sector has long been recognized. Estimates place the combined influence of direct and indirect employment, services and commodities between one-quarter and one-third of the state's gross product on a yearly basis (Troutman, et al., 1981, *Forests and the Arkansas Economy*, Industrial Research and Extension Center, University of Arkansas).

Perhaps harder to measure, but also of significant importance, is the great diversity of ecological communities within the state. Many of these communities are populated with flora and fauna that exist nowhere else. The total quality of our lives are directly or indirectly influenced by these communities and the complex interrelationships that are characterized by them.

Because the forest comprises a majority of Arkansas' total land base (52%) (Quick and Hedlund, 1979, *Forest Statistics for Arkansas Counties*, Southern Forest Experiment Station, New Orleans, La.) and because it is a complex and dynamic biological community of flora and fauna, much of the basic scientific and ecological research that is carried out in the state is forest based. Much of the pure forest research that is conducted deals not just with individual tree biology, but with large scale mensurational and ecological information that includes stand and total forest descriptions. Additionally, much of the economic research in the state takes into account the contribution of the forest sector to the state's economy.

One problem that has existed for some time in Arkansas, especially for forest researchers, is the lack of available information on the total forest system of Arkansas. Often information must be garnered piecemeal from many sources with the inherent problems of data inconsistency being rife. Requests for data often must go unanswered, or information, clearly out of date, is supplied with apology.

In order to provide a consistent base of forest resource information to researchers and planners in the state, planning was initiated in January 1985 for a computerized forest data base. The original data base, as conceived, would have provided only information on the timber resources of Arkansas, the influence of the forest industry sector on the state's economy and generally be a storehouse of timber-related statistics. The response

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to the data base concept was so well received by state officials, forest industry, regional planners and researchers that the original concept of the data base has been broadened to include information on the total forest ecosystem, including wildlife and other forest based resources. The system is now operational and data processing and research work has begun at Monticello.

Existing sources of forest information were first investigated to determine what data were available. No single source of information could provide all of the information that was desired in the Monticello data base. However, the information that could be provided, in concert, did meet the initial needs of the project. A brief description of the data and the identified sources follows.

The U.S. Forest Service (USFS) has 3200 permanent forest inventory plots located in Arkansas. These plots are resampled on a ten year cycle. The information from the plots include 98 different variables, including the volume of growing stock, growth rates of the trees on the plots, ownership class, and changes in land use of the plot. The information in published U.S. Forest Service analyses has for many years provided foresters in the state with information about the nature of the forest resource, the expected changes in the forest over the next cycle and an index to the total health of the resource. One problem with the Forest Service Survey however, is the long cycle period. Because of rapidly changing land use, changes in forest products markets and industrial shifts within the state, this information quickly becomes dated. A mid-cycle survey of 10% of the plots is conducted to ease the problems of the long cycle. However, the information from this sample is not as detailed as the full survey. Supplementary information is needed to aid in interpretation of the USFS information. The forest survey information for the last full cycle survey, and the mid-cycle survey just completed will be brought to Monticello and put in our data banks.

Supplementing and complementing the forest survey information will be information from the Arkansas Forestry Commission (AFC) in Little Rock. The State Forester has agreed to provide us with regeneration, harvest, wildlife and industrial production information for the state from their files. The addition of this information to the data base at Monticello will help to complete the picture of forest growth, removals and industry activity within the state. Reports for regions and sub-regions within the state, with information available down to county level can be developed with these additions to the data base.

Information on wildlife populations and dynamics will be obtained from the Arkansas Game and Fish Commission (AGFC) and the U.S. Fish and Wildlife Service. This will include information on herd movements, estimated herd densities and changes in the wildlife base due to changes in land use, hunting pressure and changes due to forest habitat manipulation.

A major bank of information has been collected by the Arkansas Economic Information System (AEIS) located at the University of Arkansas at Little Rock. Researchers there have for several years been amassing data that describes the total economy of the state. Included in their data is information that describes the general health of the work force, wage, employment, earnings, and productivity by industry. The information pertaining directly to the forest sector is of greatest importance to this project. Using their information, in conjunction with the forest descriptive information, the total forest sector of the state can be modeled. A model of this type will describe not only the forest resource, but also the effect that the dynamic forest sector has on the total economy of the state.

Much of the health of the forest sector is directly related to national and international markets for forest products. Prices, demand and supply projections form the basis of much of the econometric modeling that is carried on by forest industry planners. Access to regional and state stumpage price information for a considerable period of will be included to extend our data base. National marketing information is available and will complement the state level data that have already been recovered.

As we become aware of other information, we will attempt to incorporate it into the system at Monticello. We feel that only by having all of the information about the forest based resources at one place can we paint the total picture as it exists.

The initial statistical reports from the data base will be primarily of a descriptive nature. Summary statistics describing the forest resource, by location within the state should be produced within the next year. Later, summary reports will be produced for each of the major regions of the state and subregions of specific interest. We will also be able to handle requests for data from other researchers around the state. The information that we have will be available to all who desire it, limited only by our total work load. The first report of summary statistics should be completed by late 1986 and include the updated forest survey information, the status of the forest products industry within the state and growth projections for the next few years. Certain wildlife information will also be included in the report.

One of the principal concepts behind assembling the data base was to provide a basis for long term research within the state. Charting the dynamic character of the forest resources of the state will, by its very nature, take time. Cross-sectional data alone does not provide the ability to view the changes that occur over time in our resource base. Consequently, we will update the time series information to complement the periodic cross sectional views that we gain from the forest surveys and updates. Modeling the changes in the forest resource over time will give us the ability to not only accurately describe the past but to be predictive about the future.

Within a year we will be developing the first of the forest resource models, including those factors that we believe are important. For example there is considerable interest in the development of a stumpage prediction model for the state. A second, and related model will address the growth-drain patterns of timber within the state. Other models have been suggested and as time permits they will be investigated.

Because of the tremendous volume of data that will be located at Monticello, it is natural to make available as much information, in the most usable format, to the greatest number of people. Contract research, looking at relatively narrowly defined problems, is a service that we will be equipped to provide. The details of this type research have not yet been worked out, but the concept has been discussed.

Clearly, the data base as described is macro in scale and design. The information, statistics, and research flowing from it, will provide researchers with new opportunities to better understand the forest ecosystem that is such an important part of our state. The data base will be a resource data pool for anyone who desire to use it. Participation in this project by any cooperators is welcomed. The computer capability and the expertise is present to store, retrieve, merge and sort data from any different sources. However, in order to reach its true potential as a research and scientific resource, others should be included in the work that has been started. To this end, we are seeking your help and guidance on what additional information should be included in the data base. We are open to discussing participation in this project with other researchers, interested groups and cooperators within the state.

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AN INTRODUCTORY CHEMISTRY COURSE

The Department of Chemistry at Arkansas State University teaches general chemistry to over 400 non-chemistry majors each year. The range of academic preparation in the physical sciences of these students is very broad because the university has an open admissions policy. Consequently, general chemistry is presented assuming that the student has had little exposure to the study of chemistry.

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As a neophyte instructor in 1964, the author was informed that the mathematical ability of the student was the best indicator of success in chemistry. Studies of the (former) chairman indicated that high school chemistry had little impact on a student's ability to cope with general chemistry. This conclusion was compatible with that mentioned by Schelar, Cluff, and Roth (Schelar, Cluff, and Roth, J. Chem. Ed., 40, No. 7: 369-370, 1963). However, it is quite probable that our present day students cannot be so categorized.

Starting in 1964, all agriculture students were required to take general chemistry in the chemistry department at Arkansas State University. In the intervening years, the introduction of new majors within the university swelled the growth of the chemistry department disproportionately to the growth of the university. Approximately one third of the students enrolled in general chemistry have had no high school chemistry. Two thirds of this group consists of agriculture or nursing majors. Unfortunately, it has become apparent that the expansion of D, F, and W grades has outstripped the growth of the student population.

"I had to fail Chem I. I did not take chemistry in high school so I had to flunk. Now that I have done this, I will pass this time." That remark, overheard by chance, seems to sum up the attitude of an increasing number of students. This particular student was wrong on both counts, but she believed it — so did her companions.

McQuary, Williams, and Willard (McQuary, Williams, and Willard, J. Chem. Ed., 29, No. 9: 460-464, 1952) studied the factors that determine student achievement in first year college chemistry. One of their conclusions was that students who have had chemistry in high school are as a group superior to students who have not had high school chemistry. Rowe (Rowe, J. Chem. Ed., 60, No. 11: 954-956, 1983) points out that chemistry students must assimilate over 6,000 units of information, which is more than is required in the first year study of a foreign language. In addition, word meanings are new in chemistry. The work of Hadley, Scott, and Van Lente (Hadley, Scott, and Van Lente, J. Chem. Ed., 30, No. 6: 311-313, 1953) led to the observation that students who had high school chemistry, irrespective of other courses, made better records in chemistry than those who did not have high school chemistry.

First semester general chemistry sections were surveyed during the fall terms of 1981, 1982, and 1983. From a total of 789 students, 273 (34.6%) had not taken chemistry in high school. This group accounted for 51% of the D, F, and W grades and only 11.4% of the A and B grades. From another perspective, 196 of 273 students (71.8%) with no high school chemistry received a grade of less than C. From the 516 students who had taken high school chemistry, 188 (36.4%) received a grade of less than C.

A grade of D is passing at ASU. However, it is equivalent to failing for many majors. Prepharmacy students transfer after two years at ASU; a D is non-transferable. BSN nursing majors must have a C average in two chemistry courses and one zoology course. Medical technology majors must have a C average for admission into the final year of that program. Most health science majors will repeat chemistry if their grade is less than C. Therefore, D, F, and W grades were combined for the purpose of this paper.

The data for 1981 indicated that a significant number of students could be helped by some introduction to chemistry prior to their enrollment in the regular college chemistry course. Topics such as the metric system, exponential arithmetic, significant figures, etc., are routinely introduced in the first chapter of many college texts. The student acquainted with these topics from high school chemistry would have an advantage (real or imagined) over a student with no such acquaintance.

A survey of high school chemistry teachers in 1985 (Hammett, Incomplete M.S. Thesis, Arkansas State University) supports this idea. The metric system is taught by 172 respondents and 108 indicated that their students have difficulty with this subject. Likewise, 81 of 164 who teach exponents report deficiencies in this area. Since 83 percent of these teachers rank the bulk of their students in the top 25 percent of their classes, it is not unreasonable to assume that a greater percentage of students with no high school chemistry would have difficulty with these and other math topics covered in the first chapter of most college chemistry texts.

Chemistry 16003, Introduction to Inorganic Chemistry, was offered as a three hour lecture course during the fall term of 1982. The course was a true elective since it would not substitute for the physical science requirement. Advisors were requested to suggest that any student with no high school chemistry consider enrolling in this course, particularly if they were not proficient in algebra. Arrangements were made with the registrar to permit students having difficulty in the regular chemistry course to transfer into CHEM 16003 through the sixth week of school.

CHEM 16003 was initially offered at 10:00 a.m., MWF. The enrollment was small, and only four students managed to drop back into the course. Several others could not do so because of conflicts with other courses. In the fall of 1983 the course was offered at 2:00 p.m., MW. The non-prime time scheduling attracted an initial 22 students. By the end of the fifth week, enrollment had swelled to 42 due to the drop-back option.

Isolated from students with some acquaintance with chemistry, a CHEM 16003 class makes a stark contrast with a regular chemistry class. In general the students are poorly motivated, have bad study habits, are very hesitant in asking questions, and are slow to participate in any type of classroom exercise. With encouragement, some have made excellent efforts to overcome their deficiencies. The metamorphosis of these latter made the program rewarding to the instructors.

The author is under no illusions about the late transfer of (probably) failing students into the introductory course. Only a small fraction give evidence of making a significant effort to succeed.

To date, 47 students have passed CHEM 16003 and enrolled in the regular chemistry course at ASU. Twenty-seven of these subsequently passed. Thirteen of those who failed or withdrew earned only a D in CHEM 16003.

The student response to the introductory course has been positive. Those who have continued into the regular chemistry course have been emphatic in their affirmation of the worth of the course.

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INTERSPECIFIC CORRELATIONS OF HARVEST AND PRICE FOR ARKANSAS FURBEARERS: A CAUTIONARY NOTE

As part of a continuing analysis of Arkansas fur harvest records (Heidt et al., 1984; Heidt et al., 1985; Peck et al., 1985; Clark et al., 1985; and Peck and Heidt, 1985), this study investigated interspecific correlations of season length, harvest, and price as variables for fur harvest analysis of 12 Arkansas fur bearers (coyote - *Canis latrans*, muskrat - *Ondatra zibethicus*, river otter - *Lutra canadensis*, nutria - *Myocastor coypus*, mink - *Mustela vison*, eastern spotted skunk - *Spilogale putorius*, striped skunk - *Mephitis mephitis*, beaver - *Castor canadensis*, opossum - *Didelphis virginiana*, gray fox - *Urocyon cinereoargenteus*, raccoon - *Procyon lotor*, bobcat - *Felis rufus*).

The Arkansas Game and Fish Commission has maintained fur harvest records since 1939; because of the relative completeness and accuracy, records for the past 20 seasons (1965-1984) were used for this study (Peck and Heidt, 1985). Season length and total numbers of each species harvested

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were available for all years. For 1979-80 only, annual mean pelt values for all species were extrapolated from Missouri values. No correction factors were applied to the data to adjust for out-of-state sales of Arkansas fur or for inflation. The data were analysed using a statistical program (Statpak by Northwest Analytic, Inc.) on an Epson QX-10 microcomputer. Correlation coefficients were tested at the 0.01 and 0.05 levels for significance (Table 25, Rohlf and Sokal, 1981).

The data matrix of correlation coefficients for season, harvest and price correlation coefficients for Arkansas furbearers is presented in Table 1. Table 2 illustrates significance levels for the same matrix. With respect to season length, a significant negative correlation was noted for coyote, otter, gray fox, and bobcat. More animals were harvested even though season length has been shortened (116 days in 1968 to 62 days since 1982). These species demonstrated the highest prices through the 1970's and into the 1980's (Clark et al., 1985). There were no positive significant correlations between season length and harvest of furbearers (in fact, most remaining correlations were negative), indicating that shortened seasons did not constrain the take. In Arkansas, as a single variable in fur harvest dynamics, season length did not appear to be particularly important. In contrast, Erickson (1981) found that there was a significant positive correlation between season length and beaver and muskrat harvest in Missouri. Erickson also stated that season length was the only variable accounting for significant annual variation in Missouri beaver harvests.

In regard to harvest, significant correlations were found among upland long-hair species, wetland short-haired species, as well as, between species of these respective groups (Table 2). One might biologically expect to see hunting/trapping efforts toward target upland or wetland species to influence the take of other ecologically similar species. The strong correlation (Table 1) between all species (upland with wetland) would seem to indicate that the annual variations in Arkansas furbearer harvests are not based on some interspecific biological principle (e.g., beaver/otter commensal relationships [Tumilson et al., 1982]), but instead are probably based on some harvesting/marketing mechanism. Additional support for this view is illustrated by examining 16 and 20 year correlations between spotted and striped skunk and other furbearer species. When the 1981-84 seasons are removed from the calculations, skunk correlations increase with all furbearers (Table 1 and 2). The number of skunk sold in Arkansas has been greatly reduced each year since 1980, probably due to high incidences of rabies and the concomitant caution of trappers (Peck et al., 1985). This demonstrates the importance of non-interspecific biological factors influencing Arkansas fur harvest dynamics.

The most important non-biological factor shown to influence fur harvest is price (Erickson and Sampson, 1978; Erickson, 1981, 1982; Heidt et al., 1984; Clark et al., 1985; and Peck and Heidt, 1985). Tables 1 and 2 further demonstrate the importance of price in explaining variation in annual fur harvests. Once again, these data demonstrate significant and highly significant positive correlations among upland long-haired species, wetland short-haired species, and most upland and wetland species. It would also appear that as the price of bobcat, raccoon, gray fox, muskrat, and mink have increased, the season length was decreased, resulting in significant negative correlations. It should also be noted that these five species represent, over the past 10 years, Arkansas' most valuable furbearers (Heidt et al., 1985).

Data presented in this study demonstrate that extreme caution must be used when attempting to explain fur harvest dynamics by using interspecific correlations. Further, use of partial data sets (e.g., only using upland long-hair species or wetland short-hair species) may result in faulty conclusions resulting in poor management practices. While price seems to be the factor contributing the greatest impact to fur harvest dynamics, we agree with Erickson (1981) that multivariate analysis may help to identify and weigh multiple variables which may simultaneously be influencing fur harvests.

The authors would like to express their appreciation to the Arkansas Game and Fish Commission for providing fur harvest data. This study was sponsored, in part, by the UALR College of Sciences Office of Research, Science, and Technology.

Table 1. Season, harvest, and price correlation coefficients for 12 most important Arkansas furbearers. Data reflect 20 harvest seasons (1965-1984) except for SpS and StS where only 16 seasons (1965-1980) were used. Values for harvest are to the top and right in the table; values for price are to the left and lower portion of the table.

	CY	MR	OT	NU	HK	SpS	SpS 16	StS	StS 16	BV	OP	GF	RC	BC	Season
CY	---	.653	.738	.840	.723	.748	.881	.648	.822	.907	.924	.723	.950	-.453	
MR		---	.649	.675	.759	.197	.237	.175	.213	.425	.543	.690	.795	.282	.196
OT			---	.761	.751	.304	.694	.168	.653	.666	.620	.697	.829	.793	-.474
NU				---	.811	.437	.636	.371	.605	.830	.728	.802	.475	.792	-.375
HK					---	.427	.702	.372	.742	.834	.762	.812	.506	.747	-.396
SpS						---	.534	.791	.716	.560	.743	.222			
SpS16							---	.914	.693	.890	.832	.866	.879	.394	
StS								---	.432	.736	.670	.475	.646	.021	
StS16									---	.643	.866	.856	.879	.858	-.201
BV										---	.876	.810	.843	.775	-.392
OP											---	.900	.892	.883	.389
GF												---	.892	.956	-.495
RC													---	.064	-.439
BC														---	-.486
S															---

Species identifications: CY - coyote, MR - muskrat, OT - river otter, NU - nutria, HK - mink, SpS - spotted skunk, StS - eastern striped skunk, BV - beaver, OP - opossum, GF - gray fox, RC - raccoon, BC - bobcat, S - season length.

Table 2. Significance of season length, harvest, and price correlation coefficients for 12 most important Arkansas furbearers. Values for harvest are to the top and right in the table; values for price are to the left and lower portion of the table. Species identification codes are indicated in Table 1.

	CY	MR	OT	NU	HK	SpS	SpS 16	StS	StS 16	BV	OP	GF	RC	BC	Season
CY	---	**	**	**	**	**	**	**	**	**	**	**	**	**	*
MR		---	**	**	**	**	**	**	**	**	**	**	**	**	**
OT			---	**	**	**	**	**	**	**	**	**	**	**	*
NU				---	**	**	**	**	**	**	**	**	**	**	**
HK					---	**	**	**	**	**	**	**	**	**	**
SpS						---	**	**	**	**	**	**	**	**	**
SpS16							---	**	**	**	**	**	**	**	**
StS								---	**	**	**	**	**	**	**
StS16									---	**	**	**	**	**	**
BV										---	**	**	**	**	**
OP											---	**	**	**	**
GF												---	**	**	*
RC													---	**	**
BC														---	*
S															---

* = significant value, $k > 0.444$ ($n=20$, $p=0.05$) or $k > 0.561$ ($n=16$, $p=0.01$)

** = highly significant value, $k > 0.561$ ($n=20$, $p=0.01$) or $k > 0.623$ ($n=16$, $p=0.05$)

ns = nonsignificant values

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DRYOPTERIS CARTHUSIANA AT MT. MAGAZINE, LOGAN, CO., ARKANSAS

Until the present, the only verifiable Arkansas population of the spinulose wood fern, *Dryopteris carthusiana* (Villars) H. P. Fuchs (*D. spinulosa* [O. F. Muell.] Watt), was one discovered by D. M. Moore on 7 August, 1960, at the entrance to Rowland Cave in Stone Co. This population represents the most extreme southwestern population of this species in eastern North America (Carlson & Wagner, Contr. Unif. Michigan. Herb. 15:141-162, 1982). In spite of the phytogeographic importance of this species in Arkansas, its presence and location has not been known with much certainty.

It was first reported for Arkansas by Lesquereux (A catalog of the plants of Arkansas, Pp. 346-399 in Owen, *Second report of a geological reconnaissance of the middle and southern counties of Arkansas made during the years 1859 and 1860*, 1860) from "woods". Based on this report, it was included in state lists by Harvey (Bot. Gaz., Crawfordsville 6:188-190, 1881) and Branner & Coville (A list of the plants of Arkansas, Pp. 155-242, in Branner, *Annual report of the Geological Survey of Arkansas for 1888*, Vol. IV, 1891). Buchholz (Am. Fern J. 14:33-38, 1924) expressed doubt about the presence of this species in Arkansas, in that he could not locate voucher material. Based on a discovery by Dwight M. Moore in 1924 (Moore, Am. Fern J. 31:63-71, 1941), Buchholz and Palmer (Trans. Acad. Sci. St. Louis 25:91-155, 1926) reported this species from the north side of Mt. Magazine, Logan Co., Arkansas. Recent efforts to locate a voucher or plants at that locality were also unsuccessful (Taylor & Demaree, Rhodora 81:503-548, 1979; Taylor, *Arkansas ferns and fern allies*, 1984, p. 106).

On 5 October, 1985, while surveying the status of *Woodsia scopulina* D. C. Eat. on Mt. Magazine, I located 4 plants of *D. carthusiana* on the northside of the mountain, near its summit, in the vicinity of Brown's Spring. This population, associated with three other fern species also occurring as peripheral populations (*Dennstaedtia punctilobula* [Michx.] Moore, *Dryopteris marginalis* [L.] Gray, and *Woodsia scopulina* D. C. Eat.), is most probably the population initially discovered by Moore in 1924. Verification of the occurrence of a Mt. Magazine population extends the known range of *D. carthusiana* 300 km to the southwest of the Stone Co. population. The occurrence of this northern species in Arkansas appears to be related to "northern" environmental factors provided in Logan Co. by elevation (860 m) at the top of the tallest mountain in Arkansas and in Stone Co. by moderated, cool, moist air blowing from a cave entrance. Based on the known locations of *D. carthusiana* in Arkansas, it is most improbable that Lesquereux ever saw this species in Arkansas during his travels; the earlier attributions of this species in the Arkansas flora must be considered spurious.

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A SURVEY OF THE INTERIOR LEAST TERN ON THE ARKANSAS AND WHITE RIVERS IN ARKANSAS

Potential tern sites were first identified by aerial surveillance and then explored by boat. The initial step involved a two-day helicopter search for evidence of nesting terns on the Arkansas River from Little Rock to the Oklahoma state line (26 June), and from Newport to St. Charles on the White River and again on the Arkansas River from Lock and Dam #3 to Little Rock (27 June). Due to a need to refuel frequently, and the limited availability of refueling stations, the lower 30 miles of the White River and the Arkansas River from its mouth to Lock and Dam #3 were not surveyed from the air.

All potential tern colonies identified by air on the Arkansas River, upstream from Little Rock, were visited by boat (1, 2, and 8 July), and the lower White River from Lock and Dam #1 to the Mississippi River and back up the Arkansas River to Dam #2 also was surveyed by boat (17 July).

The helicopter, provided by the Corps of Engineers and piloted by Army Reserve pilots, flew at heights of 100 to 200 feet above the ground at speeds of 30 to 75 m.p.h. Care was taken not to disturb tern colonies with prop wash. Visits to sandbars upstream from Little Rock were made in early morning (before 9:00 a.m.) and evening (after 6:30 p.m.) hours to avoid exposing young birds and eggs to the heat of the mid-day sun. However, sandbars on the lower White and Arkansas rivers were searched from the water in mid-day due to the late start of that survey.

Four rookeries were observed, one of them previously known, on the Arkansas River above Little Rock, and one rookery was found at the mouth of the Arkansas River. Approximately 80 adult least terns, 86 juveniles, and 40 eggs were counted at the five rookeries. No terns were found elsewhere on the Arkansas River or on the White.

The rookery at river mile 147, located on a side channel bar (spoilbank), was surveyed three times. On 1 July, 14 adults and one downy chick were found. No eggs or egg fragments were seen. A second trip to the ternery on 19 July proved more fruitful. Eight juvenile birds, seven of which were highly mobile, and 16 adults were counted. On a third visit, made 27 July, two flying young of the year were seen, but only six adults and no nests or flightless young. Though adults dive-bombing in one area of the spoilbank indicated that at least one nest was still active,

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it appeared that several adult and juvenile birds had left the rookery.

Farther upstream at river mile 161.5, four adult birds were counted 1 July on a large side-channel bar. No juveniles, eggs, or nests were found, although three nests with three eggs each plus six empty nests and 16 adult birds had been observed there 26 May (Carroll Green pers. comm. 30 May 1985), and 30 adults, five flying young, and a nest with one hatching and one egg were found on 14 July 1984.

A mid-channel sandbar at river mile 240.4 provided habitat for ten adult birds. No juveniles and only one scrape with two eggs were counted. Fragments of three other eggs were discovered, possible indications that juvenile birds were on the island. The observation of an adult tern carrying a minnow also supports the possibility of young birds having been present.

A rookery located on a mid-channel sandbar at river mile 275 was the largest ternery on the Arkansas River above Little Rock. Twenty-four adults, seven juvenile birds (one of which was dead), and 36 eggs were found. Twenty nests, several of which contained eggs, were observed just downstream of river mile 275 on 4 July 1981. Closer to Fort Smith, six nests and three eggs were found in June 1958. In June 1959 two nests were discovered, and later in July, two juveniles were observed at the same site.

Downstream on a side-channel sandbar at the mouth of the Arkansas River (Mississippi River mile 582) was the second largest tern colony ever reported in the state. More than 20 adults and 70 juvenile birds were counted along a two-mile stretch of beach on the Mississippi River side of the island.

The distribution of interior least terns on the Arkansas River is determined by water levels. As terns move upriver into Arkansas, they settle only on exposed sandbars. Because sandbars on the lower reach of the Arkansas River from Little Rock to its confluence with the Mississippi River and the White River from Newport to the navigation channel often are inundated in May and early June, these lower river sections probably are bypassed by terns. Therefore, in May and June, the beginning of the tern nesting season in Arkansas, terns will be found upstream where sandbars are exposed.

The slope of the Arkansas River also has much to do with the location of terns and their rookeries. In the river's upper reach, the slope is greater — which causes the river to cut deeper into the channel, therefore creating higher sandbars. Below Little Rock, the slope is less, the river is broader, and sandbars are flatter, more spread out. Consequently, it takes less water (volume) to inundate downstream sandbars, which often can remain wet into June or early July.

Because of its location, the sandbar at the mouth of the Arkansas River is not influenced significantly by water levels on the Arkansas. Most of the island borders the Mississippi River and the rookery here actually should be considered a Mississippi River colony. However, since it was found as part of the Arkansas River survey, it is included in this report.

In contrast to the Arkansas River, sandbars on the White River are not as extensive. The channel of the White River is narrower and much more convoluted. Long, wide bends, ideal for the deposition of sand and gravel and common on the Arkansas River, are absent on the White. Sandbars on the White River, therefore, are smaller and usually are found on the inside bend of the channel. These areas normally remain under water into June. Together, the lack of sandbars and high water levels prohibit the use of the White River and its major tributaries for least tern nesting.

Colonies of interior least terns on the Arkansas River are vulnerable to several threats including high water levels, dredging operations, cattle grazing and all-terrain-vehicle (ATV) use. Of these, high water is probably the most serious threat to rookeries and the most difficult to control, given the unpredictability of Arkansas weather and the frequency of summer flooding in the state. For example, the sandbar downstream of Fort Smith that had a rookery on it in June 1981 was under water the next year. Had terns reused the island in 1982, eggs and newly hatched chicks would have been swept away. After such an experience, it might take several days or weeks before adult terns would attempt to renest. To illustrate further the potential threat, high water levels have been recorded at river mile 275, in May and June, six times in the last five years.

Considerable habitat destruction occurred at three of the five rookeries surveyed this year. The rookery at river mile 147 may have been impacted by a bulldozer leveling spoil material from a nearby dredging operation on 1 July 1985. Only one chick, no eggs, and very few scraps were found in an area which had been leveled recently. A part of the rookery apparently survived the bulldozing since eight juvenile birds were discovered in an undisturbed area on 19 July.

Dredging itself, posed no threat to tern colonies since no sandbars used by the terns were located in the navigation channel. The deposition of spoil during the nesting season, though, could cause serious problems for the Arkansas River rookeries.

Unusual as it may be, at river mile 161.5, cattle may have reduced a thriving colony of least terns and young in 1984 and on 26 May 1985 to only four adult birds by 1 July 1985. The sandbar, one of the most extensive surveyed on the Arkansas River, was covered with cattle tracks. On the other hand, eggs and juvenile birds observed in May could have developed into fledged young by July and left the sandbar along with the adult terns.

At river mile 240.4, ATVs were a serious threat to a rookery. ATV tracks criss-crossed the primary nesting area on the sandbar. Several scrapes were located, but only one scrape had eggs and no young or tracks of young were discovered. Spent rockets and fireworks also covered the area. The fourth of July, no doubt, is a peak period for ATV recreationists on the Arkansas.

The author appreciates the valuable contributions made to the interior least tern survey by the Little Rock District of the Corps of Engineers and the Arkansas Game and Fish Commission. As noted earlier, the Corps procured a helicopter and pilots for the aerial survey and provided a river-worthy boat for the lower Arkansas River survey. The Game and Fish Commission made available a truck and boat for the upper Arkansas River tern survey. The contributions of biologists Clyde Gates (Corp of Engineers) and Craig Uyeda (Game and Fish Commission) are noted with appreciation. Gates and Uyeda stayed with the survey throughout its duration and assisted in many ways.

The assistance provided by Bill Shepherd of The Arkansas Natural Heritage Commission was invaluable. Bill provided excellent guidance at every phase of the project, and his keen eyes and expert identification skills kept me from mistaking killdeer for terns. Lance Peacock of the Arkansas Nature Conservancy assisted by participating in the aerial survey. Special thanks are extended to Carol Smianiotto for typing the report.

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ADDITIONAL RECORDS OF DISTRIBUTION AND HOSTS FOR THE BAT BUG, *CIMEX PILOSELLUS* IN ARKANSAS

The bat bug, *Cimex pilosellus* Harvath, is a wingless, parasitic insect approximately 6mm in length. It is a common ectoparasite of many chiropteran species. As reported by Usinger (1966, Monograph of Cimicidae, Entomol. Soc. Amer., College Park, Maryland) this insect usually stays in the roost while bats forage. It is in the roost that the insect obtains its blood meal.

The initial record of *C. pilosellus*, in Arkansas was reported by Price et. al. (1982, Proc. Ark. Acad. Sci. 37:98). This record was obtained

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from a colony of *Eptesicus fuscus* in a home in Brinkley, Monroe County. For this record, specimens of the insect were collected from bats and captured by hand and from mist nets.

The authors have been conducting an extensive study of the chiropteran fauna of Southwestern Arkansas. To date the study has resulted in the collection of several hundred bats and *C. pilosellus* has been encountered on six occasions and at six new locations.

The first new record of this insect is from a well in Columbia Co., at an abandoned house site just north of the Louisiana-Arkansas border. Several bats were taken from the well by hand. Among these was a bat having two cimicides clinging to its uropatagium. In addition to the new county record, this find is notable because the bats were *Plecotus rafinesquii* and our review of the literature revealed no other report of *C. pilosellus* preying upon the eastern big-eared bat.

Bat bugs were next encountered in Sevier County. While mist netting over a rocky stream in a thickly wooded area near an open face rock quarry, sixteen bats were collected. Among the bats was an *Eptesicus fuscus* with two cimicides attached to its uropatagium. This collection was from a foraging bat substantiating that cimicides do not always remain behind in the roost when the bats leave. Additionally, these bats were collected from an area devoid of assessable human structures. All of our other records were associated in some way with human structures.

Our third new report is from Garland County. From a residence in Hot Springs, a mixed colony of *Tadarida brasiliensis* and *E. fuscus* was discovered. Although we observed many cimicides associated with the colony, they were invariably most intimately associated with *E. fuscus* rather than with *T. brasiliensis*.

The fourth new report was obtained from Calhoun County. The site was a recently demolished bridge over a shallow stream in a thickly wooded area. Of eight bats netted, one *P. rafinesquii* was found to have a cimicide attached to its right wing.

A house in Texarkana, Miller County yielded a fifth new record of *C. pilosellus*. A single cimicide was removed from the back of a *P. rafinesquii* (one of several in the house).

The most recent new record we report is from Lafayette County. From an area NE of McKamie, an additional *P. rafinesquii* was found having a cimicide attached to its uropatagium.

These six additional records of *C. pilosellus*, from scattered locations, indicate that the bats of southern Arkansas support a wide spread infestation of this ectoparasite. Interestingly, no single species is responsible for harboring *C. pilosellus* in Arkansas.

Voucher specimens from these studies have been deposited in the appropriate collections of Arkansas State University.

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EVALUATION OF A FIN RAY SCARRING TECHNIQUE FOR INDIVIDUALLY MARKING FISH

A mark for use on fish that is inexpensive, quickly applied, permanent, and permits individual identification has been needed by fisheries scientists and fish culturists for many years. A technique for marking fish that apparently meets all of the above criteria has been previously tested on several cold-water fish species under both laboratory and field conditions in Canada (Welch and Mills, Can. J. Fish. Aquat. Sci., 38:1168-1170, 1981). We report here the results of further tests conducted at both Sooner Fish Farm, a commercial catfish farm at Washington, Oklahoma, and at the University of Arkansas at Pine Bluff Agricultural Experiment Station, with two fish species used in warm water aquaculture.

The mark is created by severing a fin ray at about mid-length with fine-pointed scissors (Fig. 1). The ray should be completely severed but care should be taken not to tear the membrane between the rays, nor remove the distal portion of the severed ray. We are normally able to weigh, measure and mark a fish a minute with this method.

The severed ray mends completely in 4 to 6 weeks, forming a bony knot (Fig. 2) that is about twice the diameter of the ray. This mark is both easily seen and felt since it is larger than the rest of the ray (Fig. 3). The mark also appears darker than the rest of the ray when viewed with transmitted light.

Marks were produced in September, 1975, on the dorsal soft-rays of bigmouth buffalo (*Ictiobus cyprinellus*), averaging 2.2 kg, prior to stocking in a 1.6-ha commercial catfish culture pond. The marks were still obvious 18 months later when the pond was harvested (Fig. 3). Unfortunately, since we were unable to examine the entire population at that time, it could not be determined if some individuals had lost the mark.

The technique was subsequently used on both a dorsal soft-ray and spiny-ray of 225 blue tilapia (*Tilapia aurea*), averaging 195 g. There was 100% mark retention on the tilapia after 6 months, by which time the fish had grown to an average weight of 405 g. The marks on both the spiny-rays and soft-rays appeared equally visible (Fig. 4).

This technique is quick and easy to use, causes little trauma to the fish, and appears to be permanent, at least within the limits of this study. While the marks are visible upon examination, they would probably be overlooked by an untrained observer.

This technique can be extremely useful to fisheries scientists as well as fish culturists. While we have only applied marks to dorsal fin rays, this technique should work equally well on any fin, and on any fish species. A simple coding system using one or more marks on various soft-rays and/or spiny-rays can be used to batch mark groups, such as brood stock from different sources or age classes, as well as to mark individual fish. We have also used this technique for the short-term (<1 month) marking of fish. While the knot obviously doesn't have time to completely form in this time, the severed ray itself serves to identify the fish. We found, as did Welch and Mills (1981) that the main disadvantage of this technique is the potential for error in counting the fin rays when marking or reading the marks.

General Notes

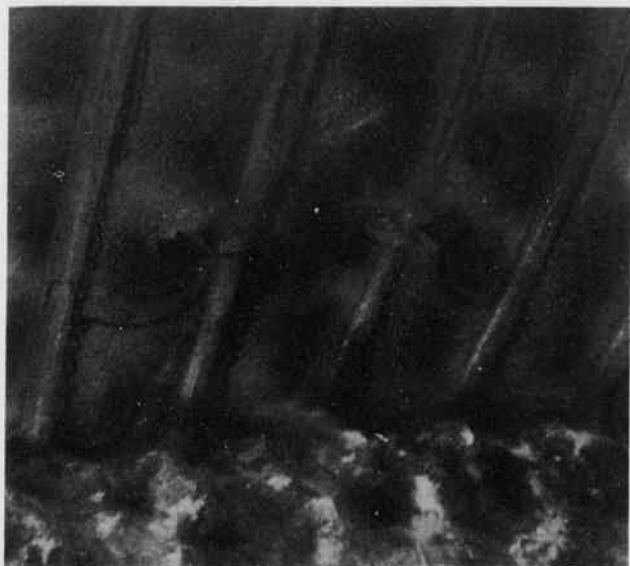


Figure 1. Dorsal fin of blue tilapia showing both a spiny-ray (left) and soft-ray (right) just after being severed (arrows).

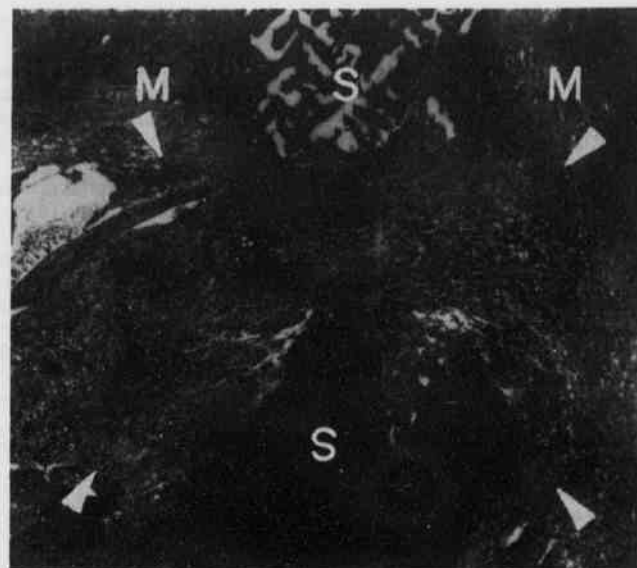


Figure 2. Medial histological section (H & E stained) through a dorsal spiny-ray of blue tilapia 10 days after being severed (arrows mark the approximate boundary of the knot being formed; S = spiny-ray; M = fin membrane).



Figure 3. Dorsal fin of bigmouth buffalo showing two marks (arrows) on soft-rays after 18 months of growth.

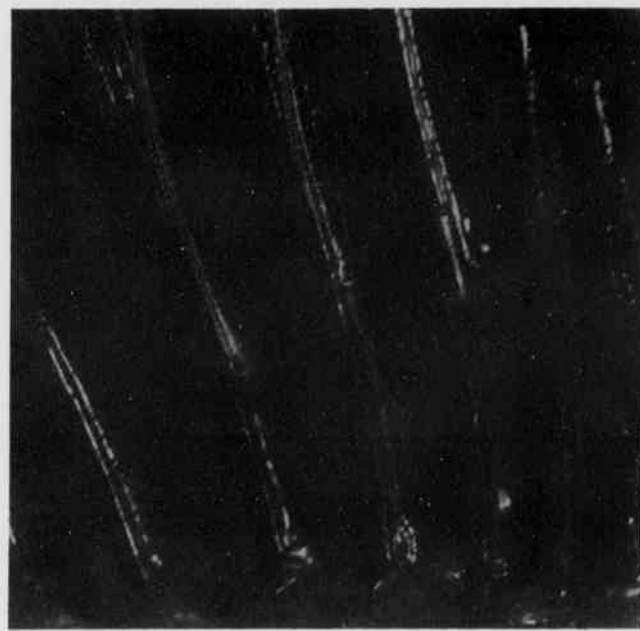


Figure 4. Dorsal fin of blue tilapia showing marks (arrows) on both a spiny-ray (left) and soft-ray (right) after 6 months of growth.

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EFFECT OF STUNTING ON THE GROWTH OF BLUE TILAPIA (*TILAPIA AUREA*, CICHLIDAE)

Aquaculture is gaining widespread importance in Africa as a means of providing high quality protein in the rural areas. Several *Tilapia* species (Family Cichlidae) are cultured in Africa because of their prolific reproduction, rapid growth, omnivorous food habits and relative hardiness. Fingerlings for stocking new or recently harvested ponds are obtained from older, established ponds. Often these fingerlings are stunted, having had their growth suppressed for several months due to over-crowding and competition for food in the older pond (Torrans, Proc. Peace Corps Pan-African Aquaculture Conf., Libreville, Gabon, 1983, in press).

The effect of previous stunting on the growth potential of fish stocked in new ponds is not clear. Stunted bluegill, *Lepomis macrochirus*, have been shown to exhibit slower growth rates than non-stunted individuals when reared under similar conditions (Murnyak, Murnyak and Wolgast, Prog. Fish-Cult., 46(2):133-138). However, researchers at the Lajas Aquaculture Center in Puerto Rico have shown that stunting has no effect on the growth potential of Nile tilapia, *Tilapia nilotica* (Anon., Southern Region Cooperative Research Project S-168 Annual Report 1983: Warm-water Aquaculture, May, 1985). We report here the results of a study conducted at the University of Arkansas at Pine Bluff Agricultural Experiment Station to determine the effects of stunting on the growth potential of blue tilapia *Tilapia aurea*.

One-year-old fish were produced in ponds during the summer of 1984 and over-wintered in indoor heated tanks until the spring of 1985. Two-year-old fish were produced in ponds during the summer of 1983 and held in indoor heated tanks for approximately 18 months. Both age classes of fish were produced from the same genetic stock, and fed maintenance diets while held indoors.

Twenty males were selected from each of the two age classes. Each fish was weighed to the nearest gram and individually marked by scarring different dorsal fin rays (Welch and Mills, Can. J. Fish. Aquat. Sci., 38:1168-1170, 1981). Both groups were stocked on May 1, 1985 in the same 0.05 ha earthen pond. The pond was previously fertilized with manure to produce a plankton bloom, and the fish were fed to satiation once daily for a 90-day period with a 32% protein floating pelleted feed.

The pond was harvested on July 30, and 17 males that were identifiable by their marks were recovered from each age class. The remaining six fish stocked in the pond were mortalities, unidentifiable individuals, and one female that was misidentified at stocking. All analyses were based on the initial and final weights of the 17 males from each age class whose identity at both stocking and harvest was certain.

The one-year-old group grew from an initial average weight (\pm S.D.) of 76.1 ± 11.8 g to 237.6 ± 17.9 g over the 90-day period, for an average growth rate of 1.79 ± 0.25 g/day. The two-year-old group grew from an initial average weight of 76.2 ± 8.5 g to 231.9 ± 13.6 g, for an average growth rate of 1.73 ± 0.21 g/day. There were no significant differences in initial weight, final weight, or growth rate between the two groups (T-Test, $n = 17$, $P = 0.05$).

The results of this study indicate that stunting has no significant effect on the growth of male blue tilapia when they are subsequently reared under conditions conducive to growth. The contradictory results previously reported for bluegill may be due to the fact that the two age groups used in that study came from two different populations, not the same population as in our study, and may have had different genetic potentials for growth.

Therefore, if tilapia are to be reared in monosex (all-male) production ponds, growth rates should not be significantly affected by prior stunting of the fish. However, if male and female tilapia are to be reared together in mixed-sex culture, as is typically the case in Africa, the stocking of fingerlings over two months old, whether stunted or not, is not recommended. Female blue tilapia reach sexual maturity at four to five months of age, and will spawn at approximately monthly intervals thereafter. If females that are approaching sexual maturity are stocked in a pond with males, the resulting recruitment can severely reduce the growth of the original stock through competition for food (Torrans, Proc. Peace Corps Pan-African Aquaculture Conf., Libreville, Gabon, 1983, in press), resulting in a harvest of fish that may be too small to market.

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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.

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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.

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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 Compara-

tive 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).

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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.

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