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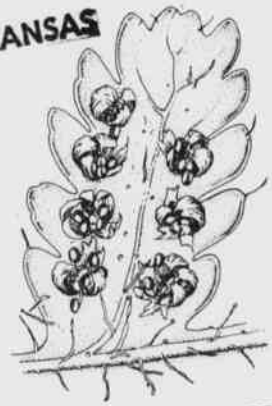

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DEPT. OF NATURAL SCIENCE
MONTICELLO, ARKANSAS 71655

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PAST PRESIDENTS OF THE ARKANSAS ACADEMY OF SCIENCE

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

INSTITUTIONAL MEMBERS

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

ARKANSAS COLLEGE, Batesville
ARKANSAS STATE UNIVERSITY, State University
ARKANSAS TECH UNIVERSITY, Russellville
COLLEGE OF THE OZARKS, Clarksville
HARDING COLLEGE, Searcy
HENDERSON STATE UNIVERSITY, Arkadelphia
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UNIVERSITY OF ARKANSAS AT FAYETTEVILLE
UNIVERSITY OF ARKANSAS AT LITTLE ROCK
UNIVERSITY OF ARKANSAS FOR MEDICAL SCIENCES, Little Rock
UNIVERSITY OF ARKANSAS AT MONTICELLO
UNIVERSITY OF ARKANSAS AT PINE BLUFF
UNIVERSITY OF CENTRAL ARKANSAS, Conway

EDITORIAL STAFF

COVER: ***Woodsia scopulina*** D. C. Eat. var. ***appalachiana*** (T. M. C. Taylor) Morton, the Appalachian Woodsia, one of the rarest ferns in the Arkansas flora; an illustration by Paul W. Nelson (reprinted with permission from the book by W. C. Taylor [1984, Arkansas Ferns and Fern Allies, Milwaukee Public Museum, Milwaukee, WI].)

PROCEEDINGS
ARKANSAS ACADEMY OF SCIENCE

Volume 41 **1987**

Secretary's Report

MINUTES OF THE SEVENTY-FIRST ANNUAL MEETING, 3-4 APRIL 1987

FIRST BUSINESS MEETING

Ed Bacon, President, called the meeting to order.

John Rickett, Local Arrangements Chairman, introduced Dr. Joel Anderson of the University of Arkansas at Little Rock, who welcomed the Academy on behalf of UALR and the Capitol city. Rickett made several announcements. He asked that the session chairpersons try to stay on time. He also asked the presenters to be sure that slides are available to the projectionist before the session.

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

Art Johnson, Treasurer, presented the Financial Report. He briefly discussed the report and indicated that the Academy is in good financial shape. He indicated that the cost of the *Proceedings* is high but that it will be covered easily. He presented the following motion:

> Mr. President, I move that the Academy raise the dues for regular members to $15, for sustaining members to $20, and for sponsoring members to $30 while leaving the Associate dues and Life memberships the same.

The motion was seconded and will be voted on at the Second Business Meeting. An Audit Committee consisting of Bob Wiley (Chairman), Jim Fribourgh, and Dave Chittenden will examine the report. A copy of the report follows.

★ ★ ★ FINANCIAL STATEMENT ★ ★ ★

Statement Approved by Audit April 6, 1985	
First State Bank and Trust Co., Conway, AR	
TOTAL Account	5,254.93
Certificates of Deposit	
Security Savings and Loan Association of Conway	
Certificate of Deposit(C 01-70048490)	1,115.10
First State Bank and Trust Co., Conway(0007-769-4)	2,266.01
TOTAL FUNDS, April 5, 1986	$ 8,636.04

SUMMARY

(March 12, 1986 to March 15, 1987)

Balance Approved by Audit on April 5, 1986		$ 8,636.04
Total Income(Page 2)	13,276.41	
Total Expenses(Page 3)	11,417.00	
Balance for the Year	$ 1,859.41	$ 1,859.41
FUNDS ON HAND AS OF MARCH 15, 1987		$ 10,495.45

DISTRIBUTION OF ACCOUNTS

TOTAL Account		$ 5,686.07
Certificates of Deposit		
First State Bank and Trust Co., Conway(0007-769-4)		2,501.26
Security Savings and Loan Assn., Conway(C 01-70048490)		1,230.87
First National Bank of Conway(78940)		1,077.25
		$ 10,495.45
INCOME: March 12, 1986 to March 15, 1987		
1. ANNUAL MEETING: OBU APRIL 4-5, 1986		$ 4,225.00
2. INDIVIDUAL MEMBERSHIPS		
a. Regular(115)	$ 1,150.00	
b. Sustaining(12)	190.00	
c. Sponsoring(15)	900.00	
d. Life(3)	600.00	
d. Associate(2)	10.00	
Total	. 2,850.00	2,850.00
3. INSTITUTIONAL MEMBERSHIPS(22)		1,100.00
4. PROCEEDINGS, Subscriptions		284.50
5. PROCEEDINGS, MISC. SALES		935.10
6. PROCEEDINGS, Page Charges		2,680.00
6. BIOTA RECEIPTS		217.65
7. INTEREST		601.22
a. First State Bank and Trust Co.(Conway)		
1) TOTAL Account	250.20	
2) CD(0007-769-4)	235.25	
b. Security Savings and Loan Assn.(Conway) CD(C-01-70048490)	115.77	
8. ENDOWMENT		360.00
9. CHECK #197 NOT REDEEMED IN 1985-86 YEAR		22.94
TOTAL INCOME		$ 13,276.41
EXPENSES: March 12, 1986 to March 15, 1987		
1. PROCEEDINGS: Publication and Distribution		
a. Phillips Litho Co., Inc.(#213)	$7,856.20	
b. V. Rick McDaniel(#210)	107.31	
c. Mary Ann McDaniel(#201)	500.00	
Total	8,463.51	$ 8,463.51
2. AWARDS		
a. Keitha H. Smith(#202)	50.00	

Secretary's Report

	b.	Monica L. Vooley(#203)	50.00	
	c.	Todd Harrison Rider(#207)	35.00	
	d.	Charles Eldon King(#208)	30.00	
	e.	Arkansas State Science Fair(#212)	200.00	
	f.	John D. Peck(#206)	28.60	
	g.	Junior Academy of Science(#215)	200.00	
		Total	593.60	593.60
3		MEETING EXPENSES(OBU STATEMENT)		1,452.67
4.		OPERATING COSTS		
	a.	President's Office(#209)	12.00	
	b.	Secretary's Office-Postage(#211,#214)	250.00	
	c.	Treasurer's Office-Supplies(#222)	20.74	
		Total	282.74	282.74
5.		NEWSLETTER		
	a.	Copy Cat(#216)	312.32	
	b.	UALR Biology Department(#217,220)	88.92	
	c.	Gloria's Print and Office Supply(#219)	184.64	
		Total	585.88	585.88
6.		DUES-National Association of Academies of Science		28.60
7.		MISCELLANEOUS(#220)		10.00
		TOTAL EXPENSES		$ 11,417.00

Respectfully Submitted

Arthur A. Johnson, Treasurer

Meeting: April 3-4, 1987
Riverfront Hilton, North Little Rock, Arkansas--Sponsored by UALR

Rick McDaniel, Editor of the *Proceedings,* was not present so no report was presented on this year's edition. James Peck, the in-coming Editor, reminded presenters that papers should be in proper journal format. He also reminded section chairs be sure to collect papers at the sessions and to turn in those papers. 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 41 of the *Proceedings.*

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

John Rickett, Editor of the Newsletter, indicated that 1327 copies of the fall Newsletter and 347 copies of the spring Newsletter were distributed. He stated that he needs institutional representatives from some institutions to gather news for the spring Newsletter. 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.

Art Johnson reported for Paul Krause concerning the Arkansas Junior Academy of Science. He discussed a letter from Krause indicating the need for financial support. He moved that the Academy appropriate the sum of $200 to support the Arkansas Junior Academy of Science. The motion was seconded and will be voted on at the Second Business Meeting.

Art Johnson also reported for Mike Rapp, Director of the Arkansas Science Fair Association, reported on the Science Fair. He moved that the Academy appropriate $200 to be given to the Arkansas Science Fair Association to support its activities. The motion was seconded and will be voted on at the Second Business Meeting. He reported on the success of the regional and state fairs. On behalf of Mike Rapp, he moved that appreciation be expressed to the regional directors. The motion was seconded. It was moved to amend the motion to include appreciation to Mike Rapp also. The amendment was seconded and passed. The final motion reads:

The Arkansas Academy of Science expresses its commendation to the following people for the many hours of hard work and planning that they and others have given. This work has provided an opportunity to encourage and recognize the work of three to four hundred junior and senior high students and teachers.

> Michael W. Rapp, State Director
> Bonnie Moody, Central Region
> Veryl Board, North Central Region
> Mark Draganjac and Joseph McGrath, Northeast Region
> Les Howick, Northwest Region
> Marc Steele, South Central Region
> Gordon Culpepper, Southeast Region
> Rudy Eichenberger, Southwest Region

The motion 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 36th Annual Arkansas Science Talent Search 1986-87, held in conjunction with the 46th Westinghouse Science Talent Search.

First Place

Kyle James Weld	School:	Weiner High School
P.O. Box 313	Teacher:	Mr. Hillard Clark
Fisher, AR 72429	Project:	Isolation of Bacteria that Modify Antibiotics

Second Place

Seth Mingea Lowrey	School:	Sheridan High School
P.O. Box 153	Teacher:	Ms. Mary Frances Harper
Sheridan, AR 72150	Project:	Excursions into Experimental Geometry

Third Place

Deidre Michelle Schuchman	School:	Oak Ridge Central High School
Route 1, Box 191	Teacher:	Ms. Angelyn Baldwin
Ravenden Springs, AR	Project:	The Presence or Absence of Auditory Stimuli: Their Effect on Cardiovascular and Neuromuscular Functions

He moved that the Academy appropriate $120 to be used by the Arkansas Science Talent Search. The motion was seconded and will be voted on at the Second Business Meeting.

Tom Palko, Director of the Arkansas Junior Science and Humanities Symposium, reported that the Symposium had 109 papers submitted. Fifteen of these were read and five of these were awarded trips to the National Symposium and four were awarded scholarships. He stated that the Symposium does not need financial support. However, he requested assistance from scientists at the various institutions in identifying students doing summer research.

Henry Robison, Historian, reported that this is the 71st Annual Meeting and that it is the 5th time the Academy has been hosted by the University of Arkansas at Little Rock or its predecessors.

Eric Sundell, Chairman of the Nominating Committee, presented the nominees for Vice President. The nominees were Leo Bowman, Arkansas Tech University, and Dave Chittenden, Arkansas State University. An additional nomination of Tom Palko, Arkansas Tech University was made from the floor. It was moved and seconded to close nominations and the motion passed. He also indicated that the committee nominated Robert Wiley, University of Arkansas at Monticello, for Treasurer. No other nominations were made and it was moved and seconded to close nominations. The motion passed.

Leo Paulissen reported on the Biota Survey. Five new checklists are available including ferns, birds and fishes. A combined list is also now available and will be available tomorrow. He expressed appreciation for a $200 contribution.

Robbin Anderson, Chairman of the Science Education Committee, indicated that a report of committee activities was available and discussed some areas of interest. He also asked those present who might be interested in activities of the committee to so indicate.

President Bacon asked for other Committee reports and there were none.

The Resolutions Committee will consist of Joe Guenter and Bob Watson.

President Bacon announced that the 1988 meeting will be at Arkansas Tech University and indicated that a site for the 1989 meeting is needed.

President Bacon asked for old business and none was presented.

President Bacon asked for new business and none was presented.

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

President Bacon announced a Development Committee meeting for 4 P.M.

President Bacon adjourned the First Business Meeting.

SECOND BUSINESS MEETING

Ed Bacon, President, called the meeting to order.

Walter Godwin, Secretary, moved the approval of the minutes of the Seventieth Annual Meeting as distributed with a correction in the spelling of the name Johnston. The motion was seconded and passed.

Eric Sundell, Chairman of the Nominating Committee, reported that the nominees for Vice President were Leo Bowman, Dave Chittenden, and Tom Palko. Ballots were distributed, collected and counted. He also reported that the only nominee for Treasurer was Robert Wiley. It was moved and seconded to accept Wiley as Treasurer by acclamation. The motion passed.

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

> The Audit Committee reviewed the attached 1986-87 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 for the past five years.
>
> Respectfully submitted,
> Robert W. Wiley, Chairman
> Dave Chittenden
> James H. Fribourgh

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 from the First Business Meeting to increase dues was restated. After some discussion, it was passed unanimously.

A report was presented on the results of the election for Vice President. A runoff was required between Dave Chittenden and Tom Palko. Ballots were again distributed, collected and counted.

Rick McDaniel, Editor of the *Proceedings,* reported that the *Proceedings* were not ready. He stated that he hoped that they would be ready by the end of the summer or at least by early fall. There will be fewer pages this year and thus less cost. The motion, presented at the First Business Meeting, to allocate $620 for editorial assistance and travel for next year was passed.

John Rickett, Editor of the Newsletter, briefly repeated his discussion of the Newsletter. His motion, presented at the First Business Meeting, to allocate $650 for the Newsletter for next year was passed.

Henry Robison, Historian, repeated his report from the First Business Meeting.

The motion, presented at the First Business Meeting, to allocate $200 for support of the Junior Academy for next year was passed.

The motion, presented at the First Business Meeting, to allocate $200 for support of the State Science Fair Association for next year was passed.

The motion, presented at the First Business Meeting, to allocate $200 concerning commendation for the State and Regional Directors of the State Science Fair was passed.

John Peck again reported for the Arkansas Science Talent Search stating that 3 students received national honors and reporting the state winners. The motion he presented at the First Business Meeting to allocate $120 for the Arkansas Science Talent Search for next year was passed.

Tom Palko, Director of the Arkansas Junior Science and Humanities Symposium, again requested assistance from memberships in aiding students in projects and identifying students who have performed projects which might be presented.

Leo Paulissen reported for the Development Committee. We have reached $1000 in the Dwight Moore Fund and the money is now in a CD. Additional monies in the amount of $600 have already been collected and he encouraged additional contributions.

Leo Paulissen also reported on the Biota Survey. Five new lists have been added including birds and vertebrates. A consolidated checklist is now available and all lists will be available after the meeting.

Phillip Kehler, Chairman of the Undergraduate Awards Committee acknowledged the Judges who were Dick Hanson, UALR, and Alex Nisbet, OBU, for Physical Science and John Bridgeman, U of O, Peggy Rae Dorris, HUS, and Neal Buffaloe, UCA, for Life Science. He reported that the Undergraduate Awards had been won by:

Physical Sciences: Hal Palmer - UALR
Thermal Analysis of Whey-Based Thermosetting Resins Using

Differential Scanning Calorimetry

Life Sciences: Belinda Raybon - UALR
Repopulation by the Prairie Vole *(Microtus ochrogaster)* in an Accidentally Burned Field in Central Arkansas

Results of the runoff election for Vice President indicated that Dave Chittenden had been elected.

Joe Guenter, Chairman of the Resolutions Committee, on behalf of himself and Bob Watson moved the adoption of the following resolution.

Be it resolved:

The members of the Arkansas Academy of Science express their gratitude to the Riverfront Hilton and the University of Arkansas at Little Rock College of Sciences for hosting the 1986 meeting of the Arkansas Academy of Science and to Vice President and Provost Joel Anderson for his warm welcome. Special thanks are due to the Local Arrangements Committee: John Rickett (Chairman), Jim Fribourgh, Dick Prior, and Gary Heidt for arranging an excellent meeting. We appreciate the interesting (if unsettling) lecture on earthquakes presented by Arch Johnston (Memphis State University).

The Academy appreciates the efforts of the various section chairpersons: Alan Price and George Harp (Aquatic/Environmental), Thomas Lynch (Biomedical), Gary Tucker (Botany), Joe Jeffers and Ralph Wolfe (Chemistry), Phillip Kehler (Geology), Dale Ferguson (Microbiology), Joe Guenter (Physics), Robbin Anderson (Science Education Symposium), Leo Bowman (Science Education), and David Saugey (Zoology).

The Academy thanks the judges for the student research papers: Dick Hanson and Alex Nisbet (physical science papers) and Peggy Rae Dorris, John Bridgeman, and Neal Buffaloe (life science papers).

The Academy also expresses gratitude to the various directors of the science activities supported by the Academy: Robbin Anderson (Science Education Committee), Mike Rapp (Director of the Arkansas Science and Engineering Fair), Tom Palko (Director of the Junior Science and Humanities Symposium), John Peck (Arkansas Science Talent Search), and Paul Krause (Arkansas Junior Academy of Science).

The Academy is grateful for the service of the officers of the Academy for 1986-1987: Edmond Bacon (President), Gary Tucker (President-Elect), Horace Marvin (Vice President), Walter Godwin (Secretary), Art Johnson (Treasurer), Rick McDaniel (Editor of the *Proceedings*), John Rickett (Editor of the Newsletter), Gary Heidt (Past President) and Henry Robison (Historian). The Academy especially appreciates the dedication and services of Art Johnson (Treasurer) and Rick McDaniel (Editor of the *Proceedings*) for the past five years.

The Academy members express their gratitude for the most enjoyable "Happy Hour" hosted by Jim Fribourgh and John Pauley and provided by UALR and UAMS.

The Academy appreciates the exhibits provided by Advanced Scientific and their representative David Brock.

Thanks is extended to Calvin Cotton for making the plaques for retiring officers and lettering the student research award certificates.

The Academy recognizes the dedicated and thorough work of the committee members and chairpersons: Leo Paulissen (biota Committee and Development Committee), Robbin Anderson (Science Education Committee), Jim Daly (Ad Hoc Committee on Sigma Xi Graduate Awards), Gary Tucker (Publicity Committee), Eric Sundell (Nominations Committee), Joe Guenter (Resolutions Committee), Rick McDaniel (Publications Committee), Robert Franke (Ad Hoc Committee on Arkansas Science and Technology Authority), Bob Wiley (Auditing Committee), Gary Heidt (Constitution Committee), and Phil Kehler (Awards Committee).

The motion was seconded and passed.

David Saugey presented a U.S. Forest Service Award to Darrel Heath for volunteer work. The award involved a Certificate of Appreciation for 1000 hours of service.

President Bacon presented a plaque in appreciation to Art Johnson who made a few brief comments. President Bacon also presented a plaque in appreciation to Rick McDaniel who also made a few brief comments. President Bacon recognized Calvin Cotton as creator of the plaques.

John Rickett expressed thanks to all the members for coming to the meeting and to the committees and students who worked on the meeting.

President Bacon read proclamations from the Governor concerning National Science Week for May of last year and for the next week for this year.

President Bacon called for old business and none was presented.

President Bacon called for new business and none was presented.

President Bacon announced that the meeting for next year will be at Arkansas Tech. He stated that there had been interest in the meeting for 1989 but no firm commitment had been made.

President Bacon called on President-Elect Gary Tucker and pased the gavel to him. President Tucker invited all members to the Arkansas Tech campus for next year's meeting. President Tucker presented Past President Bacon with a plaque in appreciation for his year of service. Bacon thanked the committees again for their work.

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

Respectfully submitted,

Walter E. Godwin
Secretary

REGULAR MEMBERS

John W. Ahlen	Arkansas Science & Technology Authority
Syed M. Aijaz	University of Arkansas at Pine Bluff
Silke Hufnagel Allen	Hendrix College
Neil T. Allison	University of Arkansas
John T. Annulis	University of Arkansas at Monticello
Michael L. Armstrong	Arkansas Game & Fish Commission
Robert K. Bacon	University of Arkansas
Sara Mills Barnett	Texarkana High School
Henry Barwood	Arkansas Mining Institute
Adelphia M. Basford	Henderson State University (Retired)
John K. Beadles	Arkansas State University
Helen Benes	University of Arkansas for Medical Sciences
John B. Bennett	Arkansas State University
Ann Marie Benson	University of Arkansas for Medical Sciences
Veryl V. Board	Arkansas College
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 Brown	University of Arkansas
Neal D. Buffaloe	University of Central Arkansas
Gary Burtle	University of Arkansas at Pine Bluff
Kay Cargill	University of Arkansas
Robert Carius	Arkansas College
Stanley L. Chapman	Univ. of Ark. Cooperative Extension Service
Frances E. Clayton	University of Arkansas
Malcolm K. Cleaveland	University of Arkansas
Richard R. Cohoon	Arkansas Tech University
Janice Lorraine Cooper	Arkansas State University
Bob W. Cowling	
R. T. Cox	
James G. Culpepper	University of Arkansas at Monticello
Fred Dalske	University of Central Arkansas
James J. Daly	University of Arkansas for Medical Sciences
James T. Daniels	SAU - Tech
Stanley N. David	Arkansas State University
David L. Davies	University of Arkansas for Medical Sciences
Don C. De Luca	University of Arkansas for Medical Sciences
Robert H. Dilday	Univ. of Ark. Cooperative Extension Service
Ronald M. Doran	Harding University
Larry W. Dorman	Univ. of Ark. Cooperative Extension Service
Peggy Rea Dorris	Henderson State University
Marian Douglas	
Benjamin T. Duhart	University of Arkansas at Pine Bluff
Danny J. Ebert	U. S. Forest Service
Jim Edson	University of Arkansas at Monticello
Rudolph J. Eichenberger	Southern Arkansas University
Hudson B. Eldridge	University of Central Arkansas
Daniel R. England	Southern Arkansas University
Don England	Harding University
Lawana England-Whaley	
Claude E. Epperson	University of Arkansas for Medical Sciences
Steve Filipek	Arkansas Game & Fish Commission
Sheldon Fitzpatrick	University of Arkansas at Pine Bluff
E. P. Floyd	U. S. Public Health Service (Retired)
Thomas L. Foti	Arkansas Natural History Commision
Robert Franke	University of Arkansas at Little Rock
Joe P. Gentry	Arkansas Science & Technology Authority
Michael George	Arkansas State University
John Giese	Arkansas Dept. of Polution Control & Ecology
Phillip S. Gipson	Arkansas Game & Fish Commission
Mattie Glover	University of Arkansas at Pine Bluff
Walter E. Godwin	University of Arkansas at Monticello
D. Leroy Gray	Univ. of Ark. Cooperative Extension Service
Gaston Griggs	John Brown University
Tyrrel C. Grohman	University of Arkansas for Medical Sciences
Mark Gross	U. of Ark. Graduate Institute of Technology
William C. Guest	University of Arkansas
Michael Halter	University of Central Arkansas
Earl L. Hanebrink	Arkansas State University
B. J. Hankins	Univ. of Ark. Cooperative Extension Service
Richard H. Hanson	University of Arkansas at Little Rock
James W. Hardin	University of Arkansas for Medical Sciences
George L. Harp	Arkansas State University
John L. Harris	Arkansas Highway & Transportation Department
Calvin J. Haskins	Arkansas Game & Fish Commission
Roger M. Hawk	U. of Ark. Graduate Institute of Technology
Mustafa Hemmati	Arkansas Tech University
Jo Ann Heslip	University of Arkansas at Pine Bluff
Craig Hilburn	Arkansas Game & Fish Commission
John R. Hodges	University of Arkansas at Little Rock
Kay Holtman	University of Arkansas at Little Rock
Arthur Hoyt, Jr.	University of Central Arkansas
Joe Jeffers	Ouachita Baptist University
Hugh A. Johnson	Southern Arkansas University
Michael I. Johnson	Nettleton High School
Jay Justice	Arkansas Dept. of Polution Control & Ecology
Phillip L. Kehler	University of Arkansas at Little Rock
William E. Keith	Arkansas Dept. of Polution Control & Ecology
Raj V. Kilambi	University of Arkansas
Scott Kirkconnell	Arkansas Tech University
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Richard Kluender	University of Arkansas at Monticello
Scott S. Knight	U. S. Department of Agriculture
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Roger E. Koeppe II	University of Arkansas
C. K. Koltman	
Randall A. Kopper	Hendrix College
Timothy A. Kral	University of Arkansas
Jack C. Kreie	Fayetteville Public Schools
Marie L. Lavallard	University of Arkansas (Retired)
Norman Lavers	Arkansas State University
Kwang Lee	University of Arkansas at Pine Bluff
Jerry L. Linnstaedter	Arkansas State University
A. H. Ludwig	U. S. Geological Survey
Thomas J. Lynch	University of Arkansas at Little Rock
Ali Mansouri	University of Arkansas for Medical Sciences
Daniel L. Marsh	Henderson State University
Chris T. McAllister	Dallas VA Medical Center
William H. McArthur	University of Arkansas at Pine Bluff
Nancy Glover McCartney	University of Arkansas
Clark W. McCarty	Ouachita Baptist University
Rose McConnell	University of Arkansas at Pine Bluff
Dennis W. McMasters	Henderson State University
Harlan McMillan	Arkansas Tech University
Lawrence A. Mink	Arkansas State University
Richard S. Mitchell	Arkansas State University
Jewel E. Moore	University of Central Arkansas (Retired)
Ronald D. Moore	Arkansas Game & Fish Commission
Leland F. Morgans	University of Arkansas at Little Rock
Walter Nesbitt	Arkansas State University
Thomas Nelson	Arkansas Tech University
Ann H. Nichols	University of Arkansas at Little Rock
Joe Nix	Ouachita Baptist University
Kelly H. Oliver	Henderson State University
Derrick M. Oosterhuis	University of Arkansas
Tom Palko	Arkansas Tech University
Bryan D. Palmer	Henderson State University
John E. Pauly	University of Arkansas for Medical Sciences
Forrest Payne	FTN Associates
John D. Peck	University of Central Arkansas
Carlos H. Pennington	USAE Waterways Experiment Station
James C. Peterson	U. S. Geological Survey
Robert A. Pierce	Univ. of Ark. Cooperative Extension Service
Albert B. Pittman	Arkansas Natural History Commission
Paul J. Polechla, Jr.	University of Arkansas
Harold Pray	University of Central Arkansas
Denver L. Prince	University of Central Arkansas
Paul L. Raines	Arkansas State University
Michael W. Rapp	University of Central Arkansas
Ruby S. Reynolds	University of the Ozarks
Edward L. Richards	Arkansas State University
Peggy Root	Southern Arkansas University
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Secretary's Report

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PROGRAM
Arkansas Academy of Science

Seventy-First Annual Meeting

UNIVERSITY OF ARKANSAS AT LITTLE ROCK

Little Rock, Arkansas

Meeting concurrently with sessions of

The Collegiate Academy of Science

Friday, 3 April

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SENIOR ACADEMY -- Executive Board Meeting

SENIOR ACADEMY -- First General Business Meeting

Lunch

SENIOR AND COLLEGIATE ACADEMIES -- Registration

SCIENCE EDUCATION SYMPOSIUM: Basic science education in Arkansas (Grades K-8): Our common concern.

SENIOR AND COLLEGIATE ACADEMIES: Papers [Concurrent Sessions]:

Aquatic and Environmental I
Biomedical
Botany
Chemistry I
Geology
Physics

SENIOR AND COLLEGIATE ACADEMIES -- Banquet

POST BANQUET SPEAKER -- Dr. Arch Johnston
Memphis State University
Memphis, TN

Saturday, 4 April

SENIOR AND COLLEGIATE ACADEMIES -- Registration

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

Aquatic and Environmental II
Chemistry II
Microbiology and Cell Biology
Science Education
Zoology

ARKANSAS SCIENCE TALENT SEARCH

SENIOR ACADEMY -- Second General Business Meeting

SECTION PROGRAMS

AQUATIC AND ENVIRONMENTAL I

Session Chairperson: Alan Price (Ark. Dept. Poll. Contr. & Ecol.)

ANALYSIS OF STRIPED BASS *(Morone saxatilis)* SCALES AND DORSAL SPINE SECTIONS BY SCANNING ELECTRON MICROSCOPY.
Barry L. Barnoski and Raj V. Kilambi, Zoology Dept., UAF, Fayetteville, AR.

EVALUATION OF STRIPED BASS *(Morone saxatilis)* AGE FROM BODY SCALES, OPERCULAR SCALES, OPERCLES AND DORSAL SPINES.
Raj V. Kilambi and Thoniot T. Prabhakaran, Zoology Dept., UAF, Fayetteville, AR.

REDISCOVERY OF THE SUCKERMOUTH MINNOW, *Phenacobius mirabilis* (GIRARD), IN ARKANSAS.
W. E. Keith, ADPCE; Thomas M. Buchanan, WestArk Community College; and Henry W. Robison, Biology Dept., SAU, Magnolia, AR.

STATUS REVIEW OF THE THREATENED OZARK CAVEFISH, *Amblyopsis rosae.*
A. V. Brown and C. S. Todd, Zoology Dept., UAF, Fayetteville, AR.

PHYSIOGRAPHY AND HYDROLOGY OF THE UPPER SALINE RIVER, SALINE AND GARLAND COUNTIES, ARKANSAS.
John Rickett, Biology Dept., UALR, Little Rock, AR.

Clinostomum marginatum METACERCARIA: INCIDENCE IN SMALLMOUTH BASS FROM A NORTH ARKANSAS STREAM AND *IN VITRO* SURVIVAL AND OXYGEN CONSUMPTION STUDIES.
James J. Daly, Howard H. Conway, and H. Michael Matthews, Depts. of Microbiology and Immunology and Physiology and Biophysics, UAMS, Little Rock, AR.

DISTRIBUTION OF FISH WITHIN HEADWATER RIFFLES OF THE ILLINOIS RIVER SYSTEM, WASHINGTON COUNTY, ARKANSAS.
Danny J. Ebert and Art V. Brown, Zoology Dept., UAF, Fayetteville, AR.

THE STATUS OF THE INSTREAM FLOW ISSUE IN ARKANSAS - 1987.
Steve Filipek, Ark. Game & Fish Comm., Lonoke, AR.

THE EFFICIENCY OF DIFFERENT STORAGE METHODS FOR PRESERVING LAKE TROUT *(Salvelinus namaycush)* EYE TISSUE.
Basil L. Joiner, Agriculture Dept., UAPB, Pine Bluff, AR and Harold L. Kincaid, Nat. Fish. Res. Dev. Lap., Wellsboro, PA.

ALUMINUM: A POTENTIAL TOXIC PROBLEM IN ARKANSAS?
Robert R. Jespersen and William R. Bowen, Biology Dept., UALR, Little Rock, AR.

EVALUATION OF SEVERAL GRAPHITE BASED ELECTRODES FOR THE MEASUREMENT OF REDOX POTENTIAL OF THE SOIL ENIRONMENT.
Ali U. Shaikh, Chemistry Dept., UALR, Little Rock, AR and Roger M. Hawk, GIT, Little Rock, AR.

SELECTED FAMILIES OF TRICHOPTERA IN ARKANSAS.
Veryl V. Board, Health & Sci. Program, Ark. College, Batesville.

DISTRIBUTION OF FISHES AMONG ARKANSAS ECOREGIONS.
William E. Keith, Ark. Dept. Poll. Contr. & Ecol., Little Rock, AR.

BIOMEDICAL

Session Chairperson: Dr. Thomas J. Lynch (UALR)

THE ENZYMATIC CONJUGATION OF 4-NITROQUINOLINE N-OXIDE WITH GLUTATHIONE.
J. Steven Stanley and Ann M. Benson, Biochemistry Dept., UAMS, Little Rock, AR.

THE INFLUENCES OF ATRIAL NATRIURETIC FACTOR ON THE FORCE OF PERISTALTIC CONTRACTIONS AND CYCLIC GMP LEVELS IN THE SMALL INTESTINE.
J. Michael Walters, Robert R. Jespersen, David L. Vesely, and Dennis A. Baeyens, Biology Dept., UALR and Dept. of Medicine, UAMS, Little Rock, AR.

MIGRATION OF ENDOTHELIAL CELLS ONTO VASCULAR GRAFTS OF DACRON MESH.
Brian S. Nichol, Paul Citrin, William R. Bowen, Harry Lubansky, Biology Dept., UALR (BSN, WRB) and Surgery & Res. Serv., McClellan Mem. Hosp., VA Med. Ctr. (PC,HL), Little Rock, AR.

SPECTRAL AND KINETIC STUDIES ON CONFORMATIONAL CHANGES IN HEMOGLOBINS OF *Pseudemys scripta elegans.*
W. R. Parker and R. C. Steinmeier, Chem. Dept., UALR, Little Rock, AR.

BIOCHEMISTRY OF GROWING OLD.
Rhetta Scaife and William M. Willingham, Nat. Sci. Dept., UAPB, Pine Bluff, AR.

THE SYNTHESIS AND CHARACTERIZATION OF ANTINEOPLASTIC MANGANESE(II) SALICYLATES.
Stanley Branch, William M. Willingham, Nat. Sci. Dept., UAPB, Pine Bluff, and John R. J. Sorenson, Biopharm. Sci., UAMS, Little Rock, AR.

DETERMINATION OF SIS-RELATED PEPTIDES DURING GESTATION AND IN TUMOR GROWTH.
Jeff Porter and Randall A. Kopper, Chemistry Dept., Hendrix College, Conway, AR.

THE EVALUATION OF THE BIOLOGICAL ACTIVITY OF LEUPEPTIN ANALOGS.
Rose McConnell, UAPB, Pine Bluff, AR.

TRANSPORT AND METABOLISM OF DEXAMETHASONE IN THE *IN VITRO* DUALLY PERFUSED HUMAN PLACENTA.
M. A. Smith, P. J. Thomford, D. R. Mattison, W. Slikker, Jr., Nat. Ctr. Tox. Res., Jefferson and Interdis. Tox., UAMS, Little Rock, AR.

INCIDENCE OF *Giardia lamblia* AND INTESTINAL AMEBAE OF HUMANS IN CENTRAL ARKANSAS.
James A. Daly, Mark A. Gross, David McCullough, Thomas McChesney, Eleanora B. Daly, Suzanne Tank, James N. Pasley, and John Clarke.

ELECTROSTATIC INTERACTIONS OF CYTOCHROME C.
David W. Spivey and Randall A. Kopper, Chemistry Dept., Hendrix College, Conway, AR.

BOTANY
Session Chairperson: Dr. Gary Tucker (ATU)

Fothergilla (HAMAMELIDACEAE) NATIVE TO THE BOSTON MOUNTAINS OF ARKANSAS.
Gary E. Tucker, Biol. Sci., ATU, Russellville, AR.

THE EFFECT OF GENETIC FAMILY AND STOCK TYPE OF LOBLOLLY PINE YIELDS FROM WET SITES.
J. F. Dickson, J. L. Yeiser, R. A. Kluender, Forest Econ., UAM, Monticello, and J. L. Paschke, Potlatch Corp., Warren, AR.

ARKANSAS PTERIDOPHYTE FLORA UPDATE: A NEW CHECKLIST AND NOTES ON ADDITIONAL COUNTY-LEVEL OCCURRENCE RECORDS.
J. H. Peck, C. J. Peck, Biol. Dept., UALR, Little Rock, AR and W. C. Taylor, Botany Div., Milwaukee Public Museum, Milwaukee, WI.

FIELD STATUS AND REPRODUCTIVE BIOLOGY OF *Woodsia scopulina* in ARKANSAS.
C. J. Peck, Nat. Sci., UAPB Pine Bluff and J. H. Peck Biology Dept., UALR, Little Rock, AR.

DISCOVERY OF *Lycopodium* COMMUNITIES IN THE GULF COASTAL PLAIN REGION OF ARKANSAS.
J. H. Peck, Biology Dept., UALR, Little Rock; C. J. Peck, Nat. Sci., UAPB, Pine Bluff; S. Orzell, Texas Nat. Herit. Prog., Austin; E. Bridges, Inst. Bot. Res., Austin; and Carl Amason, Calion, AR.

INFECTION RATE OF TALL FESCUE WITH *Acremonium coenophialum*.
B. J. Hankins, Ext. Serv., UAF, Little Rock and Terry Kirkpatrick, Ext. Serv., UAF, Hope, AR.

PHOTOASSIMILATE PARTITIONING IN RELATION TO COTTON BOLL DEVELOPMENT.
Stan D. Wullschleger and Derrick M. Oosterhuis, Agron. Dept., UAF, Fayetteville, AR.

CYLINDER SPEED VERSUS MOISTURE CONTENT OF THE GRAIN ON MILLING QUALITY OF RICE *(Oryza sativa)*.
R. H. Dilday, USDA-ARS, Stuttgart, AR.

PENETRATION OF A CHEESE WHEY RESIN ADHESIVE INTO WOOD.
Nicholas DePalo, William R. Bowen, and Tito Viswanathan, Biology and Chemistry Depts., UALR, Little Rock, AR.

EFFECTS OF STOCK TYPE AND PLANTER EXPERIENCE ON THE TIME REQUIRED TO PLANT LOBLOLLY PINE SEEDLINGS.
R. A. Kluender and J. L. Yeiser, UAM, Monticello, AR.

NEW LOCATIONS FOR PONDBERRY *(Lindera mellisifolia)* IN ARKANSAS.
Edward L. Richards, Biol. Sci., ASU, State University, AR and Steve L. Orzell, Texas Nat. Herit. Prog., Austin.

CORTICAL CELL CHANGES THAT ACCOMPANY CORK WING INITIATION IN *Euonymus alatus*.
Wylie E. Cox and William R. Bowen, Biology Dept., UALR, Little Rock, AR.

ADDITIONS TO THE ARKANSAS FLORA.
Donald E. Culwell, Biology, UCA, Conway, AR.

FRUITING BODY FORMATION IN THE SIMPLE SLIME MOLD, *Echinostelium bisporum*.
Frederick W. Spiegel, Bot. & Micro. Dept., UAF, Fayetteville, AR.

SULFUR DEFICIENCY OF WHEAT *(Triticum aestivum)* IN ARKANSAS.
Stanley L. Chapman and Donald Adams, Ext. Serv., UAF, Little Rock, AR.

CHEMISTRY I
Session Chairperson: Dr. Joe Jeffers (OBU)

THE ADDITION OF SIMPLE ESTER ENOLATES TO 2,3-DIHYDRO-4H-PYRAN-4-ONES.
K. K. Conner and T. E. Goodwin, Chemistry Dept., Hendrix College, Conway, AR.

THE PREPARATION OF A NEW CHIRON FROM D-ARABINOSE.
F. M. Griffin and T. E. Goodwin, Chemistry Dept., Hendrix College, Conway, AR.

DETERMINATION OF DISSOCIATION CONSTANTS OF SOME DIHALOGENATED NICOTINIC ACIDS.
Robert O. Shaver, Ella M. Gray, Ali U. Shaikh, and Frank L. Setliff, Chemistry Dept., UALR, Little Rock, AR.

THE SYNTHESIS OF 4-METHYL-5-ARYLOXYPRIMAQUINES.
J. C. Byrd and T. E. Goodwin, Chemistry Dept., Hendrix College, Conway, AR.

SYNTHESIS OF ENKEPHALIN ANALOGUES.
A. N. Voldeng, School of Pharmacy, UAMS, Little Rock; T. Day, David Coussens and T. E. Goodwin, Chemistry Dept., Hendrix College, Conway, AR.

SYNTHESIS OF NOVEL CARBOHYDRATE-DERIVED CHIRONS.
B. L. Shirkey and T. E. Goodwin, Chemistry Dept., Hendrix College, Conway, AR.

PREPARATION OF DIAZABORINES FROM AZULENE CARBOXALDEHYDES.
C. Lichti and T. E. Goodwin, Chemistry Dept., Hendrix College, Conway, AR.

SYNTHESIS AND REARRANGEMENT OF ISOXAZOLIDINE TOSYLATES.
J. Montgomery, D. Coussens, E. Jacobs, and T. E. Goodwin, Chemistry Dept., Hendrix College, Conway, AR.

ADDITION OF AROMATIC ALDEHYDES TO A CARBOHYDRATE-DERIVED 2,3-DIHYDRO-4H-PYRAN-4-ONE.
M. N. Ford and T. E. Goodwin, Chemistry Dept., Hendrix College, Conway, AR.

SEPARATION OF RIBONUCLEOTIDES AND ASSESSMENT OF INOSINE METABOLISM BY HPLC.
Dwayne Daniels and Randall Kopper, Chemistry Dept., Hendrix College, Conway, AR.

PSORALEN CROSSLINKING UNDER DENATURING CONDITIONS IN THE ELUCIDATION OF mRNA SECONDARY STRUCTURE.
Joseph R. Bishop III, Randal A. Kopper, and Charles D. Liarakos, Chemistry Dept., Hendrix College, Conway, AR.

INVESTIGATION OF PSORALEN PHOTOCHEMISTRY OF NUCLEIC ACIDS.
Kay A. Hilscher, Randall A. Kopper, Charles D. Liarakos, Chemistry Dept., Hendrix College, Conway, AR.

MECHANISM OF COLCHICINE-TUBULIN INTERACTION.
Michael D. Kyzer and Randall A. Kopper, Chemistry Dept., Hendrix College, Conway, AR.

ENZYME ACTIVITY IN ORGANIC SOLVENTS.
Steve Byars and Randall Kopper, Chemistry Dept., Hendrix College, Conway, AR.

METAL CATION EFFECTS UPON ALDOLASE IN THE ABSENCE OF S100.
Dave Deal and Randall A. Kopper, Chemistry Dept., Hendrix College, Conway, AR.

GEOLOGY
Session Chairperson: Dr. Philip Kehler (UALR)

THE GEOLOGIC HISTORY OF THE NEW MADRID SEISMIC ZONE: A SUMMARY.
Philip Kehler, Earth Science Dept., UALR, Little Rock, AR.

FLUVIAL RESPONSE TO QUATERNARY GROUND TILTING IN NORTHEASTERN ARKANSAS.
R. T. Cox, West Fork, AR.

TEXTURAL AND LITHOLOGIC DIFFERENCES OF CRETACEOUS, TERTIARY AND QUATERNARY TERRACE AND FLOODPLAIN GRAVELS OF SOUTH ARKANSAS.
Lesli J. Wood, Geology Dept., UAF, Fayetteville, AR.

LIMULID TRACKWAYS IN THE ROOF SHALES OF THE PARIS COAL.
Harry L. Barwood, Ark. Mining Inst., ATU, Russellville, AR.

OCCURRENCE OF THE TRACE FOSSIL BURROW OF *Pelecypodichnus*, WITH ITS ATTENDANT BODY FOSSIL, FROM THE SAVANNA SANDSTONE, PARIS, ARKANSAS.
Victor Vere, Randall Hosey, Merrick, Rotenberry and Glenn Spicer, Geology Dept., ATU, Russellville, AR.

PHYSICAL WEATHERING DUE TO RAPID FUNGAL GROWTH, MT. MAGAZINE, ARKANSAS.
Victor Vere, Geology Dept., ATU, Russellville, AR.

NEW MADRID - A GLANCE BACKWARD, A GLIMPSE FORWARD.
Daniel Cicirello and David L. Vosburg, Office of Emerg. Serv., Conway, AR and ASU, State University, AR.

BOTANICAL EVIDENCE OF HOLOCENE MOVEMENT OF ROCK STREAMS IN ARKANSAS.
S. Marie Lookingbill, Central Jr. H.S., Springdale, AR; Malcolm K. Cleaveland and Margaret J. Guccione, Depts. of Geography and Geology, UAF, Fayetteville, AR.

PROJECT GO.
John D. McFarland III, Charles G. Stone, J. Michael Howard, and William L. Prior, Ark. Geological Comm., Little Rock; David Vosburg, ASU, State University, AR.

PHYSICS
Sessions Chairperson: Dr. Joe Guenter (UAM)

APPLICATION OF GELIGAM SOFTWARE TO THE ANALYSIS OF X-RAY SPECTRA.
R. S. Sanders, H. L. Pray, and H. B. Eldridge, Physics Dept., UCA, Conway, AR.

X-RAY DENSITOMETER.
Paul D. Williams and Hudson B. Eldridge, Physics Dept., UCA, Conway, AR.

BGO FULL ENERGY PEAK EFFICIENCY.
Michael A. Halter and Hudson B. Eldridge, Physics Dept., UCA, Conway, AR.

ANALYSIS OF STOCHASTIC VARIATIONS FROM PARTIAL DIFFERENTIAL APPROXIMATES: ISING MODELS AND TEST SERIES.
M. J. George and D. Croom, ASU, State University, AR; J. J. Rehr, Cornell Univ., Ithaca, NY.

ELECTRICAL BREAKDOWN WAVES: EXACT NUMERICAL SOLUTIONS FOR THE QUASI-NEUTRAL REGION.
Mostafa Hemmati and Richard G. Fowler, Dept. Physical & Life Sciences, ATU, Russellville, AR and Dept. Physics & Astronomy, Univ. of Oklahoma, Norman.

AQUATIC AND ENVIRONMENTAL II
Session Chairperson: Dr. George L. Harp (ASU)

DIMLIN FOR CONTROL OF *Lernaea* IN GOLDEN SHINER PONDS.
Gary Burtle and John Morrison, UAPB, Pine Bluff, AR.

THE EFFECT OF MUNICIPAL SURFACE RUNOFF ON THE DIVERSITY OF AQUATIC MACROINVERTEBRATES OF SUGAR CREEK IN CLAY COUNTY, ARKANSAS.
Kay Cargill and George L. Harp, Biological Sciences, ASU, State University, AR.

DISTRIBUTION AND STATUS OF RARE AND ENDANGERED NAIADES (MOLLUSCA: MARGARITIFERIDAE, UNIONIDAE) IN ARKANSAS.
John L. Harris, Env. Division, Ark. Hwy. & Transp. Dept., Little Rock, AR.

FISHERIES MANAGEMENT IMPLICATIONS ASSOCIATED WITH RELATIVE ABUNDANCES OF LITTORAL AND LIMNETIC ZOOPLANKTON IN LAKE FAYETTEVILLE, ARKANSAS.
Donald C. Jackson, Wildl. & Fish. Dept. Mississippi State University and Eugene H. Schmitz, Zoology Dept. UAF, Fayetteville, AR.

RECENT COLLECTIONS OF FISHES FROM THE SPRING RIVER DRAINAGE IN NORTHEAST ARKANSAS.
Steve C. Baker and Michael L. Armstrong, Ark. Game & Fish Comm., Little Rock, AR.

RESIDUAL PESTICIDES IN FISHES FROM LAKE CHICOT, ARKANSAS.
C. M. Cooper and S. S. Knight, USDA-ARS Sed. Lab., Oxford, MS.

PRODUCTION OF HYBRID SUNFISH (*Lepomis* spp.) IN CAGES BY ATTRACTING AERIAL INSECTS.
Ron Moore, Ark. Game & Fish Comm., Little Rock, AR and Scott H. Newton, Petersburg, VA.

FEEDING ECOLOGY OF THE FANTAIL DARTER, *Etheostoma flabellare* RAFINESQUE, FROM AN ARKANSAS OZARK STREAM.
Stephen R. Moulton, Cove Corp., Lusby, MD and George L. Harp, Biol. Sci., ASU, State University, AR.

LOW ALKALINITY STREAMS OF ARKANSAS.
James C. Petersen, USGS, Little Rock, AR.

CURRENT WATER QUALITY MONITORING STRATEGIES OF THE ARKANSAS DEPARTMENT OF POLLUTION CONTROL AND ECOLOGY.
Alan D. Price, ADPCE, Little Rock, AR.

ANALYSIS OF SURFACE WATER FOR ORGANOCHLORINE PESTICIDES AND PCBs AT 121 SAMPLE SITES OF THE NORTHEAST ARKANSAS ENVIRONMENTAL QUALITY MONITORING GRID.
Ahmad Shateri-Mirabadi, William V. Wyatt, and Paul D. Gwinup, Chem. Dept., ASU, State University, AR.

CONTROL OF OFF-FLAVOR IN CHANNEL CATFISH THROUGH POLYCULTURE WITH BLUE TILAPIA.
Les Torrans and Fran Lowell, Agriculture Dept., UAPB, Pine Bluff, AR.

CHEMISTRY II
Session Chairperson: Dr. Ralph Wolf

CATALYTIC HYDROGENATION OF QUINOLINE USING POLYMER ANCHORED Pd(II) ANTHRANILIC ACID COMPLEXES.
Laurence J. Boucher, Thomas Pope, and Robert Metz, Depts. of Chemistry, ASU, State University, AR and Western Kentucky University, Bowling Green, KY.

MASS SECTROMETRIC STUDY OF THE EQUILIBRIUM VAPORS FROM METAL SULFITE-GRAPHITE MIXTURES AT HIGH TEMPERATURES.
J. E. Bennett, Colin Hester, and Thomas Black, Chemistry Dept., ASU, State University, AR.

EFFECT OF BOND STRETCH EXCITATION ON THE ATTENUATION OF BENDING FORCES.
Devinder S. Bhatia and Ralph J. Wolf, Chemistry Dept., UALR, Little Rock, AR.

THE SYNTHESIS OF OXAZOLIDINES FROM EPHEDRINE AND PSEUDOEPHEDRINE.
Michael D. Massey and Richard B. Walker, Nat. Sci., UAPB, Pine Bluff, AR.

A NOVEL PATHWAY FOR THE METABOLIC ACTIVATION OF QUINOLINE.
David R. Cross, Robert H. Heflich, and Denzil L. Tullis, Chemistry Dept., UALR, Little Rock, AR.

THERMAL ANALYSIS OF WHEY-BASED THERMOSETTING RESINS USING DIFFERENTIAL SCANNING CALORIMETRY.
Tito Viswanathan and Hal Palmer, Chemistry Dept., UALR, Little Rock, AR.

RICE HULL REINFORCED PARTICLE BUILDING BOARDS USING ADHESIVES DERIVED FROM WHEY.
Tito Viswanathan and Mona Smith, Chemistry Dept., UALR, Little Rock, AR.

COMPARISONS OF METHODS TO MEASURE AFLATOXINS B1, B2, G1, G2, UTILIZING HPLC WITH ELECTROCHEMICAL DETECTION.
Tina R. Allen, LaWanda D. Jones, and Benjamin T. Duhart, UAPB, Pine Bluff, AR.

SYNTHESIS OF OXIDIZED DERIVATIVES OF NITRO-POLYCYCLIC AROMATIC HYDROCARBONS.
D. T. C. Yang, P. P. Fu, Y. C. Wu, C. C. Lai, and J. S. Lai, Depts. of Chemistry, UALR, Little Rock, AR and Providence College, Taichung, Taiwan, ROC.

SYNTHESIS OF 5-METHYLBENZ(A)ANTHRACENE AND ITS OXIDIZED DERIVATIVES.
Jia Che and D. T. C. Yang, Chemistry Dept., UALR, Little Rock, AR.

HIGH TEMPERATURE CHEMISTRY OF METAL CARBONATES AND CARBONATE-GRAPHITE MIXTURES, THE SODIUM CARBONATE-GRAPHITE SYSTEM.
Maria Hammond and J. E. Bennett, Chemistry Dept., ASU, State University, AR.

CATALYTIC PRODUCTION OF HIGH-GRADE FUEL (GASOLINE) FROM *Juniper virginiana* (EASTERN RED CEDAR) ETHER EXTRACTS.
Kathy Plaster, Dewey H. Sifford, and Bob D. Johnson, Chemistry Dept., ASU, State University, AR.

THE STRUCTURAL CHARACTERIZATION OF COPPER(I) HALIDE COMPLEXES OF PYRAZINE, QUINOXALINE AND PHENAZINE.
Mark Draganjac, ASU, State University, AR and Jeffery Armstrong, Abdas-Sami Malik and Elizabeth M. Holt, Chemistry Dept., Okla. St. Univ., Stillwater.

THE PREPARATION OF A SERIES OF BENZAMIDO PYRIDINES OF POTENTIAL AGRICULTURAL INTEREST.
Frank L. Setliff, Steve H. Rankin, and Hal E. Palmer, Chemistry Dept., UALR, Little Rock, AR.

MICROBIOLOGY AND CELL BIOLOGY
Session Chairperson: Dr. Dale Ferguson (UALR)

PHOTOREACTIVATION OF LETHAL DAMAGE INDUCED IN HAMSTER X *Xenopus* HYBRID CELLS AND THEIR PARENTAL CELLS BY U-V LIGHT.
David Bohlender, Stuart Williams, Emir Cruz, and Gaston Griggs, Biology Dept., JBU, Siloam Springs, AR.

SURFACE WATER QUALITY OF THREE SOUTHWEST ARKANSAS RESERVOIRS ACCORDING TO BACTERIAL INDICATORS.
J. D. Bragg, Biology Dept., HSU, Arkadelphia, AR.

THE ULTRASTRUCTURE OF RUBBER FORMATION IN GUAYULE.
R. A. Goss, Biology Dept., UALR, Little Rock, AR; M. A. Foster and C. R. Benedict, Dept. of Biochemistry & Biophysics, Texas A&M Univ., College Station.

PROTECTIVE IMMUNITY TO *Trichomonas vaginalis* IN THE MOUSE VIRULENCE MODEL.
Terry L. Hostetler (1), Timothy J. O'Brien (2), Roger G. Rank (1) and James J. Daly (1); (1) Dept. of Microbiology/Immunology and (2) Dept. of Obstetrics/Gynecology, UAMS, Little Rock, AR.

THE A85 *Xenopus* CELL LINE: A REMARKABLY ADAPTABLE TISSUE CULTURE LINE.
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Paul J. Polechla, Zoology Dept., UAF, Fayetteville, AR.

FUR HARVEST RECORDS FROM ARKANSAS POST, LOUISIANA TERRITORY, 1805-1810.

Paul J. Polechla, Zoology Dept., UAF, Fayetteville, AR.

PHOTOREACTIVATION OF LETHAL DAMAGE INDUCED IN HAMSTER X *XENOPUS* HYBRID CELLS AND THEIR PARENTALS BY UV LIGHT

DAVID BOHLENDER, STUART WILLIAMS, EMIR CRUZ, and GASTON GRIGGS
Department of Biology
John Brown University
Siloam Springs, AR 72761

ABSTRACT

A85 *Xenopus* cells that exhibited a high level of photoreactivation (PR) and V79B2 hamster cells that exhibited little PR were fused to produce the V79B2 × A85 cell line — a hybrid line which possessed a relatively stable karyotype, with most cells containing the entire V79B2 and A85 genomes. UV and UV plus PR fluence-survival relations were then determined and compared for the hybrid and parental lines in a first attempt to elucidate interactions of the parental PR mechanisms in the hybrid. It was anticipated that the A85 genome in the hybrid would produce PR enzyme in sufficient concentration and of such a nature as to efficiently PR UV-induced lethal damage in both A85 and V79B2 DNA, and little difference would be observed in the levels of PR exhibited by the V79B2 × A85 and A85 lines. To the contrary, the level of PR observed for the hybrid was substantially below that observed for the A85 line. To assist in the interpretation of this unexpected observation, three additional preliminary studies were carried out: 1) Comparison of the optimum PR schemes for the A85 and hybrid lines, 2) examination of relations between the PR and dark UV repair mechanisms possessed by these lines, and 3) comparison of the levels of PR of chromatid deletions induced by UV in selected V79B2 and A85 chromosomes of the hybrid. The results suggested that the relatively low level of PR manifested by the hybrid cells was a consequence of their inability to efficiently PR pyrimidine dimers induced by UV in V79B2 DNA.

INTRODUCTION

Previous studies have indicated that A84 amphibian *(Xenopus)* cells possess photoreactivating enzymes and are capable of photoreactivating a relatively high level of lethal damage induced by low doses of UV light (Regan *et al.*, 1968; Griggs and Bender, 1972; Griggs and Orr, 1979; Griggs and Payne, 1981). Photoreactivation (PR) of UV-induced lethal damage has not been clearly demonstrated in V79B1 mammalian (hamster) cells, although photoreactivating enzyme activity has been detected in mammalian cells (Sutherland *et al.*, 1974; Sutherland *et al.*, 1976). Recently, Kulp *et al.* (1985) tried to elucidate the differences in these PR mechanisms by studying interactions of the mechanisms in a V79B1 × A84 hybrid cell line: an approach suggested by the success of previous attempts (*e.g.*, Limbosh, 1982) to describe relations between the radiation repair mechanisms possessed by different parental lines through examining interactions of the mechanisms in hybrid lines formed from the parentals. It was anticipated that the A84 genome in the hybrid would produce PR enzyme in sufficient concentration and of such a nature as to efficiently photoreactivate UV-induced lethal damage (pyrimidine dimers) in both V79B1 and A84 DNA, and the level of PR observed for the hybrid would closely approach that observed for the A84 parental line. To the contrary, the level of PR exhibited by the hybrid did not closely approach that of the A84 line. However, the results of this study were complex and difficult to interpret, possibly due to the fact that the karyotype of the hybrid was not completely stable throughout the experimentation. Thus, we decided to carry out similar experiments with recently cloned hamster and *Xenopus* parental lines (V79B2 hamster and A85 *Xenopus*) and a V79B2 × A85 hybrid line, which possessed a more stable karyotype than the V79B1 × A84 line.

MATERIALS AND METHODS

The A85 *Xenopus* line was cloned from the A8W243 line described by Griggs and Bender, (1972). The V79B2 hamster line was cloned from the B79B1 line described by Kulp *et al.* (1985). The V79B2 × A85 hybrid line was formed by a polyethylene glycol technique similar to that described by Davidson and Gerald (1976). Monolayers for routine maintenance of the cell lines were grown in F12 medium (Gibco) supplemented with 15 percent foetal calf serum (Hazelton) at 31 °C (A85) and 33 °C (V79B2 and V79B2 × A85) in light-tight incubators containing a humidified atmosphere of 5 percent CO_2 in filtered air. Techniques employed in UV irradiations, photoreactivations, caffeine treatments, single cell plating, colony assays, cell synchronizations, mitotic arrest, preparation of chromosome spreads, and chromatid aberration analysis closely paralleled those described by Griggs and Bender (1972), Griggs and Orr (1979), and Kulp *et al.* (1985).

RESULTS AND DISCUSSION

Fig. 1 displays UV and UV + PR fluence-survival relations for A85 and V79B2 parental lines and the V79B2 × A85 hybrid line. The A85 line was substantially less resistant than the V79B2 line under UV treatment; however, only the *Xenopus* line exhibited a detectable level of photoreactivation. The V79B2 × A85 hybrid line was somewhat more resistant than either parental line to UV irradiation, yet seemed to lack the efficient PR repair capability of the A85 line. These results were quite similar to those obtained by Kulp *et al.* (1985) with their unstable V79B1 × A84 hybrid line, and suggested that the relatively low photoreactivation repair potential of that hybrid line was not due entirely to karyotype instability. These alternative explanations were then examined:

1. Perhaps the PR mechanisms for the A85 line and the V79B2 × A85 line differ in such a manner as to require that significantly different schemes for administration of photoreactivating light be employed with each line to produce optimal PR for that line. The photoreactivating light administration scheme employed in establishing the UV + PR curves for Figure 1 may have significantly favored the A85 line and a higher level of PR might have been observed in the hybrid line if an

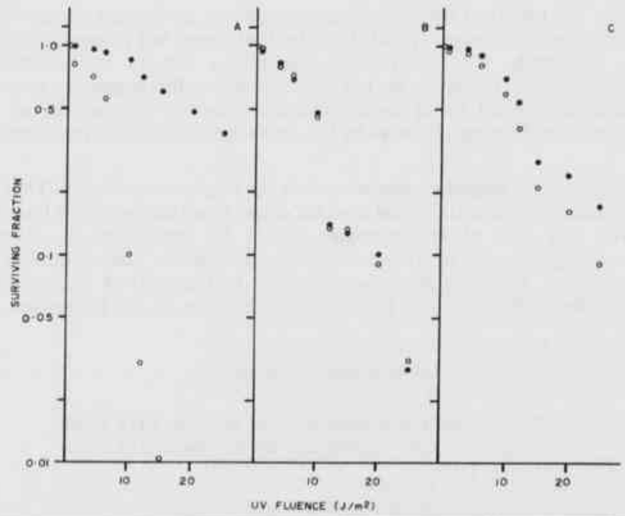

Figure 1. The UV (open circles) and UV + PR (filled circles) survival curves for A85 cells (A), V79B2 cells (B), and V79B2 × A85 hybrid cells (C). Photoreactivating light was administered at 24 °C. The fluence rate and total fluence were 10w/m² and 25 × 10³ J/m² respectively. All irradiations were carried out under red light.

optimal scheme for it had been employed. To test this explanation, experiments were conducted to compare the optimal PR light administration schemes for the cell lines. These schemes were considered to be composed of optimal values for three parameters: temperature, fluence rate, and total fluence. The results indicated that optimal value "ranges" existed for the three parameters and the range for each parameter was the same for both cell lines (temperature, 20-24 °C; fluence rate, 5.0-15.0 w/m²; total fluence, 20,000-28,000 j/m²). Furthermore, the parametric values used in the scheme for establishing the UV + PR curves for the two cell lines fell within these ranges (caption for Fig. 1). Thus, suggested explanation (1) appears contradicted.

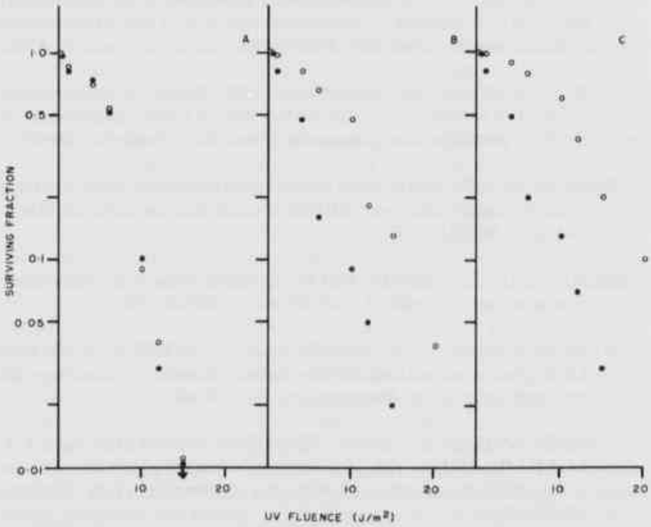

Figure 2. Survival curves following UV (open circles) and UV + CF (filled circles) for A85 cells (A), V79B2 cells (B), and V79B2 × A85 cells (C). The cells were incubated in a medium containing 0.80mM/l caffeine from immediately following irradiations until termination of experiments.

2. The data of Figure 1 coupled with that of Figure 2 suggest that the hybrid line and the A85 parental line may possess similar PR mechanisms, but only the hybrid line possesses an efficient caffeine sensitive repair CSR mechanism. In a caffeine (CF) free hybrid intracellular environment, the CSR mechanism successfully competes with the PR mechanism for UV-induced pyrimidine dimers in the hybrid DNA and this competition reduces PR to the relatively low level observed. In a hybrid intracellular environment containing CF, CSR should be blocked, CSR competition eliminated and a higher level of PR observed. Efficient CSR does not exist in the A85 intracellular environment and, thus, a much higher level of PR was observed for the A85 line. Specifically, explanation (2) proposes that if samples 1 and 2 of the hybrid cells were treated with 10J/m² UV + 0.80 mM/1 CF + 25 × 10³ J/m² PR and 10J/m² UV + 0.80 mM/1 CF respectively, while samples 3 and 4 were treated with 10J/m² UV + 25 × 10³ J/m² PR and 10J/m² UV respectively, then one would expect SF1 − SF2 > SF3 − SF4 (where SF1 = surviving fraction of sample 1, etc.) Samples of cells were treated in this fashion to test the inference and the results are recorded in Table 1. Comparison of the normalized surviving fractions of experiments 1 and 2 with those of experiments 3 and 4 indicates that SF1-SF2 > SF3-SF4 and explanation (2) is contradicted.

Table 1. Survival of V79B2 × A85 cells following UV, UV + CF, UV + PR, and UV + CF + PR treatments.

Experiment number *	UV fluence (J/m²)	PR fluence (J/m²)	caffeine concentration (mM/liter)	Number of cells isolated	Normalized surviving fraction
0	0	0	0	6,000	1.00
1	10	25,000	0.80	6,000	0.26
2	10	0	0.80	6,000	0.16
3	10	25,000	0	6,000	0.68
4	10	0	0	6,000	0.56

* Cell sample number

3. A low UV fluence would be expected to induce in V79B2 and A85 chromosome segments of equal length approximately the same number of pyrimidine dimers that lead to a given end point. However, perhaps the A85 PR mechanism photoreactivates the dimers in A85 chromosomes more efficiently than it does the dimers in V79B2 chromosomes. Thus, since the hybrid cells contained both A85 and V79B2 chromosomes, while the A85 cells contained only A85 chromosomes, the A85 cells were capable of photoreactivating a greater fraction of their UV-induced dimers leading to the end point cell death than were hybrid cells. Since chromosomal aberrations are also end-points for pyrimidine dimers (Griggs and Bender, 1973), this proposed explanation predicts that, following a given UV fluence, the hybrid cells should also photoreactivate aberrations induced in A85 chromosomes more efficiently than aberrations induced in V79B2 chromosomes. The experiment described next was performed to test this prediction.

Six sets of synchronous G1 phase hybrid cells were prepared. Set 1 received no radiation; set 2 received 25 × 10³ J/m² PR light; set 3 received 14.0 J/m² UV; set 4 received 14.0 J/m² UV + 25 × 10³ J/m² PR light. Each set was then separated into two subsets, a and b. Subset a cells were allowed to progress to mitosis. Samples of subset b cells were used for mitotic index monitoring to determine the appropriate time for colcemid collection of subset a mitotic cells for preparation of metaphase chromosomes spreads. These spreads contained a number of small V79B2 and A85 metacentric chromosomes very similar in appearance and so difficult to distinguish that a detailed aberrational analysis of the entire karyotype did not appear feasible. Instead, the aberrational analysis was restricted to comparing the number of chromatid terminal deletions produced by the various treatments in an

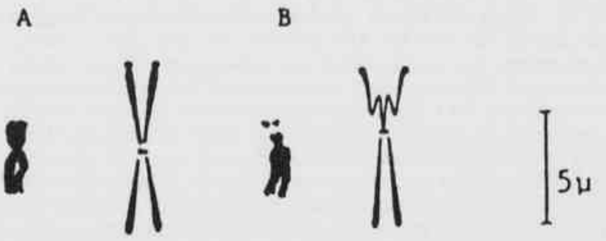

Figure 3. Photographs and schematics for (A) the V79B2 chromosome and (B) the A85 chromosome used in the PR study of UV-induced chromatid deletions.

A85 chromosome and a V79B2 chromosome which were approximately equal in length and easily distinguished. The V79B2 chromosome was a metacentric with small satellites (Figure 3A) and the A85 chromosome was a submetacentric with what appeared to be aberrant supercoiling in one arm (Fig. 3B). The resulting data, displayed in Table

Table 2. PR of chromatid deletions induced by UV in two chromosomes of G1 phase V79B2 × A85 cells.

Experiment number *	UV fluence (J/m^2)	PR fluence (J/m^2)	Cell Collection time range (h after UV)**	Number cells scored	Mean number of deletions/trail ± standard errors observed in the chromosomes A85	V79B2
1	0	0	22-30	1200	2	3
2	0	25,000	22-30	1200	2	4
3	14	0	42-56	1200	36.0 ± 0.6	39.3 ± 0.81
4	14	25,000	22-34	1200	7.0 ± 1.0	31.4 ± 1.50
5	18	0	50-65	1200	45 ± 1.8	44.6 ± 1.3
6	18	25,000	22-40	1200	10 ± 2.1	33.0 ± 2.2

* Each experiment consisted of three trials with 400 cells scored in each trial.
** Metaphase spreads were collected by colchemid treatments that spanned the indicated time ranges.

2, reveals that the difference in the numbers of deletions observed for the two chromosomes following a given UV exposure is rather small compared to the difference in the numbers of deletions observed for the two chromosomes following that UV exposure plus PR. For example, comparison of the chromatid data of experiments 3 and 4 for the A85 chromosome indicates that PR reduces the number of deletions induced by 14.0 J/m^2 UV from 36.0 ± 0.6 to 7.0 ± 1.0 (approximately 80 percent of the deletions photoreactivated), while comparison of the data of these same experiments for the V79B2 chromosome indicates that PR reduces the number of UV-induced deletions from 39.3 ± .081 to 31.4 ± 1.50 (only about 20 percent of the deletions photoreactivated). These data tend to confirm the prediction of proposed explanation 3 and, thus, support this proposal.

In conclusion, the results of the UV and UV + PR fluence-survival experiments tend to confirm the earlier, somewhat unexpected, observation by Kulp *et al.* (1985) that hamster X *Xenopus* hybrid cells do not PR UV-induced lethal damage as efficiently as *Xenopus* parental cells. The results of additional experimentation, performed to explain this observation, suggest that the hybrid cells may not possess ability to efficiently PR UV-induced pyrimidine dimers in hamster chromosomes. However, the key data supporting this suggestion is indirect and limited, being results of an experiment to compare the percentages of deletions, induced by UV, in a single hamster chromosome and a single *Xenopus* chromosome that can be photoreactivated. Thus, questions appropriately arise as to the extent to which the results found with this pair of chromosomes should be generalized to other heterologous pairs of hybrid chromosomes. Similar aberrational experiments, involving larger segments (or perhaps all) of the hybrid genome would constitute a more convincing test of the suggestion.

ACKNOWLEDGEMENT

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DIMILIN FOR CONTROL OF *LERNAEA* IN GOLDEN SHINER PONDS

GARY BURTLE and JOHN MORRISON
University of Arkansas at Pine Bluff
P.O. Box 4005
Pine Bluff, AR 71601

ABSTRACT

A single application of Dimilin (UNIROYAL), diflubenzuron, was tested in 9 (nine) ponds containing golden shiner minnows, *Notemigonus crysoleucas,* infested with the parasitic copepod *Lernaea cyprinacea.* The chemical was applied at a rate of 10 or 30 μg/l and compared to untreated controls. Fish were periodically sampled to determine levels of infestation, and zooplankton numbers were monitored for chemical effect. Dimilin treatment significantly reduced ($P < 0.05$) parasite infestation four to eight days after treatment. No significant difference ($P < 0.05$) was noted between the two levels of treatment. Zooplankton populations decreased in the Dimilin treated ponds following chemical application. Rotifer populations rebounded later during the period, but copepod populations in the ponds treated with 30 μg/L remained depressed from two days after treatment for one month until the study ended. Complete parasite control was not obtained with either chemical concentration using a single application. These results suggest that a single treatment is not effective for *Lernaea* control. Future research will test two applications 10 days apart at the 10 and 30 μg/L levels.

INTRODUCTION

The fish parasite, *Lernaea cyprinacea,* is an ectoparasite that lowers fish stamina, kills small fish and causes red sores that adversely effect the marketability of many fish (Gaines and Rogers, 1975). This crustacean lacks host specificity and probably infects all freshwater fish (Hoffman, 1970; Meyer, 1966). One *Lernaea* attached in the heart region can kill a golden shiner (Guidice, *et al.,* 1981). *Lernaea* control is particularly important to Arkansas fish producers because of the large acreage devoted to golden shiner and goldfish production. In 1985, 20,181 acres were devoted to golden shiner production with a value of $14,681,100, while goldfish were valued at $1,823,300 in 1,452 acres. (Anonymous, 1986). *Lernaea* infection is common in these fish. Fish producers are reluctant to admit that *Lernaea* exists on their farms. However, recent brisk sales of insecticides commonly used for *Lernaea* control indicate a high level of concern of baitfish producers that *Larnaea* is a problem in baitfish ponds. Cases documented at the Lonoke and Pine Bluff laboratories of the Arkansas Cooperative Extension Service show that *Lernaea* control is practiced by more than half of the baitfish producers.

Benzene hexachloride was used to control *Lernaea* in the 1950's and 1960's but, evidence of resistance to this chemical was determined by Meyer (1966). Compounds presently used to control *Lernaea* infections are trichlorfon and fenthion (Guidice *et al.,* 1981; Rogers, 1968; Dupree and Huner, 1984; Brown and Gratzek, 1980). Trichlorfon and fenthion become less effective at temperatures near and above 85 °C because of temperature enhanced degradation (Dupree and Huner, 1984). Dimilin, the trade name for diflubenzuran, is a chitin inhibitor used to control mosquitos, and insect pests of rice and cotton. By preventing chitin production, Dimilin may be effective at low concentrations, less than 30 μg/L, in preventing carapace formation in the copepod stages of *Lernaea* development. Water temperature does not significantly reduce Dimilin activity (Moody, 1986). Dimilin may have less toxic effects on fish than fenthion and trichlorfon. Dimilin is not toxic to fathead minnows at concentrations of 100 mg/liter (Julin and Sanders, 1978), while fenthion and trichlorfon are toxic at 2.44 mg/l and 7.90 mg/l, respectively (Johnson and Finley, 1980). The toxicity (48-h EC 50, 22 °C) of Dimilin to *Daphnia magna* is 16 μg/L. Fenthion is toxic (48-h EC 50 15 °C) to *Daphnia pulex* at 0.8 μg/L and trichlorfon kills *Daphnia pulex* at 0.18 μg/L (48-h EC 50, 16 °C) (Johnson and Finley, 1980). Even though fenthion and trichlorfon are more toxic than Dimilin, recommended treatment rates are higher than those proposed for Dimilin — 0.25 mg/l versus 0.010 or 0.030 mg/l (Dupree and Huner, 1984).

The fact that Dimilin's effectiveness is not greatly diminished by heat or light and is less toxic to fish suggests it could be applied at a concentration that would be present in pond water for several days. During that time, *Lernaea* eggs in the pond would hatch and more developing *Lernaea* copepods would be exposed to Dimilin. This study was designed to test whether Dimilin toxicity to *Lernaea* is adequate with a single treatment to completely control the parasite. Also, because Dimilin remains in the water for several days at concentrations toxic to copepods, the toxic effect to nontarget copepods and other zooplankton was measured.

METHODS AND MATERIALS

Golden shiners infected with *Lernaea* were stocked in nine 1/12 acre ponds at a rate of 1,800 per pond on July 18, 1986. Ponds were randomly assigned to three treatments based on application rates of 0, 10 and 30 μg/l of Dimilin.

Dimilin wetable powder, 25% active, was suspended in three gallons of water and sprayed on the surface of each pond with a hand sprayer. Treatment quantities were calculated from depth and surface area measurements at the time of application on September 25.

Infestation rates were assessed on September 23 and 24. Because handling the *Lernaea* infected fish in July resulted in significant mortalities, the level of infection of the population was reduced. To allow the fish to recover from handling, application was postponed until September 25. At that time infection rates had increased and treatments were assigned to ponds after randomizing with random number tables. Each pond was seined on days 4, 8, 15, and 29 after treatment and approximately 500 fish were examined by visual inspection for adult *Lernaea.* Golden shiners with one or more entire, attached, adult *Lernaea* were counted as infected fish.

Zooplankton samples were taken on September 24 and on days 1, 5, 12, 19, and 27 after treatment. Six water column (2" diameter, from surface to near bottom) samples were taken with a column sampler (Boyd, 1979) from representative pond areas and pooled for each pond. Zooplankton was concentrated from a 10 liter volume of each pooled sample with a Wisconsin plankton net (80 micrometer mesh). Samples were preserved in 5% buffered formalin. The concentrated sample volume was recorded and a Sedgwick - Rafter cell count made for each sample (APHA, 1985).

All numerical analyses were performed on an IBM 3278 mainframe computer with SAS (SAS Institute, Inc., 1982). Data from counts of *Lernaea* infected fish were calculated as percentages transformed as arcsines to normalize the distribution of percentage values (Sokal and Rohlf, 1973) and means were compared by analysis of covariance (Steel and Torrie, 1960; Zar, 1974; SAS Institute, Inc., 1982). Mean copepod, rotifer and total zooplankton densities were also compared by analysis of covariance to address variation in population size and treatment effects over time.

RESULTS AND DISCUSSION

Lernaea infection rates (Table 1) varied from 1.0 to 4.5% at the time of treatment. These rates of infection were sufficient to cause observable mortalities, low tolerance to handling, and unmarketable golden shiners (because of visible sores and attached parasites).

Table 1. Lernaea infection rate in golden shiners, as percent of fish infected before and after treatment with Dimilin.

Treatment	Pond	9/24 Pretreatment	9/28	10/2	10/9	10/23
0	41	2.8	5.0	6.5	2.5	5.8
0	46	4.5	6.8	13.6	18.4	10.8
0	63	1.6	1.9	1.4	1.4	0.6
10 µg/L	43	1.9	0.8	0.6	0	0
10 µg/L	45	1.0	0.2	0.2	0	0
10 µg/L	65	2.0	0.4	0.6	0	0.2
30 µg/L	64	1.1	0.8	0.4	0	0
30 µg/L	67	4.2	4.2	2.2	0.6	0.2
30 µg/L	68	2.2	2.6	2.6	1.2	1.3
Mean infection rate per treatment.*						
0		3.0	4.6	7.2	7.4	5.7
10 µg/L		1.6	0.5	0.5	0.0	0.1
30 µg/L		2.5	2.5	1.7	0.6	0.5

*Analysis of covariance from 9/24 to 10/23 indicates a difference between 0 and 10 µg/L at $P < .0855$ and between 0 and 30 µg/L at $P < .0588$. Arcsine transformations of percent infection were used for the ACOVA.

Reductions in infection rates (Table 1) occurred after treatment with both 10 and 30 µg/L Dimilin while increases were observed in control ponds. The decrease observed in the treated ponds was significant, but not significant between treatment concentrations ($P < 0.05$). The treatments did not cause all of the adult *Lernaea* to drop off their hosts. Attachment after treatment in both levels of treatment shows that Dimilin does not immediately eliminate all mature *Lernaea* at these concentrations. Dimilin apparently kills copepods as they regenerate carapaces and prevents reinfection of fish until eggs released by adults hatch and start the four-week life cycle again. Reinfection at 29 days was apparent in ponds at both treatment levels. The study was terminated after 29 days because cooling temperature contributed to a general decline in zooplankton numbers.

Copepod populations were markedly reduced ($P < 0.05$ within 5 days after treatment at both levels of application and remained depressed in the 30 µg/L treatment. Considerable repopulation had occurred by 28 days after treatment with 10 µg/L. Cooling temperatures were presumed responsible for the gradual decline of the control populations (Table 2).

Rotifer populations also showed reduction within 6 days after treatment but, the populations appeared to recover 11 days after treatment. No significant differences between treatment mean rotifer numbers over time were indicated by analysis of covariance ($P < 0.05$). No significant ($P < 0.05$) decline over time in total zooplankton density was detected between treated or control ponds (Table 2). When copepod

Table 2. Zooplankton population means after golden shiner ponds were treated with Dimilin* (Organisms/ml).

DATE	TREATMENT	COPEPODS	ROTIFERS	TOTAL ZOOPLANKTON
9/24	0	368[a]	548[a]	1014[a]
	10	563[a]	970[a]	1699[a]
	30	302[a]	2217[b]	2778[a]
9/26	0	378[a]	497[a]	932[a]
	10	105[ab]	273[a]	392[a]
	30	23[b]	592[a]	689[a]
9/30	0	290[a]	641[a]	1073[a]
	10	16[b]	286[ab]	313[a]
	30	0[b]	97[b]	195[a]
10/7	0	151[a]	236[a]	424[a]
	10	48[ab]	1006[b]	1093[b]
	30	0[b]	264[a]	348[a]
10/14	0	175[a]	145[a]	334[a]
	10	198[a]	436[ab]	660[a]
	30	20[a]	1460[b]	1474[a]
10/22	0	174[a]	328[a]	502[a]
	10	224[a]	480[ab]	664[a]
	30	0[b]	1364[b]	1363[b]

*Means in columns by date followed by the same letter are not significantly different $P < .05$) after arcsine transformations of percent total zooplankton.

populations remained low, rotifer populations increased, presumably because of reduced consumption by copepods. By 19 days after treatment, copepod and rotifer populations had begun to rebound in the 10 µg/L treatment. However, the 30 µg/L treatment showed suppressed copepod populations and high rotifer populations as a percentage of total zooplankton until the end of observation.

CONCLUSIONS

Dimilin kills *Lernaea* and other copepods in ponds. Although complete, lasting control of *Lernaea* was not achieved with one application, other application frequencies for Dimilin may provide long term control.

The low level of 10 µg/L was effective when temperatures were declining. However, a higher treatment concentration may be required in the spring or summer if copepod populations recover more rapidly in warmer weather.

ACKNOWLEDGEMENTS

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THE *HYLA VERSICOLOR-CHRYSOSCELIS* SPECIES COMPLEX OF GRAY TREEFROGS IN ARKANSAS: HISTOLOGICAL AND ULTRASTRUCTURAL EVIDENCE

PHYLLIS CHAFFIN and STANLEY E. TRAUTH
Department of Biological Sciences
Arkansas State University
State University, AR 72467

ABSTRACT

We investigated the *Hyla versicolor-chrysoscelis* species complex (tetraploid and diploid species, respectively) of cryptic gray treefrogs from Arkansas using light and scanning electron microscopy. From previous studies of this treefrog complex in other states, *H. versicolor* has been shown to exhibit larger nuclear diameters and larger toe pad epithelial cells than *H. chrysoscelis*. Based upon average nuclear diameters of eyelid epithelial cells, we found two or possibly three groups of frogs. The presumed *H. versicolor* exhibited greatly enlarged toe pad epithelial cells using scanning electron microscopy and were found in four counties, three of which are in the Ozark Mountains. *Hyla chrysoscelis* occurs throughout the state.

INTRODUCTION

The gray treefrog species complex has long posed as an enigma to researchers. Two cryptic species, *Hyla versicolor* (Eastern Gray Treefrog) and *H. chrysoscelis* (Cope's Gray Treefrog), are distinguishable in the field by the male breeding call with *H. versicolor* exhibiting a relatively slow pulse rate compared to a fast rate in *H. chrysoscelis*. Wasserman (1970) separated the two species by examination of their karyotypes (*H. versicolor*, 4n = 48; *H. chrysoscelis*, 2n = 24).

Recently, a variety of methods have been used to differentiate between the two species. Ralin (1968) examined the stomach contents, calling positions, and effects of temperature and humidity on the trill rates; he concluded that *H. chrysoscelis* was more arboreal and preferred lower humidity than *H. versicolor*. Micro-complement fixation was utilized by Maxson *et al.* (1977) to separate the two species and to estimate the age of origin of tetraploidy in *H. versicolor*. Noting "east" and "west" populations of *H. chrysoscelis*, they concluded that one class of Texas *H. versicolor* was immunologically identical to the eastern *H. chrysoscelis*, another class was immunologically identical to the western *H. chrysoscelis*, and a third (and largest) class was immunologically heterogenous. Ralin and Rogers (1979) performed an analysis of thirteen external morphological characters. They concluded that none of the populations in the study were statistically different from other groups for any one measurement. In addition, they distinguished three groups of populations. One group consisted of five southcentral Texas populations of *H. chrysoscelis;* the second was three Texas populations of *H. versicolor*, and the third was from four populations of *H. chrysoscelis* from different parts of its range.

Green (1979) used scanning electron microscopy of the digital toe pads of a number of frog species (including gray treefrogs). He found that while all *Hyla* species were very simmilar in morphology, *H. versicolor* was distinguished by the greater size of its toe pad cells compared to those of *H. chrysoscelis*.

Cash and Bogart (1978) theorized that the physical dimensions of the tetraploid nucleus should be greater than those of the diploid. Their study demonstrated that the measurement of nuclear diameters from paraffin histosections was an accurate method for species recognition; the spherical volumes of *H. versicolor* nuclei were approximately twice the size of *H. chrysoscelis*.

Although previous studies on the distribution of the *H. versicolor-chrysoscelis* species complex have been conducted in the border states of Mississippi (Ralin and Rogers, 1979), Missouri (Johnson, 1977), and Texas (Johnson, 1959; 1963) and in Kansas (Hillis *et al.*, 1987), no studies have addressed the distinction of these species in Arkansas. The objectives of the present study were to determine the identity and distribution of gray treefrogs species in Arkansas from museum specimens using histological and ultrastructural techniques.

MATERIALS AND METHODS

A total of 120 gray treefrogs from the Milwaukee Public Museum, University of Arkansas at Monticello, Arkansas Tech University, and Arkansas State University Museum of Zoology was examined. The sample included specimens from 66 sites in 28 counties; the snout-vent length (SVL) was recorded for each animal. Eyelids were removed and placed in vials of 70% ethanol. Standard histological techniques were used to prepare tissues for light microscopy (Humason, 1979). Tissues were dehydrated in a graded series of ethanol and toluene, embedded in paraffin, sectioned serially at 10 μm, stained with Harris hematoxylin, and counterstained with eosin. In addition, we oriented eyelids tangentially during sectioning in order to maximize the number of cells in the field of view. Ninety nuclear diameters were measured from a routinely-selected area of each eyelid using an ocular micrometer to the nearest 0.1 μm.

The toe pads of 20 specimens were examined using scanning electron microscopy (SEM). Toes from the left hind foot were excised, dehydrated in a graded series of ethanol and amyl acetate, dried with Samdri critical point dryer, coated with gold/palladium with a Hummer IV sputter coater, and viewed with a JEOL 100 CXII TEMSCAN electron microscope at an accelerating voltage of 40 kV.

RESULTS

Two distinct groups of frogs were observed in our sample (Fig. 1). Those which exhibited higher average nuclear diameters were presumed to be *H. versicolor*, whereas those with lower average nuclear diameters were presumed to be *H. chrysoscelis*. Within the presumed group of *H. versicolor*, nuclear diameters ranged from 9.6 - 12.6 μm ($\bar{x}$ = 10.9 μm; N = 9); in the presumed *H. chrysoscelis*, nuclear diameters ranged from 7.7 - 8.7 μm ($\bar{x}$ = 8.4 μm; N = 101). We found no significant correlation between the average nuclear diameter and SVL ($P >$ 0.05). In addition, we noted a third (intermediate) group whose average

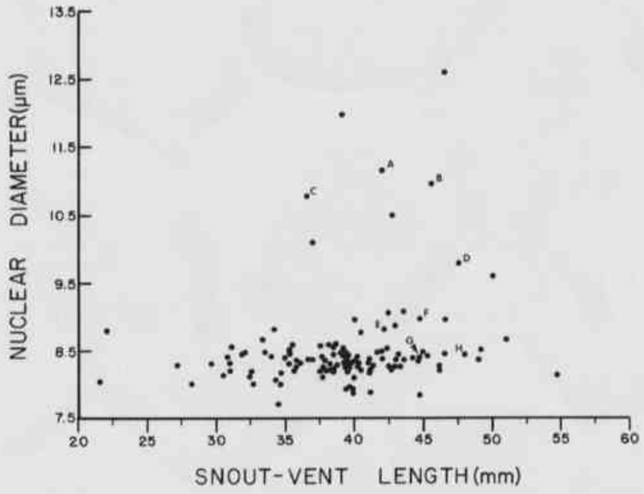

Figure 1. Relationship between average nuclear diameter of eyelid epidermal cells and SVL of gray treefrogs of the *Hyla versicolor-chrysoscelis* species complex from Arkansas. Letters correspond to specimens whose digital toe pad cells are depicted in Fig. 2.

nuclear diameters ranged from 8.7 - 9.1 μm ($\bar{x}$ = 8.9 μm; N = 10). This latter group did not display the large nuclear diameters of presumed *H. versicolor*, yet their diameters were larger than presumed *H. chrysoscelis*. The same existed with respect to their toe pad cells (Fig. 2). With the exception of one animal (from Columbia Co.), all intermediate treefrogs were collected from counties within the Ozark Mountains of northern Arkansas (Fig. 3). Presumed *H. chrysoscelis* specimens were found throughout Arkansas, whereas most of the presumed *H. versicolor* were from the northern regions of the state. In many instances, presumed *H. versicolor* and *H. chrysoscelis* occurred in close proximity to one another. This condition was similar to the situation found in Kansas (Hillis *et al.*, 1987).

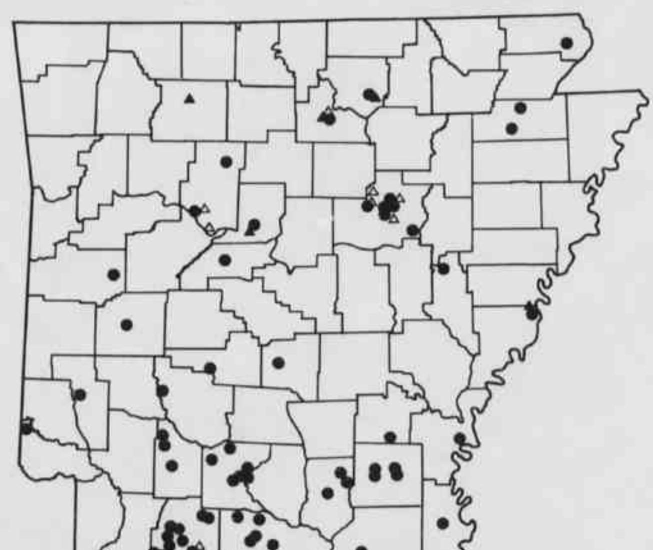

Figure 3. Locations for museum specimens of the *Hyla versicolor-chrysoscelis* species complex of gray treefrogs from Arkansas. Solid circles = presumed *H. chrysoscelis;* solid triangles = presumed *H. versicolor;* open triangles = intermediate males.

Variation in the size of digital toe pad cells of the complex using SEM is shown in Fig. 2. Cells of presumed *H. versicolor* (Fig. 2 A-D) are much larger than those of intermediates (Fig. 2 E and F) or of presumed *H. chrysoscelis* (Fig. 2 G and H). A pairing of toe cell size with average nuclear diameter in Fig. 1 yielded a proper species identification in 88% (excluding intermediates) of the specimens.

DISCUSSION

In our study of the *H. versicolor-chrysoscelis* species complex of gray treefrogs, we only used data on average nuclear diameter of eyelid cells to separate the two species mainly because Green (1979), using SEM, was able to match toe pad cell size with the proper species 79% of the time. Earlier studies used specimens from previously identified populations and then sought to further distinguish the two species (Brown and Brown, 1972; Gayou, 1984; Green, 1979; Maxson *et al.*, 1977; Ralin, 1968; Ralin and Rogers, 1979) with varying degrees of success.

Previous investigations were not helpful in decifering the gray treefrog complex in Arkansas. Ralin and Rogers (1979) and Maxson *et al.*, (1977) mention "eastern" and "western" populations of *H. chrysoscelis*. The former authors refer to the "eastern" group as occurring in South Carolina, Georgia, Ohio, and Mississippi, whereas the "western" group were from Texas. Although *H. versicolor* and *H. chrysoscelis* occur sympatrically throughout much of their ranges, current usage of geographic terms to imply genetic similarities or differences only tend to obfuscate the complex, especially in regions poorly studied. Ralin and Rogers (1979) suggested that populations in the Midwest, border states, and western portions of the South might be intermediate or integrade populations of *H. chrysoscelis*. While Ralin's (1968) distributional map for the two species showed the entire state of Arkansas as having almost exclusively *H. chrysoscelis* (with the exception of extreme northwestern Arkansas), our study indicates that what we assume to be *H. versicolor* is found throughout northcentral Arkansas as well as in the extreme eastern portion of the state. We also concur with Hillis *et al.*, (1987) that additional studies are needed to evaluate the possibility of multiple origins of polyploidy in the gray treefrog complex. These investigations would be especially important in northern Arkansas where we detected intermediate treefrogs.

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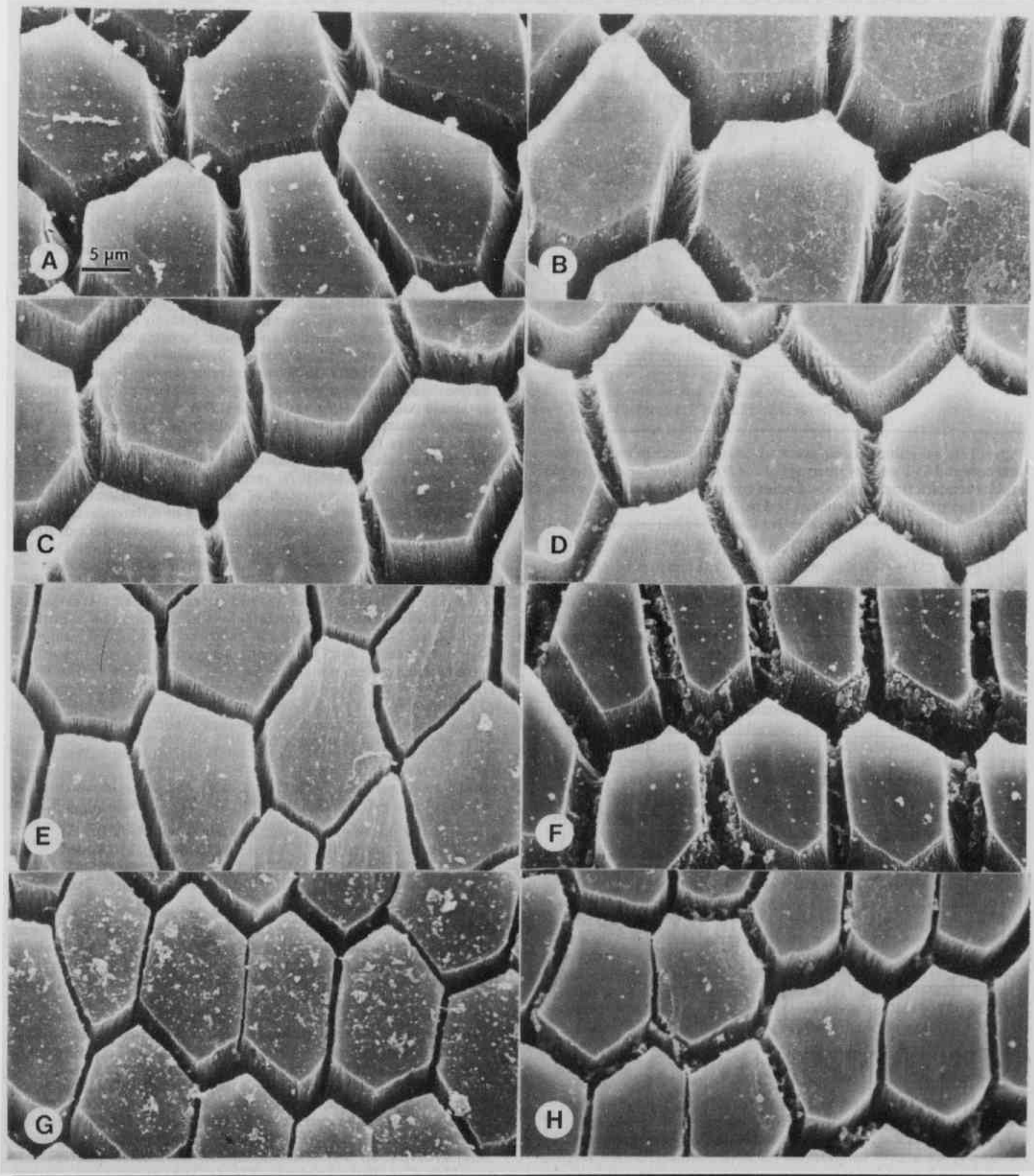

Figure 2. Scanning electron micrographs of toe pad epidermal cells from the hind foot (middle digit) of gray treefrogs of the *Hyla versicolor-chrysoscelis* species complex from Arkansas. X2,000. A - H correspond to A - H of Fig. 1. A-D Polygonal cell surfaces representative of *H. versicolor*. E and F. Cells from intermediate males. G and H. Cells from *H. chrysoscelis*.

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AN IMPROVED SYNTHESIS OF 5-METHYLBENZ(A)ANTHRACENE

JIA CHE and T.C. YANG
Department of Chemistry
University of Arkansas at Little Rock
Little Rock, AR 72204

ABSTRACT

A revised synthesis of 5-methylbenz(a)anthracene is reported. It involves only three simple and convenient steps starting from a commercially available compound, and gives a 82% overall yield. Bromination of 5-methylbenz(a)anthracene with N-bromosuccinimide (NBS) in carbon tetrachloride furnishes 5-bromomethylbenz(a)anthracene in a 92% yield. When bromination is carried out using dimethylformamide as the solvent, 7-bromo-5-methylbenz(a)anthracene is formed as the exclusive product.

INTRODUCTION

It has been well established over a period of about sixty years that many polycyclic aromatic hydrocarbons (PAHs) are carcinogens; they are also widespread environmental pollutants (Dipple *et al.*, 1984). PAHs require metabolic activation in order to exert their biological activities, including carcinogenicity (Dipple *et al.*, 1984; Gelboin and Ts'o, 1978). It is not clearly understood why some PAHs are carcinogenic while others arenot carcinogenic.

Methylbenz(a)anthracenes (MBAs) are PAHs that have been found in cigarette smoke and in the environment (Thomas *et al.*, 1978). Among the twelve MBAs, 6-,7-,8-, and 12-MBAs were found to be carcinogenic, but the other isomers are either very weakly carcinogenic or non-carcinogenic (Newman, 1976). Investigation of why these twelve compounds exhibit different carcinogenicity requires syntheses of large quantities of all twelve compounds for detailed metabolic studies.

A simple synthetic procedure for synthesis of 5-MBA was reported by Newman (1950). It involves four steps. The first step is a Friedel-Crafts acylation of 1-methylnaphthalene with phthalic anhydride to give keto-acid *1* in 96% yield. The second step is reduction of the keto-acid to acid *2* (90%) by zinc dust in sodium hydroxide. In the third step, the acid is cyclized by concentrated sulfuric acid. In the fourth step the resulting ketone is reduced by zinc dust to 5-MBA *3*. The over-all yield of this method is 46%.

Newman's method was modified by Fu *et al.*, (1982). The keto-acid *1* was similarly prepared and was cyclized by concentrated sulfuric acid to 5-MBA-7,12-dione. Reduction of the dione by HI in acetic acid gave 5-MBA in a 96% yield. This modified procedure requires only three steps. However, the over-all yield was still low, only 51%. In this report, we describe a modified synthesis of 5-MBA and two of its ring substituted and side-chain-substituted brominated derivatives which also increases the % yield.

METHODS OF INVESTIGATION

Proton NMR spectra were recorded with a Joel WM 100 spectrometer. Mass spectra were obtained on a Finnigan Model 4023 gas chromatograph-mass spectrometer system, via solid probe insertion, by electron impact ionization at 70 ev and anion source temperature of 25 °C.

(*3*) - A Mixture of 2-(1-methyl-4-naphthyl)benzoic acid (*2*) (2.76 g, 10 mmol) and 57% HI (10 ml) in glacial acetic acid (120 ml) was refluxed for 6 hrs. After the resulting solution was poured into a sodium bisulfite solution, the precipitate was collected by filtration and washed with water. Upon purification by silica gel column chromatography and elution with hexane, 5-methylbenz(a)anathracene was obtained as colorless solid (2.6 g, 96%), mp. 156-157 °C (benzene), lit. (Fu *et al.*, 1982) mp. 156-157 °C. This compound was further confirmed by comparison of its mass and NMR data with those of an authentic sample.

(*4*) - A mixture of 5-methylbenz(a)anthracene (605 mg, 250 mmol) and NBS (45 mg, 0.25 mmol) in DMF (15 ml) was heated at reflux for 2 hrs. The precipitate, succinimide, was removed by filtration. Chromatography of the filtrate on silica gel with benzene-hexane (1:1) as eluant afforded 7-bromo-5-methylbenz(a)anthracene (736 mg, 92%), mp. 162-165 °C (Recrystallization from benzene as yellowish needles); mass spectrum: m/z 320 (M^+); NMR (acetone-d_6): 2.72 (s, 3H, CH_3), 7.4-8.3 (m, 8H, $H_{2\text{-}4,6,8\text{-}11}$), 9.04 (d,1H,$H_1$) and 9.0 ppm (s, 1H, H_{12}).

(*5*) - To a solution of 5-methylbenz(a)anthracene (605 mg, 250 mmol) in 20 ml of CCl_4 was added NBS (45 mg, 0.25 mmol) and benzoyl peroxide (10 mg). The resulting heterogeneous solution was refluxed under nitrogen for 2 hrs. Workup and column chromatography as described above followed by recrystallization with benzene afforded 5-bromomethylbenz(a)anthracene as colorless needle (704 mg, 88%), mp. 164-166 °C; mass spectrum: m/z 320 (M^+); NMR (acetone-d_6): 4.8 (s, 2H, CH_2), 7.3-8.5 (m, 8H, $H_{2\text{-}4,6,8\text{-}11}$), 8.4 (s, 1H, H_7), 9.02 (d, 1H, H_7), 9.02 (d, 1H, H_1) and 9.38 ppm (s, 1H, H_{12}).

RESULTS AND DISCUSSION

The modified method for the synthesis of 5-MBA requires only three simple steps (Fig. 1). The first two steps, synthesis of *1* and *2*, are the same as those reported by Newman. The novelty is in the last step. The acid *2* can be simultaneously cyclized and reduced to 5-MBA by HI in glacial acetic acid under reflux for 6 hours. The yield is 96%. The over-all yield of these three steps is 82%, which is much higher than the 46% yield reported by Newman, and the 51% yield reported by Fu *et al.* The 5-MBA synthesized is very pure, and can be used for biological study just after one recrystallization from benzene. The simplicity and the much higher overall yield of this improved synthesis compared to the other two known methods are ascribed to avoidance of concentrated sulfuric acid as the cyclization reagent.

Bromination of 5-MBA by NBS in dimethylformamide affords 7-bromo-5-MBA (*4*) in 92% yield. The structural assignment was based on analysis of its mass spectrum, which shows the molecular ions at m/z 320 and 322, and its proton NMR data which indicates that the resonance assigned for the proton at carbon-7 is missing. Based on perturbation molecular orbital theoretical calculation, the 7-position is the most reactive position of 5-MBA in an electrophilic aromatic substitution reaction (Dewar, 1969). Thus, the formation of 7-bromo-5-MBA is not only consistant with these calculations, but also confirms that bromination using NBS is dimethyl formamide is *via* an ionic mechanism. On the other hand, bromination of 5-MBA *via* a free radical mechanism is expected to take place at the side chain methyl group, and bromination using NBS in carbon tetrachloride is known to proceed by a free radical mechanism. Indeed, bromination of 5-MBA by

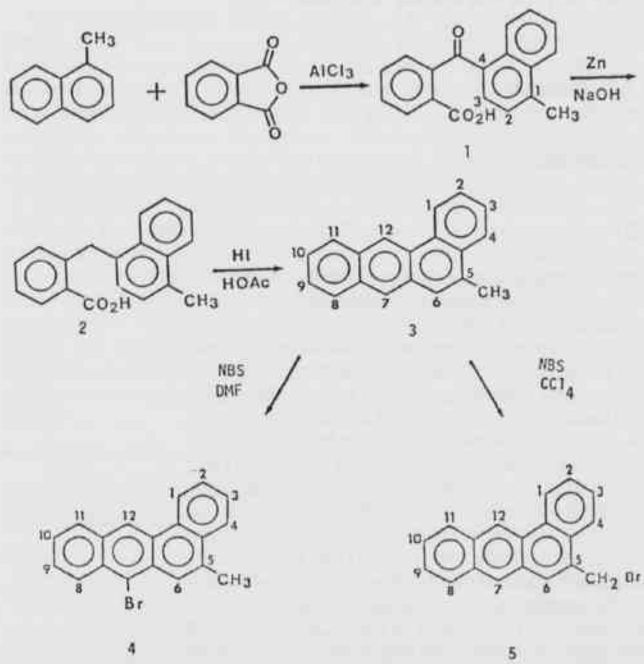

Figure 1. Synthetic scheme for 5-methylbenz(a)anthracene and its derivatives

this reagent provide 5-bromomethylbenz(a)anthracene (*5*) as the sole product, without the detection of 7-bromo-5-MBA. The structure of (*5*) was also assigned from its mass spectrum which had the molecular ions at m/z 320 and by analysis of its proton NMR data. These two bromo compounds are important intermediates for the synthesis of other 5-MBA derivatives which are useful for biological studies.

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RESIDUAL PESTICIDES IN FISHES FROM LAKE CHICOT, ARKANSAS

C.M. COOPER and S.S. KNIGHT
USDA-ARS National Sedimentation Laboratory
P.O. Box 1157
Oxford, Mississippi 38655

ABSTRACT

Samples of fish from isolated and flow-through portions of Lake Chicot, Arkansas, were analyzed for residual pesticide concentrations from 1978 and 1981. Where appropriate ecologically, fish flesh, viscera and whole fish, were analyzed for the common organochlorine insecticides DDT [1,1,1-trichloro-2,2bis(p-chlorophenyl)-ethane], DDE [1,1-dichloro-2,2-bis(p-chlorophenyl)-ethyene], DDD [1,1-dichloro-2,2-bis(p-chlorophenyl)-ethane], toxaphene (chlorinated camphene), chlordane, heptachlor, heptachlor epoxide, dieldrin, and endrin. DDT, DDT metabolites, and heptachlor were significantly ($\alpha = 0.05$) higher in spotted gar *(Lepisosteus oculatus)* and yellow bullhead catfish *(Ictalurus natalis)* than in other species examined. Pesticide concentrations did not exceed the acceptable levels established by the U.S. Environmental Protection Agency although toxaphene levels in one white crappie (*Pomoxis annularis)* and one freshwater drum *(Aplodinotus grunniens)* were as high as 0.01 μg/g. Bottom feeding and piscivorus fishes had consistently higher concentrations of pesticides than fishes belonging to other feeding groups. The main body of the lake, with a large drainage area (930 km²) had higher concentrations of suspended solids than did the isolated northern basin and produced fish with significantly ($\alpha = 0.05$) higher levels of toxaphene, DDD, and DDT. Insecticide concentrations were consistently greater in viscera with toxaphene, DDT, DDE and DDD levels significantly ($\alpha = 0.05$) greater than in either whole fish or fish flesh samples. Eight years after banning, residual pesticides in fish from both basins of Lake Chicot were still significantly ($\alpha = 0.05$) higher during years of increased runoff, indicating the importance of watershed management practices on longterm downstream water resources.

INTRODUCTION

Although the use of organochlorine pesticides from 1940 to the early 1970's provided greater crop yields, low degradability resulted in worldwide contamination by residual pesticides (Breidenbach, *et al.*, 1964; Woodwell, *et al.*, 1971; Crump-Wiesner, *et al.*, 1974). Bioaccumulation of these pesticides in terrestrial and aquatic ecosystems occurred to the point that reproductive processes were affected in several species of wildlife by mid-1960's (Walker, *et al.*, 1973; Hickey *et al.*, 1966). Although use of organochlorine pesticides has ceased, concentrations of these compounds are still high in fish and wildlife in areas where extensive application occurred.

Lake Chicot is located in the alluvial plain of the Mississippi River in eastern Arkansas, an area noted for its agricultural productivity. Because of the intensive agriculture in this region, numerous organochlorine pesticides were applied for several decades to control insect pests. The purpose of this study was to examine residual pesticide concentrations in Lake Chicot fishes, a group of vertebrates known to bioaccumulate many pesticides. Fish pesticide concentrations were compared by species, yearly watershed runoff, lake basin, and ecological and anatomical groupings.

MATERIALS AND METHODS

Lake Chicot (19.3 km^2), an oxbow lake of the Mississippi River (Fig. 1) located in east Chicot County, Arkansas, is 27 km long and averages approximately 0.8 km in width. The watershed draining into the lake is primarily in intensive agriculture with principal crops being cotton *Gossypium hirsutum*, rice *Oryza sativa*, and soybeans *Glycine max*. Prior to 1927, Lake Chicot was a single body of water with limited inflow from Connerly Bayou and outflow via Ditch Bayou. Floods in 1927 deposited large quantities of materials across the lake immediately north of the mouth of Connerly Bayou and formed a sizable sand spit. Simultaneously, the normal lake level was lowered as both Connerly and Ditch Bayou were deepened by scouring. In 1948, additional materials were added to the sand spit by Arkansas Game and Fish Commission to form a levee that bisected the lake into two basins: an isolated northern basin (3.9 km^2) and a larger flow-through southern basin (15.4 km^2). Watershed enlargement, both intentional and by the 1927 flood event, increased the drainage area of the southern basin from approximately 100 km^2 to 930 km^2. The isolated northern basin has only ephemeral runoff from a small predominantly agricultural watershed of <100 km^2.

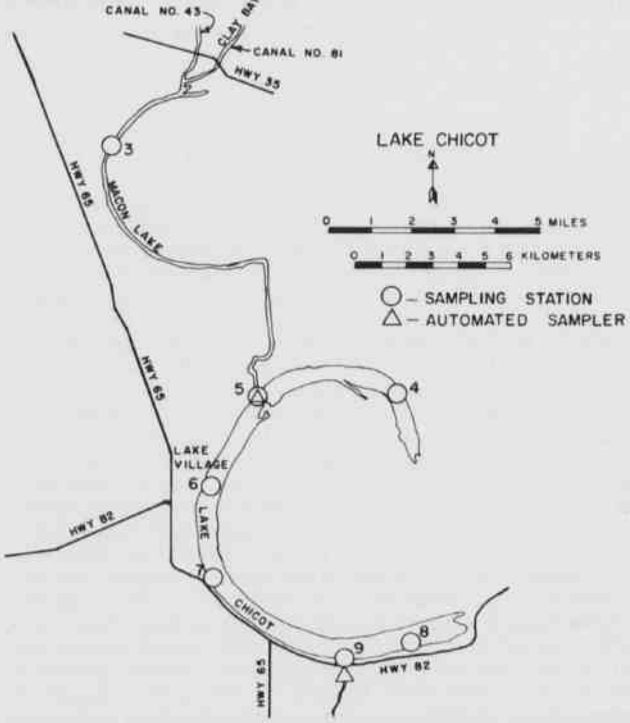

Figure 1. Map of Lake Chicot, Arkansas, depicting fish sampling sites and automatic water sampling sites.

Fish were collected at selected sites (Fig. 1) by seining and gill or hoop netting. They were wrapped in aluminum foil, and packed in ice for transport. Samples were then frozen and transported to the Soil-Plant Analysis Laboratory, Northeast Louisiana University, Monroe, Louisiana where they were analyzed for DDT, DDE, DDD, endrin, dieldrin, toxaphene, chlordane, heptachlor, and heptachlor epoxide using analytical procedures as described by the U. S. Environmental Protection Agency (1971). One hundred and thirty-six samples of flesh, viscera, or whole fish were analyzed from Lake Chicot from 1978 through 1981 (Table 1). Prey fish which are typically eaten whole were analyzed as whole fish samples. Smaller size groups were comprised of a minimum of 10 individuals per sample. "Game" fishes such as largemouth bass and channel catfish were analyzed as separate flesh and viscera samples. An analysis of variance was used to test for yearly, lake, species, feeding groups and type of sample (flesh, viscera, whole fish) effects for all pesticides. A Duncan's multiple range test was used for differences in yearly means, means for each species, lake means, and sample type means.

Table 1. Fish species analyzed for organchlorine pesticides in Lake Chicot, Arkansas from 1978 through 1981.

Species	Samples Collected		Feeding* Group
	Northern Basin	Southern Basin	
Dorosoma cepedianum	6	3	f
Aplodinotus grunniens	5	6	b
Ictiobus bubalus	4	4	b
Ictiobus cyprinellus	0	2	b
Lepomis gulosus	2	0	o
Lepomis macrochirus	6	1	o
Lepomis megalotis	2	0	o
Lepomis humilis	1	1	o
Lepomis cyanus	0	2	o
Pomoxis annularis	6	10	p
Micropterus salmoides	5	0	p
Ictalurus melas	0	3	b
Ictalurus punctatus	20	12	b
Ictalurus natalis	2	0	b
Morone chrysops	10	0	p
Lepisosteus oculatus	2	2	p
Cyprinus carpio	7	10	b
Notropis umbratilis	0	1	o
Labidesthes sicculus	0	1	o

* b = bottom feeders, p = piscivores, f = filter feeders, o = omnivores.

RESULTS AND DISCUSSION

Concentrations of organochlorine pesticides were generally similar from species to species. Heptachlor, however, was significantly higher in yellow bullhead catfish *(Ictalurus natalis)* than in the other species of fish examined while spotted gar *(Lepisosteus oculatus)* had significantly higher levels of DDE and total DDT metabolites. Pesticide concentrations in whole fish samples never exceeded the upper limit (0.1 $\mu g/g$) established by U. S. Environmental Protection Agency (1973). However, two specimens, a white crappie *(Pomoxis annularis)* from the southern basin and a freshwater drum *(Aplodinotus grunniens)* from the northern basin, had toxaphene levels of 0.01 $\mu g/g$. When grouped by feeding habits, bottom feeding fish, including yellow bullheads and freshwater drum, and piscivorus fishes such as the spotted gar and white crappie had significantly (α = 0.05) higher concentrations of pesticides (Fig. 2). Piscivorus fish occupy a high position in the food chain and might be expected to have elevated levels of pesticides through step-wise bioaccumulation through the food chain. Bottom feeding fish have greater exposure to pesticides concentrated in the sediment-water interface and likely accumulate pesticides from mud ingested with their food.

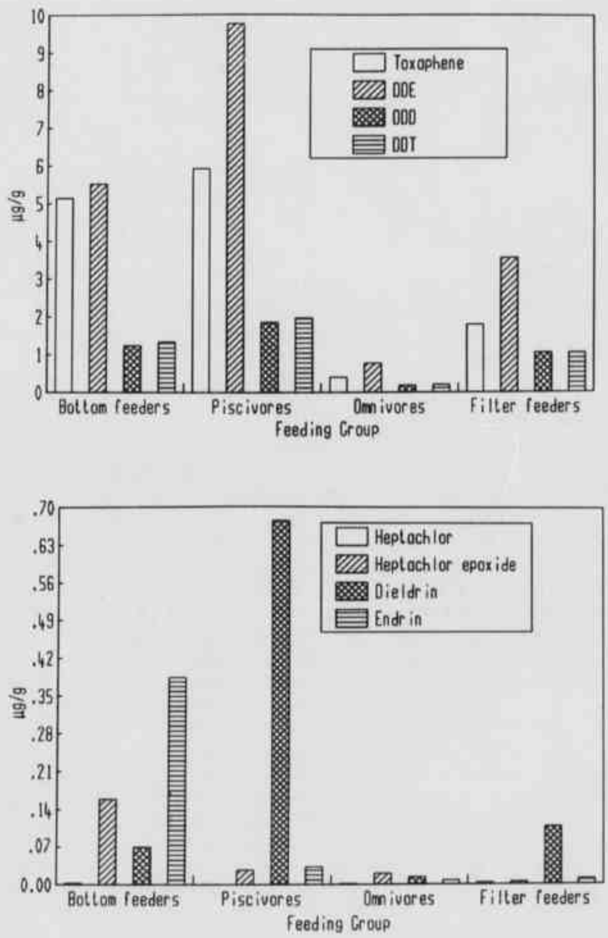

Figure 2. Concentrations of pesticides in fish categorized by feeding group (trophic level), from Lake Chicot, Arkansas, 1978 thru 1981.

Basin to basin comparisons revealed significantly (α = 0.05) higher concentrations of toxaphene, DDD, and DDT in the flow-through southern basin. This observation was expected since the southern basin receives a greater amount of agricultural runoff. Year to year comparisons showed significantly (α = 0.05) higher amounts of toxaphene, heptachlor, DDD, DDE, and DDT in 1979 and 1980 than in the other years (Table 2). Stage-discharge records indicated runoff amounts in 1979 were 413 percent greater than in 1977. Both 1979 and 1980 had increased runoff as a result of high ground water levels (Schiebe, *et al.*, 1984). There were significantly yearly and basin effects; however, there was not a significant year-basin interaction.

Organochlorines have been shown to concentrate in the fatty tissues of several species of animals (Matsumura, 1976; Murty, 1986). Viscera samples had higher concentrations of all pesticides than did flesh or whole fish samples. Viscera were also significantly (α = 0.05) higher in concentration of toxaphene and DDT and its metabolites. Humans consume the fleshy portions of fish so pesticides concentrations may not pose as great a problem to humans as to other predators.

Table 2. Pesticides with significantly different average concentrations in fish by year in Lake Chicot, Arkansas.

Pesticide	Year*			
Toxaphene	79	80	78	81
Heptachlor	80	79	78	81
DDT Metabolites	79	80	81	78
DDE	79	80	81	78
DDD	80	79	78	81
DDT	79	80	78	81

* Underscore indicates no significant differences between years.

SUMMARY

An analysis of flesh, viscera or whole fish samples from 19 species of fish from Lake Chicot, Arkansas indicated significantly ($\alpha = 0.05$) higher concentrations of heptachlor, and DDT metabolites especially DDE in yellow bullhead catfish and spotted gar than in other species. Pesticides never exceeded the recommended maximum concentrations set by the EPA (1973). Bottom feeding and piscivorus fishes had higher levels of pesticides than did other groups of fish. Lake to lake differences were observed for toxaphene, DDD and DDT. Toxaphene, heptachlor, DDD, DDE and DDT were significantly ($\alpha = 0.05$) higher in samples collected during 1979 and 1980, years which followed periods of unusually high runoff; there were no significant year-basin interactions. While all pesticides analyzed were concentrated in viscera at relatively high levels, only toxaphene, DDD, DDE, and DDT were significantly ($\alpha = 0.05$) higher in viscera than in flesh or whole fish samples.

Fish were found to be excellent indicators of residual pesticides as are other top consumers in the food chain. Even year to year changes could be detected when sample size and species variety were large enough for statistical analysis. Residual pesticides were still measurable and accumulating in fish in Lake Chicot five to eight years after these pesticides were banned. With no further application of these pesticides, gradual degradation should continue to reduce concentrations in this ecosystem.

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CLINOSTOMUM MARGINATUM METACERCARIA: INCIDENCE IN SMALLMOUTH BASS FROM A NORTH ARKANSAS STREAM AND *IN VITRO* OXYGEN CONSUMPTION STUDIES

JAMES J. DALY[1], HOWARD H. CONAWAY[2] and TERRY L. HOSTETLER[1]
Departments of Microbiology and Immunology[1] and Physiology and Biophysics[2]
University of Arkansas for Medical Sciences
Little Rock, AR 72205

H. MICHAEL MATTHEWS
Department of Biology
University of Arkansas at Little Rock
Little Rock, AR 72204

ABSTRACT

Smallmouth bass *(Micropterus dolomieui)* captured from Crooked Creek (Marion Co., Arkansas) in the summers of 1977 and 1987 were found to have a high incidence of infection with the metacercaria of *Clinostomum marginatum* (yellow grub). Of 41 fish collected in 1977, 32 (78%) were found infected with metacercariae with some fish containing large numbers of parasites. The number of larvae per fish ranged from 1 to 184, with an average of 23.2 ± 38 per smallmouth. Eighty-six percent of the bass collected in 1987 were found positive for *C. marginatum*. The number of metacercariae per fish ranged from 1 to 227 with an average of 32.7 ± 54 per fish. Fish from both collection groups ranged in size from 12 to 34 cm. No significant correlation could be found between the number of metacercariae per fish and the length of the host. Using metacercariae removed from host tissue, the effect on oxygen consumption by glucose, serotonin and insulin, singularly or in combination, was measured by manometric methods. Glucose alone did not stimulate oxygen utilization, serotonin alone and with glucose was stimulatory, and insulin with glucose also increased oxygen consumption.

INTRODUCTION

Crooked Creek, located in North-Central Arkansas, has an excellent reputation for its smallmouth bass *(Micropterus dolomieui)* fishery. However, the smallmouth from this stream have had a reputation of being "wormy" with this condition being due to the presence of large numbers of metacercariae of the trematode *Clinostomum marginatum*. The adult stage of this fluke is found in the mouth and esophagus of fish-eating birds. This larval form, also called "yellow grub", is relatively large (~ 5 mm) and easily seen making the fish an unpalatable prospect for eating. Although this infection has been noted with fish from other Arkansas streams it has not been seen with the same intensity as found in Crooked Creek smallmouth bass. However, "yellow grub" in Crooked Creek fish has not been specifically studied and information regarding this infection is entirely anecdotal. Therefore, it was decided to examine smallmouth bass from Crooked Creek in order to obtain quantitative data to verify previous informal reports of excessive parasite loads.

Experimental work on trematodes is somewhat limited by their availability. Husbandry of trematodes in the laboratory is complicated by life cycles requiring a mollusc intermediate host. Also, because of medical or economic importance the majority of trematode metabolic work has been done primarily with the adults of two genera, *Schistosoma* and *Fasciola*. The heavy infestations of fish from Crooked Creek offered an opportunity to provide enough parasites for physiologic studies on an infrequently examined stage (metacercaria) of an important, but little studied fluke infection of fish. This report presents data on preliminary manometric experiments measuring oxygen consumption in the singular or combined presence of glucose, serotonin, and insulin. Glucose is known to stimulate the metabolism of trematodes, serotonin and insulin are known to stimulate the carbohydrate metabolism of adult trematodes, but it is not known whether trematode metacercariae are affected by insulin or serotonin.

METHODS AND MATERIALS

Smallmouth bass were collected by rod and reel from Crooked Creek between Pyatt and Yellville (Marion Co.), Arkansas in the summers of 1977 and 1987. The fish were transported to the University of Arkansas for Medical Sciences in Little Rock and stored at 4°C until examined for parasites. The fish were measured (standard length), skinned, and all muscle tissue examined for the presence of metacercaria. Worms were gently removed from a fish, placed into poikilothermic saline solution (0.75%), counted, and then pooled with worms taken from other fish. The pooled worms were then used immediately for the physiology studies. The maximum time from stream to experimental use of the worms did not exceed 48 hr.

Oxygen consumption was measured by the direct method of Warburg (Umbreit *et al.*, 1964). Forty metacercariae in 2.6 ml of Hedon-Felig solution (Dawes, 1954) were placed in 20 ml double side-arm manometry flasks. A small central compartment contained 0.2 ml of 30% KOH absorbed on fluted filter paper to remove metabolically produced CO2. One side arm contained 0.2 ml of substrate and/or hormone. Flasks were oscillated and incubated at 30°C in a water bath, and allowed to equillibrate for 30 min before addition of substrate and/or hormone. Oxygen consumption was measured, after additions, for 60 min or 90 min. Final concentrations of additives used were: 20 mM glucose (Pfanstiehl Laboratories, Waukegan, IL), 1 mM serotonin

(Sigma Chemical Co., St. Louis, MO), and 0.02 units insulin crystalline (Eli Lilly & Co., Indianapolis, IN).

RESULTS

Thirty-two of forty-one smallmouth bass (78%) collected in 1977 were found to be infected with metacercariae of *C. marginatum*. The length of infected fish ranged from 13 to 32 cm with the average length being 20.2 ± 4.9. Nine uninfected fish averaged 21.3 cm in length. Parasite load per fish ranged from 1 to 184 worms with an average of 23.2 ± 38 per fish. Nineteen of twenty-two fish (86%) collected in 1987 were positive for *C. marginatum*. Positive fish ranged in length from 12 to 27.9 cm (21.2 ± 4.1), had 32.7 ± 54 worms per fish, and individual parasite loads from 1 to 227. The heavy infections in the bass appeared consistent even after a ten year hiatus in collection times. Although no attempt was made in this study to note the worm burdens in different areas of fish musculature we observed that the areas around the dorsal and tail fins were more susceptible in heavy infections. Also,in some fish the cheek muscle under the operculum was so heavily infected that most of the normal tissue had been replaced by parasites. Metacercariae were also found on the gills, in the gill cavity, on the peritoneal wall, and attached to internal organs. Little correlation was seen between length of fish and parasite load when comparing arithmetic, semilogarithmic, and logarithmic relationships using either measurement as dependent and independent variables. R values for the four comparisons ranged from 0.027 to 0.17 and P values were not significant ranging from 0.34 to 1.0. No data was obtained on weight or age of fish, therefore relationships between these variables and number of grubs per fish were not examined.

Table 1. Oxygen consumption by metacercaria of *Clinostomum marginatum* in Hedon-Fleig solution at 30 °C with glucose, serotonin, glucose and serotonin, and glucose and insulin added. QO_2 is the microliters of oxygen consumed per hour by forty worms. % is the percent stimulation of oxygen consumption above the endogenous rate.

Experiment	QO_2 Endogenous	QO_2 Glucose	%	QO_2 Glucose + Serotonin	%	QO_2 Serotonin	%	QO_2 Glucose + Insulin	%
1	136	126	93	201	148	194	143	165	121
2	125	109	87	200	160	195	156	N.D.	---
3	170	176	104	234	138	N.D.*	---	208	122
$\bar{X} \pm$S.D.	144±24	135±35	95**	212±19	147**	196	135**	197	130**

*N.D. = Not determined
** = $\bar{X}$ QO_2 Additive/$\bar{X}$ QO_2 Endogenous

Oxygen consumption values are found in Table 1. Surprisingly, glucose did not stimulate utilization of oxygen and its presence may even have been repressive, as indicated by two experiments in which lower values were obtained in the presence of glucose. However, differences between the two means were not significant ($P = 0.8$). A significant difference between absolute values ($Q O_2$) was found between the endogenous and glucose + serotonin ($P = 0.02$). Values for the combination were slightly higher than for the use of serontonin alone. A difference between serotonin alone and the endogenous $Q O_2$ value is apparent but cannot be statistically tested due to only two values being available for this combination. In both experiments where insulin + glucose was used there was also stimulation well above the endogenous $Q O_2$ production.

DISCUSSION

Clinostomum marginatum metacercariae are found in a variety of fish species. Hoffman (1967) lists 56 species of North American freshwater fishes as infected by *C. marginatum*. Torres and Price (1971) have summarized the status of *C. marginatum* infections in fish that "the nominal *Clinostomum* infection involves 20 or fewer parasites, and still heavier infections being relatively rare". In Arkansas this trematode has been reported in centarchids from Lake Fort Smith (Hoffman, *et al.*, 1978) and from the Buffalo and White Rivers (Kilambi and Becker, 1977) but not with the same high infection rate or excessive parasitism as seen in smallmouth from Crooked Creek. The most extensive study has been done on bass from the Buffalo River. Kilambi and Becker observed that 33% of 127 smallmouth collected from three sites contained *C. marginatum* metacercariae but infections were relatively light with an average of only 1.4 parasites per host. One bass, however, was found with 59 cysts. Heavy infections, similar to those in Crooked Creek smallmouth, have been reported in other areas of the U.S. for both individual fish and fish populations. In nearby Southwest Missouri, Taber (1972) noted infections in 5 centarchid species from the Spring, James, Niangua, Gasconade, Little Sac, and Pomme de Terre rivers. The smallmouth bass had the highest incidence of infection with 88% of 25 fish being positive for metacercariae but with only an average of 7.7 grubs per fish. Largemouth bass had the heaviest individual infections with an average of 39 yellow grubs per fish. One spotted bass was found to have 230 metacercarial cysts. The record number of metacercariae per fish may be the 500 larvae found in a brown bull head *(Ictaluris nebulosus)* collected near Lancaster, Pennsylvania by Torres and Price (1971). This fish was caught in poor condition and the parasites apparently contributed to its sad state since a large number of metacercariae were found issuing from a large abdominal perforation. Schwartz (1956) reported that heavy infestation with *C. marginatum* apparently killed 3 catfish *(Noturus miuris)* and Van Cleave and Muller (1934) reported two yellow perch *(Perch flavescens)* with 191 and 325 metacercariae each. It is not known what effect the metacercariae, especially in large numbers, have on the survival of the host. Some observers, such as ourselves, have not been able to detect behavioral differences in uninfected and heavily infected fish. However, these judgments are lacking empirical examination. It is hard to accept that such heavy parasite burdens would not affect the host adversely, especially if the disability would make the fish more susceptible to the fish-eating definitive host and promote the parasite's life cycle.

In the present report we were not able to detect a relationship between length of fish and the number of metacercariae found. However, Elliot and Russert (1949) found that the average number of parasites per fish showed a regular arithmetic increase with age and size of *Perca flavescens* taken from a northern Minnesota lake. Miller (1967) also noted such a relationship in log-log transformations with the length of threadfin shad *(Dorosoma petenense)* from a California reservoir and the number of metacercariae per fish. Failure to have found such a relationship with infected Crooked Creek smallmouth might be due to the limited number of fish (53) that were examined relative to the other two studies (2200 and 134 samples, respectively), intrinsic host-parasite factors, or different ecological relationships in a stream as compared to a lake. Self-expulsion of yellow grub has been found to be induced by higher temperatures during late summer as reported by Van Cleave and Muller (1934) in Lake Oneida (N.Y.), but not with infected fish in Wisconsin (Fischtal, 1949). Whether self-expulsion of metacercariae occurs in Crooked Creek bass is not known but smallmouth from the Buffalo River study were found infected in the winter at two of three collecting sites.

Anecdotal comments made to the senior author (JD) by local residents in Marion County have indicated that the smallmouth bass in Crooked Creek are not highly desirable as food because of their reputation as "wormy fish". Paradoxically, if the infections of *Clinostomum* do not hinder the reproduction or survival of smallmouth in Crooked Creek the parasites may actually inhibit overfishing by local fishermen. The outstanding reputation for smallmouth bass fishing that Crooked Creek enjoys may, in part, be the result of heavy trematode infections.

Adult trematodes are primarily anaerobic in their metabolism whereas the miracidium and cercarial larval stages are aerobic. Little is known of terminal respiration in metacercarial forms and our decision to use oxygen consumption was based on the findings of Thomas and Gallicchio (1967) who found evidence for aerobic metabolism in metacercariae of *Clinostomum campanulatum* by demonstrating the presence of CO_2 fixation, and the studies of James and Richards (1972) and Richards *et al.* (1972) who used oxygen consumption in Cartesian divers to study metabolism of *Microphallus pygmaeus* metacercariae. The failure of glucose alone to stimulate oxygen consumption in the present study was surprising since this sugar is known to be taken up by *C. marginatum* by both facilitated diffusion and active transport mechanisms (Uglem and Larson, 1987). Glucose stimulation of aerobic respiration may require a reduction in glycogen reserves or a factor supplied by the final definitive host.

Serotonin (5-hydroxytryptamine) is a neurotransmitter, regulates motility, and has an epinephrine-like effect on carbohydrate metabolism in trematodes (Mansour, 1984). The present report is the first to show a stimulatory effect by this compound on metacercarial forms. Although an additive effect was seen with glucose this difference was not large enough to be other than indicative due, perhaps, to the limited number of experiments done. Serotonin may be one of the definitive host factors involved in "metabolic awakening" in the change from larval form to adult fluke. Cho and Mettrick (1982) have demonstrated that the circadian migration of a gut tapeworm, *Hymenolepis nana,* correlated with the serotonin levels of worm tissue in the intestinal lumen and in the intestinal mucosa.

Initial work regarding insulin effect on flukes was in some dispute. Isseroff and Read (1968) claimed insulin was not stimulatory and that impurities were responsible for the earlier evidence that it stimulated carbohydrate metabolism of *Fasciola hepatica*. However, at the same time, Hines (1969) showed that in order for insulin to show maximum effect on *F. hepatica* the oral suckers had to be tied, implying that insulin was transported across the worm's tegument. Insulin, in the presence of glucose, stimulated the metabolism of *C. marginatum* metacercariae without having to tie the rather miniscule oral sucker of this larval trematode. Unfortunately, because of lack of parasites in certain experiments, it was not possible to include insulin alone. It had been expected that glucose alone would stimulate and any insulin stimulation could be determined as an additive effect. The stimulatory effects of both insulin and serotonin on oxygen consumption maybe independent of glucose uptake, relying on glycogen stores rather than direct utilization of glucose. This hypotheses can be tested in future experiments by obtaining parallel data on glucose uptake and glycogen content in the presence of the two hormones.

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GENETIC FAMILY AND STOCK TYPE INFLUENCE SIMULATED LOBLOLLY PINE YIELDS FROM WET SITES

J.F. DICKSON, J.L. YEISER, and R.A. KLUENDER
Department of Forest Resources
University of Arkansas at Monticello
P.O. Box 3468
Monticello, AR 71655

J.L. PASCHKE
Mangement Forester/Silviculture
Potlatch Corporation
Warren, AR 71671

ABSTRACT

Planting adapted families or a bulked seedlot of bare-root and container-grown-seedlings of loblolly pine (*Pinus taeda* L.) were contrasted as cost effective alternatives for regenerating Arkansas' wet sites. Survival data from two wet sites were used to simulate 15 years of growth. Containerized seedlings provided 17% greater survival than bare-root seedlings, but yielded a lower present net worth than bare-root seedlings. Planting families adapted to excessive moisture provided 7% greater survival and yielded a greater present net worth than planting a bulked seedlot consisting of adapted and poorly adapted families.

INTRODUCTION

Many loblolly pine sites in the South have soils underlain with a hardpan. During the traditional planting season a perched water table may develop making these sites especially hard to regenerate, as seedlings often die. Periodic flooding may complicate successful regeneration even more (Yeiser and Paschke, 1987). Planting during periods of excessive soil moisture increases the probability of seedling mortality due to anaerobic conditions. Postponing planting until the water table recedes can increase first-year survival, if the use of containerized seedlings can be economically justified (Yeiser and Paschke, 1987).

Survival of seedlings on wet sites may be increased by planting seedlings from families known to be well adapted to excessive soil moisture. The adaptability of families to these sites may be determined by a two-stage testing scheme described by Byram *et al.* (1986).

Planting of seedlings from families which have shown the ability to survive well on wet sites increases first-year survival, and consequently, by providing the desired spacing, increases yield of wood and income from these sites. First-year survival and future yields may also be increased by late planting of containerized rather than bare-root seedlings (Yeiser and Paschke, 1987).

Containerized seedlings are generally more expensive than bare-root seedlings due to limited production and availability. Also transportation costs for containerized seedlings are higher than those for bare-root seedlings (Guldin, 1983). Conventional planting practices include planting bare-root seedlings originating from bulked seedlots. A common industry minimum acceptable stocking is 300 seedlings per acre.

The objectives of this study were as follows:

1. To compare the 15-year simulated mean per acre yield of two families of loblolly pine selected for high adaptability to wet sites against the mean of five families representing a bulked seedlot, and

2. To contrast the cost effectiveness of planting two families of loblolly pine with high adaptability to wet sites with a bulked seedlot comprised of five families both planted as bare-root and containerized seedlings.

MATERIALS AND METHODS

Survival Data

First-year seedling survival from two wet sites in south Arkansas was selected for analysis. Site one is located near Ingalls, Arkansas, on a moderately drained Myatt silt loam (Larance, 1961). The second site is located near Locust Bayou, Arkansas, on a poorly drained Amy silt loam soil (Gill *et al.*, 1980). For a more detailed account of planting sites see Yeiser and Paschke (1987).

Seven families of loblolly pine, all part of a tree breeding program, were tested by Yeiser and Paschke (1987) for their ability to survive on wet sites. Progeny test data were available for only five of these seven families, so this study was restricted to these five families. Two families (CR-BL-33 and PC-58) showed significantly better survival than the others and were considered well adapted for general planting on wet sites (Yeiser and Paschke, 1987). Their first-year survival rates were averaged to produce the survival rate for adapted families. The first-year survival rates of all five families, consisting of well adapted and poorly adapted families, were averaged to produce the survival rate for the bulked seedlot. Each family was planted as both containerized and bare-root stock. Simulations were based on actual field survival rates

Table 1. First-year survival rates after perched water tables receded in 1984.

Site	Seedling Type	
	Containerized	Bare-root
Ingalls, AR	Adapted---99.33% (676 TPA[1])	Adapted---92.67% (631 TPA)
	Bulked---98.13% (668 TPA)	Bulked---87.20% (594 TPA)
Locust Bayou, AR	Adapted---71.33% (486 TPA)	Adapted---47.33% (322 TPA)
	Bulked---62.40% (425 TPA)	Bulked---34.93% (238 TPA)

[1]TPA = Surviving trees per acre.

as observed after perched water tables receded in 1984. Table 1 shows the first-year survival rates after perched water tables receded in 1984 and the number of surviving trees per acre by site, based on the planted stocking of 681 trees per acre.

Growth Model

Matney and Sullivan's (1982) FORTRAN stand table projection model was used to project yields based on first-year survival. Due to the different growth patterns of loblolly pine when planted on old-fields (upon which the model is based), and excessively wet sites, projected volumes are probably optimistic. However, a more appropriate model was not available. Since all families were part of a tree improvement program, use of the model's volume gain as a result of genetic improvement was possible.

Table 2 shows the origin of the volume gain for both adapted and bulked groups. This gain in terms of feet of site index was calculated by entering the base site index, then increasing the feet of site index due to the genetic gain until the desired percent volume increased was achieved. Table 3 contains the increase in feet of site index used.

Table 2. Progeny test volume growth projections of families by group showing derivation of genetic volume gains used in simulations.

Group	Family	Percent About Check lot[1]	Number of Tests[2]
Adapted	CR-BL-33	17.4%	2
	PC-58	20.5%	3
	Average =	18.6%	
Bulked	CR-BL-33	17.4%	2
	PC-58	20.5%	3
	PC-62	14.6%	3
	PC-28	12.6%	1
	S4PT6	-3.5%	1
	Average =	12.3%	

[1]The mean performance of the South Arkansas check lot was based on 42 tests.

[2]The number of progeny tests on which the average percent about the check lot was computed.

Yield Projections

Yields were projected for seven different treatment combinations based on actual first-year survival rates. Yields were projected through age 15 by entering first-year survival rates, and a number of other variables which were held constant for all projections. Table 3 shows variables used in growth simulation.

Financial Analysis

Establishment cost, and stumpage proceeds from harvests were discounted to year zero, and a present net worth calculated for all treatment combinations. Present net worth was used as an economic indicator to determine whether increased survival and growth, due to either planting adapted families, or planting containerized seedlings, increased yield sufficiently to justify these nontraditional practices. The present net worth values represent stumpage returns from harvests discounted to year zero, minus reforestation costs, based on cost of seedling type (Table 3).

Table 3. Values used during the growth simulations and economic analysis.

Variable	Value
Site Index	74 feet @ base age 25
Genetic gain--adapted families	12.424 feet of Site Index
Genetic gain--bulked families	7.756 feet of Site Index
Discount Rate	6.00 percent
Pulpwood Stumpage	$11.50 per cord[1]
Reforestation Expense (containerized seedlings)	$143.00 per acre[2]
Reforestation Expense (bare-root seedlings)	$129.00 per acre[2]

[1]Stumpage values are from August 1986 Forest Marketing Bulletin (Geisler, 1986).

[2]Actual reforestation expense includes $80.00 for site preparation (herbicide), $30.00 for planting, and seedling costs of $19.00 for bare-root and $33.00 for containerized (Yeiser and Paschke, 1987).

RESULTS AND DISCUSSION

Yield at Ingalls

Projected yields are presented in Table 4. Overall survival at Ingalls was 94.3% and high regardless of genetic group or seedling stock. After 15 years, families with high adaptability to wet sites averaged 8.4% more cords per acre than the bulked seedlot. This increase was due to the increased density and growth caused by planting adapted families.

Containerized seedlings produced similar though slightly less pulpwood per acre than bare-root seedlings. This is probably due to the higher survival (60 trees per acre) achieved with containerized than bare-root seedlings. The full effect of genetic adaptability and container grown seedlings was probably not realized due to high survival. If the high survival at this test site could be consistently achieved, cost-effectiveness could be increased by planting fewer seedlings per acre and reducing costs.

Table 4. Total yields after 15 years of simulated growth.

Treatment	Surviving # of TPA[1]	Total Yield in cords
Ingalls Adapted Container	676	77.5
Ingalls Bulked Container	668	71.0
Ingalls Adapted Bare-root	631	78.3
Ingalls Bulked Bare-root	594	72.7
Locust Bayou Adapted Container	486	80.8
Locust Bayou Bulked Container	425	72.9
Locust Bayou Adapted Bare-root	322	77.0
Locust Bayou Bulked Bare-root	238	Insufficient survival to project

The number of stems at age one.

Yield at Locust Bayou

Overall survival at Locust Bayou was low, but only bare-root seedlings originating from a bulked seetlot exhibited sufficient mortality for a replant of the site. After 15 years, projected yields from planting adapted families were 8.3% greater than for a bulked seedlot. Yields from planting containerized and bare-root seedlings were very similar, excluding the planting of bare-root seedlings originating from a bulked seedlot whose survival was too low to project.

Present Net Worth

Planting bare-root rather than containerized seedlings produced similar, although slightly higher returns (present net worth values), despite lower first-year survival (Table 5). Planting families specifically adapted to survive on wet sites provided higher returns than planting seedlings from a bulked seedlot, because of increased survival and better growth.

Table 5. Present net worth values for seven alternatives when regenerating wet sites. (Discount rate = 6.00%, Projected for 15 years)

Site	Seedling Type	
	Containerized	Bare-root
Ingalls	Adapted---$229.08	Adapted---$246.58
	Bulked---$197.56	Bulked---$219.95
Locust Bayou	Adapted---$242.71	Adapted---$240.44
	Bulked---$206.67	Bulked--- [1]

[1]Not projected due to insufficient survival

SUMMARY AND CONCLUSIONS

Differences in volume and present net worth were relatively small when good survival was achieved. However, when survival was poor the differences in volumes and values were more evident. Therefore, a fair estimation of probable survival is necessary. If survival is likely to be poor with bare-root seedlings planted during the traditional planting season, late planting of containerized seedlings would be more cost effective than replanting. If survival is likely to be high, the benefits of planting containerized seedlings will not be realized.

Planting families of loblolly pine well adapted to excessive moisture can increase the stand productivity on wet sites. This is attributable to augmented first-year seedling survival which allows forest managers to (1) manipulate stand density through thinnings to produce the desired product for more return per invested dollar, and (2) reduce planting costs by planting fewer seedlings per acre and increase the return per invested dollar.

Mortality resulting from excessive soil moisture justifies the planting of adapted families. Presently, containerized seedlings cost considerably more than bare-root seedlings. This difference in cost outweighs benefits derived from higher survival and yield. However, Guldin (1983) states that containerized seedlings can be produced at prices near the cost of bare-root seedlings. Where bare-root and containerized seedlings are available at similar costs, managers should plant container-grown, genetically-adapted families for cost-effective management. Without similar costs for containerized and bare-root stock, planting bare-root families with demonstrated adaptedness to wet sites is a substantially better investment for forest managers than planting containerized seedlings.

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INFLUENCE OF THRESHER CYLINDER SPEED AND GRAIN MOISTURE AT HARVEST ON MILLING YIELD OF RICE

R.H. DILDAY
USDA-ARS-SPA
Stuttgart, AR 72160

ABSTRACT

The percentage of broken rice *(Oryza sativa)* kernels was determined after threshing the grain at varying cylinder speeds of the thresher and moisture contents of the grain at harvest. Moisture contents of the individual grain samples ranged from 12 to 26% and the two cylinder speeds were 600 and 1000 RPM. Significant differences between germplasm, cylinder speed and moisture content of the grain at harvest on milling yield was observed. For example, Newbonnet had the fewest broken kernels while Leah had the greatest amount of broken kernels. Lemont produced the highest total milling yield; whereas, L202 produced the lowest total milling yield. Newbonnet produced thie highest and Leah produced the lowest head rice yield. Percentage of broken kernels approximately doubled when the cylinder speed was increased from 600 to 1000 RPM. Generally there was a significant increase in the percentage of broken kernels as the moisture content of the grain at harvest decreased.

INTRODUCTION

Milling yield, as defined in the United States standards for rough rice *(Oryza sativa)* and milled rice (Smith, 1972) is based on the quantity of whole kernels (head rice) and total milled rice (whole and broken kernels combined) that is produced in the milling of rough rice to a well-milled degree. The market value of rough rice is based mainly upon its milling quality or milling yield. Whole kernels (fancy), broken kernels, and total milled rice are usually expressed as a percentage of rough rice that is subjected to USDA milling procedures (Anonymous, 1982, 1983).

The effects of moisture content of the grain at harvest on milling quality of rice are well documented. In the 1930's, Smith *et al.* (1938) showed that rice harvested between 23 to 28% moisture content resulted in maximum grain yields and the highest percentage of head rice yields after drying and milling. Long-grain, 'Edith'; medium grain, 'Early Blue Rose' and 'Supreme Blue Rose'; and short-grain, 'Caloro', cultivars were evaluated in this study at a time when rice was harvested with a binder, placed in shocks for curing, and then threshed. In the 1940's and 1950's McNeal (1950) showed that the highest milling quality, after drying, occurred when the grain was threshed between 16 to 24% moisture content. Four cultivars (Zenith, Rexark, Nira, and Prelude) were evaluated and a small variation between the cultivars for optimum moisture content of the grain at harvest was noted. These data are among the earliest indications of differences in milling quality due to germplasm.

Inthe 1960's Kester *et al.* (1963) showed that the highest head rice yield, after drying, of 'Calrose', a medium-grain cultivar, and Caloro was obtained at moisture contents between 25 to 32% at harvest. Morse *et al.* (1967) showed that the maximum head rice yields of Caloro was obtained when the grain was between 28 to 30% moisture content at harvest. In the 1970's Calderwood *et al.* (1980) evaluated two long-grain (Lebonnet and Labelle) and two medium-grain (Brazos and Nato) cultivars and found that the percentage of total milled rice increased with delays in harvest date, but the percentage of head rice reached a maximum at an intermediate harvest date, then declined rapidly with delays in harvesting. The authors concluded that both Brazos and Lebonnet required a higher moisture content at harvest than did Labelle and Nato to maintain the same head rice yield. Conclusions were not drawn about the range in moisture content that would give maximum head rice yield because of the variation between cultivars. However, these data do indicate that a rapid decline in head rice yield occurs after the grain of Lebonnet and Brazos reaches about 17% moisture content and after Labelle and Nato reach 14% moisture content of the grain.

Obviously, grain moisture content at harvest has an influence on head rice yield. However, a minimum amount of data are available on factors other than grain moisture at harvest which influence milling yield. Objectives of this research were to: 1) determine the influence of cylinder speed of the thresher on milling yield; 2) determine the influence of moisture content of the grain at harvest versus cylinder speed of the thresher and; 3) determine the influence of germplasm, if any, on milling quality in rice.

MATERIALS AND METHODS

Four experiments were conducted during a two-year period. Field trials with 11 cultivars were conducted in 1985 and 1986 at the Rice Research and Extension Center, Stuttgart, Arkansas, on a Crowley silt loam soil which is a fine montmorillonitic, thermic Typic Albaqualf. The experimental design for each test was a randomized block design with four replications. The tests were drill seeded in plots, 14 rows by 4.57 m, with a 0.191 m row spacing on May 2, 1985 and April 23, 1986. The seedlings emerged on May 11, 1985 and May 4, 1986, respectively. Plots of the 11 cultivars were harvested each year at 10 harvest dates. Harvesting started at a moisture content of approximately 25% and the harvest continued for twice a week for five weeks. The number of days after heading was noted for each harvest sample.

A single row 3.66 m long was hand-harvested from the center 10 rows of each plot generally between the hours of 1100 and 1400 when the kernels were free of dew and surface moisture. The outer two rows on each side of each plot were not harvested. The amount of rice harvested from the 3.66 m row generally was within the range of 450-750 g. A vogel thresher was used to separate kernels from straw. Each cultivar was threshed at a cylinder speed of 600 and 1000 RPM at each harvest date. The samples were passed through a screen to remove the larger leaves and stems. Samples were weighed in the laboratory and the moisture content was determined with a DICKEY-john Model Gac II grain analysis moisture meter. The samples were immediately placed in a zipper-top plastic bag and taken to Riceland Cooperative, Stuttgart, Arkansas the following day for analysis. Determinations of milling yield were carried out in accordance with the standard procedure of rice graders (Anonymous, 1982, 1983; Smith, 1972), except that an amount smaller (162 g) than 1,000 grams was processed.

Grain yield, head rice yield, total milled rice, and percentage of broken kernels for each variety was analyzed using the General Linear Models procedure. The LSD procedure was used for mean separation.

RESULTS AND DISCUSSION

Moisture content, milling quality, and cylinder speed for rice samples harvested in 1985 and 1986 are shown in Tables 1, 2, and 3. An F-test did not show significant differences between years for total milling yield, head rice yield, or percentage of broken kernels. However, there was a significant difference between cultivars, moisture content of the grain at harvest within years, and cylinder speed in the combined analysis for total milling yield, head rice yield, and percentage broken kernels. Also, there was a significant interaction affect of cultivar X moisture content for head rice yield and percentage of broken kernels. Each of these characteristics is discussed in the following sub-sections.

Table 1. Change in Grain Moisture Content Over Time in 1985 and 1986 for a Long-Grain (Tebonnet), Medium-Grain (Mars) and Short-Grain (Nortai) Cultivar.

Time of Harvest*	Tebonnet 1985	Tebonnet 1986	Mars 1985	Mars 1986	Nortai 1985	Nortai 1986
1	24.1	25.9	25.0	26.4	23.8	25.8
2	20.9	23.6	22.9	24.8	22.0	25.3
3	18.6	19.2	23.9	22.5	21.1	24.3
4	17.3	18.4	19.5	22.5	18.2	23.4
5	18.5	18.4	17.4	21.5	19.4	22.4
6	14.6	17.2	16.3	22.2	15.3	21.8
7	13.8	19.9	13.9	18.1	17.8	23.4
8	13.1	14.2	13.1	16.3	13.6	19.8
9	12.5	14.7	14.5	16.3	12.8	17.3
10	12.5	13.5	12.1	15.8	12.5	17.7

* 2 per week beginning at about 25% moisture

Table 2. Percentage of Broken Kernels of Rice at Two Cylinder Speeds and a 2% Increment of Grain Moisture Contents at Harvest.

Variety	Cylinder Speed-600 RPM: Grain Moisture % 14-16	16-18	18-20	20-22	>22	Means	Cylinder Speed-1000 RPM: Grain Moisture % 14-16	16-18	18-20	20-22	>22	Means
	% Broken Kernels											
Bond	18+	14	16	11	9	13.6+++	29	24	24	20	20	23.4
Leah	27	28	24	20	12	22.2	37	32	35	26	24	30.8
Lebonnet	23	18	17	12	13	16.6	35	23	24	22	22	25.2
Lemont	19	16	16	12	13	15.2	30	24	23	19	21	23.4
L202	8	7	7	8	8	7.6	19	18	15	16	18	17.2
Mars	15	14	10	8	7	10.8	27	22	16	13	13	18.2
Newbonnet	5	6	6	5	6	5.6	11	11	10	10	11	10.6
Newrex	15	12	14	11	14	13.2	23	19	19	20	20	20.2
Nortai	-	7	10	9	7	8.2	-	12	15	13	11	12.8
Starbonnet	6	5	6	6	6	5.8	13	10	11	12	12	11.6
Tebonnet	13	11	11	10	11	11.2	25	21	19	22	20	21.4
Means++	16^a	12^b	12^b	10^c	10^c		25^a	19^b	19^b	17^c	17^c	

\+ LSD = 5.9 Within variety X cylinder speed X grain moisture
\+ + LSD = 1.8 Within grain moisture X cylinder speed
\+ + + LSD = 2.5 Within variety X cylinder speed

Harvest Moisture

Grain moisture content tended to decrease with time in both 1985 and 1986. However, the moisture content of the grain at certain later harvest periods was higher than at earlier harvest periods (*e.g.* harvest period 5 versus harvest period 4 for Tebonnet, see Table 1). A possible explanation could be the rewetting of the grain from an extremely heavy dew or rain. Also, moisture content of the grain at harvest had an influence on the amount of broken kernels that were present after threshing at high and low cylinder speeds (Table 2). When the means from all cultivars were compared there was generally a significant inverse relationship between moisture content of the grain and percentage of broken kernels (Table 2). Also, there were significant differences between and among cultivars for percentage of broken kernels versus moisture content of the grain at harvest. Furthermore, there was a significant increase in the moisture content of the grain as the cylinder speed increased (Table 3). This was possibly due to the nature in which grain drying occurs. The moisture in the grain moves from the kernel to the hull and then to the atmosphere in the normal drying process. An increase in the amount of hulling of the grain occurs when the cylinder speed increases from 600 to 1000 RPM. Consequently, there are more hulled-moist kernels present at the 1000 RPM cylinder speed which results in an increased moisture reading.

Table 3. Influence of Cylinder Speed on Milling Quality of Rice.

Cultivar	Broken 600 RPM	Broken 1000 RPM	Head Rice 600 RPM	Head Rice 1000 RPM	Total 600 RPM	Total 1000 RPM	Moisture 600 RPM	Moisture 1000 RPM
Tebonnet	12.4	22.0	55.8	48.2	68.2	70.2	18.4	18.6
Newbonnet	5.7	11.0	60.5	57.5	66.2	68.5	19.9	20.5
Bond	16.7	25.4	49.9	42.7	66.6	68.2	16.7	17.4
Starbonnet	5.9	12.0	60.2	54.2	66.2	66.2	19.0	19.5
Mars	10.1	16.8	57.0	50.7	67.1	67.5	20.3	21.0
Nortai	7.8	11.8	60.5	56.9	68.3	68.8	22.3	22.6
Lemont	15.2	23.8	54.3	46.8	69.5	70.6	19.6	20.2
Lebonnet	17.5	26.3	49.1	43.1	66.7	69.4	18.5	19.4
Newrex	13.4	20.4	52.1	44.1	65.6	64.5	17.3	17.9
L202	8.0	16.8	55.4	49.5	63.3	66.2	19.4	20.0
Leah	22.6	30.6	44.8	37.6	67.3	68.2	18.8	19.4
Grand Mean +	12.6^a	19.8^b	54.4^a	48.3^b	67.0^a	68.2^b	19.1^a	19.7^b
LSD ++	1.0		1.9		0.9		0.4	

\+ Means followed by different letters indicate differences between cylinder speeds for the respective characteristics based on the F-test.

\+ + LSD for comparing differences between cylinder speed and between varieties.

Milling Yield and Cylinder Speed

Delayed harvesting, which resulted in lower moisture content, and cylinder speed were associated with a wide variation in the head rice yield and broken kernels (Tables 2-3). There was a significant increase in head rice yield, moisture content of the grain, total milling yield, and percentage of broken kernels as the cylinder speed increased from 600 to 1000 RPM. For example, the percentage of broken kernels approximately doubled in Bond (9-18%), Leah (12-27%), Lebonnet (12-23%), and Mars (7-15%) at a cylinder speed of 600 RPM when the moisture content of the grain at harvest changed from below 16% to 22% or greater. There was essentially no change in the percentage of broken kernels in L202 (7-8%), Newbonnet (5-6%), Starbonnet (5-6%), Newrex (11-15%), Nortai (7-10%), and Tebonnet (10-13%) at a cylinder speed of 600 RPM as the moisture content of the grain changed from below 16% to 22% or greater (Table 2). Also, when all factors were held constant except cylinder speed the percentage of broken kernels approximately doubled when the cylinder speed was increased from 600 to 1000 RPM. This is probably due to the grain hitting the cylinder and cylinder walls at a higher force which results in more broken kernels at higher RPM. Consequently, head rice yields decreased about 6-7 percent as cylinder speed was raised from 600 to 1000 RPM. Total milling yield increased about 1-2 percent for all cultivars except Starbonnet and Newrex. A decrease in foreign matter is one explanation for an increase in total milling yield; or explained another way, a sample with less foreign matter will result in an apparent higher total milling yield. Consequently, a higher cylinder speed will result in better removal of foreign matter and total milling yield will appear greater.

Germplasm

There were significant differences between the cultivars for total milling yield, head rice yield, and percentage of broken kernels. For example, Newbonnet had the fewest broken kernels at both cylinder speeds, 5.7 and 11.0%, respectively; while Leah had the greatest amount of broken kernels at both 600 and 1000 RPM, 22.6 and 30.6%, respectively. Lemont produced the greatest total milling yield at both 600 and 1000 RPM, 69.5 and 70.6%, respectively; whereas, L202 produced the lowest total milling yield at 600 RPM (63.3%) and Newrex produced the lowest at 1000 RPM (64.5%). Newbonnet produced the highest and Leah produced the lowest head rice yield at both 600 and 1000 RPM, 60.5 and 57.5% and 44.8 and 37.6%, respectively (Table 3). These data indicate that advancements can be made within the existing rice germplasm for improvements in milling quality either through genetic manipulation or selection.

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DISTRIBUTION OF FISH WITHIN HEADWATER RIFFLES OF THE ILLINOIS RIVER SYSTEM, WASHINGTON COUNTY, ARKANSAS

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

and

ARTHUR V. BROWN and CAROLYN B. FIELDER
Department of Zoology
University of Arkansas
Fayetteville, AR 72701

ABSTRACT

Quantitative sampling of fish was performed in five headwater riffles of the Illinois River System, Washington County, Arkansas during low flow conditions. This study revealed differing fish species composition, biomass and feeding guild segregation between head and tail riffle reaches in 1st through 3rd order. Thirty species representing 10 families were identified. Of this number, darters (Percidae), sculpins (Cottidae), madtoms (Ictaluridae), and central stonerollers *(Campostoma anomalum)* (Cyprinidae) comprised 67 to 98 percent of riffle head populations. Fish biomass was greater for riffle head areas (0.58-6.6/0.28-2.0 g/m²) with insectivores and herbivores dominating. Total fish numbers decreased from riffle heads to tails, while number of species increased. Dominant fish groups in tail areas were minnows (Cyprinidae), darters (Percidae), and sunfishes (Centrarchidae). Feeding guild fish groups in tail areas were predominately insectivore and insectivore-piscivore. Stomach analysis of *Cottus carolinae,* the dominant headwater riffle predator, indicated selective feeding of macrobenthic invertebrates and fish based on size class. Abundance of herbivore and insectivore fishes in riffles, particularly head reaches, suggests a correlation with positive rheotaxic behavior, microhabitat preference or abundance of macrobenthic invertebrate populations.

INTRODUCTION

Stream fish distribution, species number, and diversity have been found to increase with longitudinal distance from headwaters. Increase in species has been found by numerous investigators to be addition of species rather than replacement (Evans and Noble, 1979). Increase in diversity downstream has been steepest for those rivers with the steepest decrease in physical variability, and number of species in downstream sections was greater in rivers with more constant habitat conditions (Horwitz, 1978). Sheldon (1968) cited stream depth rather than longitudinal position in explaining observed changes. In biologically diverse streams distribution of fish species has been found to be constrained by environmental tolerances, competition, and predator-prey interactions (Smith and Powell, 1971). Distribution has also been correlated with habitat preference. Matthews and Hill (1979a; 1979b) and Matthews and Maness (1979) noted that seasonal changes and varying tolerances and preferences of cyprinids might result in differing patterns of distribution and movement.

Investigations into species preferences have suggested positive trends in specific habitat partitioning in a southern Mississippi river (Baker and Ross, 1981) and less structured overlap and transitory associations in a southwestern Oklahoma river (Matthews and Hill, 1980). Multivariate analysis has been used to delineate species preferences for habitat and distribution within stream reaches (Felley and Hill, 1983).

Community structure of fish populations has been shown to change with habitat type and season. Orth and Maughn (1984) working in a southeast Oklahoma stream stated that standing fish stocks were higher in pools than riffles. They also noted a difference in feeding structure between habitat type, with seasonal cycles dictating dominance of feeding guilds in riffles and pools. Matthews (1982) investigated six watersheds in the White River drainage of northwest Arkansas and southeast Missouri and found that the mutual abundance of thirteen species of fish was no more structured than could be explained by random occurrence.

Dewey (1981) reported that seasonal fluctuations in fish abundance occurred throughout the year in Mud Creek, a tributary of Clear Creek, in the Illinois River system, north-central Washington County, Arkansas. Five species of fish, *Notropis boops, Pimephales notatus, Fundulus olivaceus, Labidesthes sicculus,* and *Etheostoma spectabile* populations were estimated by the mark-recapture method twice monthly for one year. Dewey (1981) found *E. spectabile* and *Campostoma anomalum* to be stable, dominant species in his riffle substation. He also noted that riffle substation fish populations remained relatively stable throughout the year while pool populations fluctuated. Gerking (1959), Reed (1968), and Winn (1958) reported that *E. spectabile* was restricted in its movement, seldom moving from one riffle to another.

Position of fish species in riffles may be dependent on food availability or prey selectivity. Lotrich (1973) and Todd and Stewart (1985) have commented on the insectivorous feeding of darters and sculpins. In both studies habitat partitioning and prey selection were important factors in feeding of darters and sculpins.

Brown and Brown (1984) have documented a strong upstream-biased distribution of lotic insects within riffles of the Brazos River, Palo Pinto County, Texas, with greater abundance of insects toward the heads of riffles. Hoover (1985) noted that five species of fish inhabiting riffles of the Illinois River in Oklahoma fed on a diverse assemblage of invertebrates, primarily mayflies and chironomids. Todd and Stewart (1985) working in Flint Creek, Delaware County, Oklahoma found mayflies, chironomids, amphipods and crustacenas to be important dietary items of *E. spectabile, E. punctulatum* and *C. carolinae.* These investigations suggest that if invertebrates are distributed in riffles with an upstream bias, fish feeding on invertebrates might show a similar bias.

This investigation tested the hypothesis that stream fishes inhabiting headwater riffles in the Illinois River System, Arkansas are partitioned in their distribution based on food and/or microhabitat preference during low flow conditions. And that fish biomass will change from head to tail within riffle reaches.

STUDY AREA

The Illinois River System lies in the extreme northeastern portion of Arkansas draining an area of approximately 1,200 km^2. The river is located in the Ozark Plateau, flows out of the Boston Mountains Plateau, across the predominantly limestone Springfield Plateau for 64 km attaining fifth order before being impounded at Lake Francis on the Arkansas-Oklahoma border (Limbeck, 1986). The majority of the drainage basin is karst-chert substratum covered by oak-hickory forest and pasture. Continuous flow in the headwater stream reaches is dependent on extended rainfall. Intermittent flow occurs in late summer and early fall (Borengasser, 1968).

Stream channels in the Illinois River System are fluvially-formed alluvial, riffle-pool structure from headwaters to at least fifth order. Long, deep, slow flowing pools alternate with short, shallow riffles. Gravel is concentrated in riffle areas and slopes of pools, while pool bottoms are predominantly bedrock (Brussock, 1986).

MATERIALS AND METHODS

Quantitative fish samples were collected in headwaters through third order reaches of the Illinois River system, Washington County, Arkansas (Fig. 1). Each riffle was visually inspected, measured, then partitioned into two areas, (head-tail) based on depth, flow, and substrate. Small mesh block nets were placed at the ends of each area to prevent fish movement in and out of the study area. Fishes were captured by electroshocking with a generator coupled to a variable voltage pulsator (Coffelt VVP-2C) and hand held electrodes. Specimens were preserved in 10% formalin in the field. Upon return to the laboratory, fish were identified to species (Buchanan, 1973), weighed, measured, preserved in 50% isopropanol and catalogued.

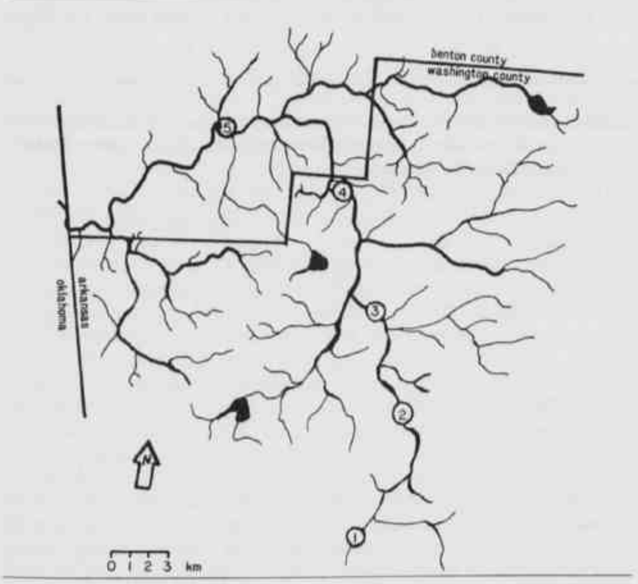

Figure 1. Map of Illinois River System, northwestern Arkansas from Brussock (1986). Stream orders in circles.

Population size for each species was estimated. Areas within sites were compared for fish community distribution and partitioning. Food preference was estimated for selected species. All species were grouped by feeding guilds based on general descriptions of food habits (Pflieger, 1975).

Food habits were determined for *C. carolinae*. After collection specimens were placed on ice. Upon return to the laboratory individual fish were weighed (gm), measured (mm), and 10% formalin was injected into abdominal cavities to preserve stomach contents. Individuals were segregated according to riffle head or tail and size class. Ten representatives were randomly selected from each size class, stomach contents analyzed (Hyslop, 1980), and identified to order. Surber samples were collected in head and tail riffle areas at two sites. Samples were preserved in 10% formalin in the field, upon return to the laboratory samples were washed in tap water, benthic organisms separated, enumerated and identified to order (Merritt and Cummins, 1984; Usinger, 1956).

Structure of the fish community at each site and habitat type was summarized using percentage composition of biomass by species and by feeding guild. Flow, dissolved oxygen, temperature and substrate particle size were determined in each study area following Platts *et al.* (1983).

RESULTS

A total of 1,720 individuals comprising ten families and thirty species were represented in electrofishing samples (Table 1). Although headwater riffle areas had fewer species (6-12/6-15) biomass was consistently higher than tail areas (0.58-6.6/0.28-2.0 g/m^2). Fish biomass did not show an increase with stream order, but numbers and total weight of fish samples increased with stream order (Table 2). Mean length and weight per individual also increased with stream order. Darters (Percidae), sculpins (Cottidae), stonerollers (Cyprinidae), and madtom catfish (Ictaluridae) dominated riffle head samples (67-98%) and comprised a substantial percentage of tail area populations (35-77%).

Table 1. Species list for selected riffles, 1st through 3rd order reaches of the Illinois River System, Washington County, Arkansas (1 = herbivore-detritivore; 2 = omnivore; 3 = insectivore; 4 = insectivore-piscivore).

Clupeidae	Poeciliidae
Dorosoma cepedianum (2)	*Gambusia affinis* (3)
Cyprinidae	Atherinidae
Campostoma anomalum (1)	*Labidesthes sicculus* (3)
Hybopsis x-punctata (3)	
Nocomis asper (3)	Centrarchidae
Notropis boops (3)	
Notropis chrysocephalus (3)	*Ambloplites ariommus* (4)
Notropis nubilus (3)	*Lepomis cyanellus* (4)
Notropis spp. (3)	*Lepomis macrochirus* (3)
Notropis rubellus (3)	*Lepomis megalotis* (3)
Notropis telescopus (3)	*Micropterus dolomieui* (4)
Pimephales notatus (2)	*Micropterus salmoides* (4)
Catostomidae	Percidae
Hypentelium nigricans (3)	*Etheostoma blennioides* (3)
Moxostoma spp. juvenile (3)	*Etheostoma flabellare* (3)
	Etheostoma punctulatum (3)
Ictaluridae	*Etheostoma spectabile* (3)
	Etheostoma zonale (3)
Noturus exilis (3)	*Percina caprodes* (3)
Cyprinodontidae	Cottidae
Fundulus olivaceus (3)	*Cottus carolinae* (4)

Sunfishes (Centrarchidae) and minnows (Cyprinidae) were abundant in tail areas (23-61%) (Table 3).

Dominant feeding guilds in riffle head areas were herbivores and insectivores, while riffle tails were dominated by insectivores, insectivores-piscivores, and omnivores (Table 1). *C. anomalum*, a herbivore, was the most numerous specimen collected at all sites, and was primarily concentrated in head areas of riffles. Large-size *C. carolinae*, insectivore-piscivore, *E. flabellare, E. spectabile* and *Noturus exilis*, insectivores, were also abundant in riffle heads. Smaller sizes of *C. carolinae* were consistently collected in riffle tails. *Lepomis cyanellus, L. megalotis, Micropterus dolomieui*, and *M. salmoides*, insectivores-piscivores; *N. boops, N. spp., N. telescopes*, insectivores; and *P. notatus*, an omnivore; dominated riffle tail areas.

A total of seventy-two *C. carolinae* (49 riffle heads; 23 riffle tails) were colllected. Large-size *C. carolinae* (75-112 mm) were more abundant than small-size sculpins in riffle head areas. Dominant food items for this group consisted of Isopoda (17.4%), Decopoda (26.1%), and fish (43.5%), while Diptera (61.8%) and Ephemeroptera (18.1%) were major food items for small-size sculpins (37-59 mm) (Table 4). In forty percent of large *C. carolinae*, fish and *Orconectes* (Decopoda) were the only food items in stomachs. Surber samples at two sites showed a high abundance of Diptera (Chironomids) and Ephemeroptera in both riffle heads and tails (Table 5).

Study areas differed greatly in channel and water width, depth, substrate particle size, and length (Table 6). Riffle heads were smaller in area (m^2), shallower, swifter and had a more heterogenous substrate than riffle tails. Channel water width was wider in head areas, but length

Table 2. Fish biomass, numbers, and area for head/tail riffle areas of selected reaches (1st - 3rd order) of the Illinois River System, Washington County, Arkansas.

3rd order ---------------)------------------)-----------------> 1st order

	Hwy 31		Savoy Road		Harmon Road		Great House		Small Trib.	
	H	T	H	T	H	T	H	T	H	T
Length (m)	29	43	12	21	60	60	8	30	7	30
Width (m)	17.6	14.3	22.3	7.4	32.0	32.0	17.5	7.3	4.2	6.3
Area (m^2)	510.4	614.9	276.6	255.4	1920	1920	140	219	29.2	189
Number Fish	305	123	706	167	114	72	94	34	47	58
Weight Total	528	568	1384	315	1113	538	262	122	192	153
Biomass (g/m^2)	1.03	0.92	5.00	2.03	0.58	0.28	1.87	0.56	6.60	0.81
Species Number	7	15	12	15	11	11	8	6	7	6

Table 3. Percent composition by number of fish group in head and tail riffle areas (1st - 3rd order), Illinois River System, Washington County, Arkansas.

3rd order --------------)-----------------------)-------------> 1st order

	Hwy 31		Savoy Road		Harmon Road		Great House		Small Trib.	
	H	T	H	T	H	T	H	T	H	T
Darters % Total	0.05	0.06	0.05	0.19	0.06	0.11	0.64	0.21	0.57	0.02
Sculpins % Total	0.02	0.07	0.03	0.03	0.07	0.16	0.10	0.32	0.28	0.03
Stonerollers %Total	0.91	0.36	0.84	0.53	0.34	0.14	0	0.09	0.06	0.30
Madtoms % Total	0	0	0.03	0.02	0.02	0.03	0.13	0.08	0	0
Total (x100)	98	49	95	77	49	44	87	70	94	35
Sunfish % Total	0.02	0.08	0.02	0.01	0.06	0.16	0.07	0	0.06	0.01
Minnows % Total	0	0.25	0.03	0.22	0.42	0.39	0.04	0.26	0	0.60
Total (x100)	2	33	5	23	48	55	11	26	6	61

Table 4. Percentage of food items by number for two size classes of Cottus *Cottus carolinae*, Illinois River System, Washington County, Arkansas.

Food Item	Size Class (37 - 59 mm)	(75 - 112 mm)
Diptera (Chironomids)	61.8	0
Ephemeroptera	18.1	8.7
Plecoptera	1.8	4.3
Tricoptera	7.3	0
Amphipoda	9.1	0
Isopoda	1.8	17.4
Decopoda (Orconectes)	0	26.1
Fish	0	43.5

Table 5. Percentages of benthic organisms by number identified from Surber samples of two sites in headwater riffles, Illinois River System, Washington County, Arkansas.

Organism	Otter Creek Head	Tail	Great House Spring Head	Tail
Diptera	24.3	19.3	42.7	17.2
Ephemeroptera	44.3	22.7	33.0	41.3
Tricoptera	5.2	7.6	5.6	3.4
Decapoda	0.8	0.8	0.8	10.3
Amphipoda	9.6	18.5	0	0
Isopoda	0.8	2.5	0	0
Annelida	0	4.2	0	10.3
Odonata	13.9	17.6	8.1	0
Megaloptera	0	0	1.6	0
Coleoptera	0	0	0.8	13.8
Mollusca	0	0	5.6	3.4
Unidentified	0.8	3.4	0	0

of head areas was substantially less than tails. Dissolved oxygen, specific conductance and canopy closure did not change through study sites (Table 6). Steambank erosion was great, canopy closure and instream cover were lacking in several sample reaches.

Table 6. Physical and chemical parameters for selected riffles (1st - 3rd order) of the Illinois River System, Washington County, Arkansas.

3rd order--------------->------------------>--------------->----------> 1st order

	Hwy 31		Savoy Road		Harmon Road		Great House		Small Trib.	
	H	T	H	T	H	T	H	T	H	T
Channel Width (m)	17.6	14.3	24.4	29.5	---	---	21.2	25.5	---	--
Water Width (m)	17.6	14.3	22.3	7.4	32.0	32.0	17.5	7.3	4.2	6.3
Depth (ft) 1/4	0.5	1.3	1.3	3.1	---	---	1.4	1.5	0.3	0.5
1/2	1.1	2.1	1.4	1.9	---	---	1.5	1.0	0.5	0.8
3/4	1.2	1.4	1.3	0.7	---	---	1.1	1.5	0.4	0.7
Substrate	gr/cb	gr/cb	gr/cb	gr	gr	bd	gr/cb	gr/cb	gr	gr
Length (m)	29.0	43.0	12.0	21.4	60.0	60.0	8.1	30.0	7.0	30
Dissolved Oxygen (mg/1)	8.7	8.7	8.7	8.7	8.2	8.2	8.3	8.3	8.6	8.6
Specific Conductance (umhos)	230	224	228	230	218	226	232	228	224	230

DISCUSSION

Stream fish distribution, species number and diversity have been found to increase with longitudinal distances from headwaters. Increase in species number has been attributed to addition rather than replacement of species (Evans and Noble, 1979). Increase in diversity has been highest with highest decrease in variability (Horwitz, 1978). In biologically diverse streams, such as the Illinois River system, distribution of fish species has been found to be constrained by environmental tolerances, competition and preditor-prey interactions (Smith and Powell, 1971); and habitat and food preference (Matthews and Hill, 1979a, 1979b; Orth and Maughn, 1984). In this investigation bottom dwelling insectivorous, and herbivorous fish species preferred riffle heads over tails. Lotrich (1973) and Todd and Stewart (1985) have documented the selective feeding of sculpins (Cottidae) and darters (Percidae) on mayflies (Ephemeroptera) and chironomids (Diptera). Todd and Stewart (1985) further stated that primary food sources of *E. spectabile* and *C. carolinae* in Flint Creek, Oklahoma were mayflies, chironomids, amphipods and crustaceans. Both of these fish were primary species in every riffle head collection of this investigation.

Food analysis of *C. carolinae* stomach contents confirmed findings of both investigations, however we found large *C. carolinae* to contain a high amount (43.5%) of fish material in their stomach contents. In 40% of large-size *C. carolinae* fish and Decopoda were sole food items. This suggests that large-size *C. carolinae* preferred fish and Decopod crustaceans over smaller food items and may indicate a greater availability of food items (fish and macrobenthos) in riffle heads. There was also a noticeable difference in the preference for food items between the two size classes of *C. carolinae*. *No Diptera larvae were found in the larger-size class of C. carolinae,* this group was the dominant food of small-size individuals. Daiber (1956) reported that chironomids decrease as a food source for sculpins as the sculpins increase in size. Larger food items such as fish and Decopoda represent a high energy food source, and may be correlated with increased mouth size in large-size sculpins. Food habit studies concerning sculpins have generated conflicting results, Gill (1905) described sculpins as omnivores; Todd and Stewart (1985) described sculpins as insectivores; Northcote (1954), Yoshiyama (1980), and Bailey (1952) stated that young sculpins feed an aquatic insects, their food habits changing with increasing size. Northcote (1954) stated that food items of large-size sculpins are primarily fish, due in part to large mouth-size. Food preference of *C. carolinae* in headwater areas of the Illinois River system is vital in understanding the fish community structure because riffle fish populations are stable over all seasons. *C. carolinae* may represent the top carnivore of headwater riffles in the Illinois River system.

Brown and Brown (1984) found several species of Ephemeroptera, Trichoptera, and Diptera (Chironomidae) to be positively attracted to riffle heads in the Brazos River, Palo Pinto County, Texas. Brown (per. comm.) has noted similar tendencies of these groups in Clear Creek, Washington County, Arkansas, a 3rd order tributary of the Illinois River. It appears that high populations of macrobenthic invertebrates, especially insects, in head portions of riffles attract darters, sculpins, and madtom catfish all of which are insectivores at various life stages.

C. anomalum was the most abundant species in 60% of sample stations, and occurred in highest numbers in riffle head areas (50%/29%). Orth and Maughn (1984), Pflieger (1975), and Sewell *et al.* (1980) consider this species to be herbivorous. Bottom substrate in all sample sites was covered with periphyton. Although there was no visual difference in periphyton coverage between riffle heads or tails, Brown and Todd (per. comm.) have found greater concentrations of periphyton in riffle heads in the Illinois River based on dry weight, ATP, and chlorophyll a analyses. Position of *C. anomalum* in riffle heads may have been due to abundance of periphyton, current, depth, positive rehotaxis, or a combination of factors.

In this investigation fish biomass was highest in head areas of riffles (0.58-6.6/0.28-2.0 g/m^2). This concentration of insectivores and herbivores did not carry through to riffle tails. In tail areas more general feeders insectivores, insectivores-piscivores and omnivores dominated populations. Centrarchids and cyprinids, preferred slower flowing, deeper riffle tail areas.

Although numerous studies have been conducted on fish habitat preferences in stream systems on a holistic basis, no intensive studies have dealt with riffle habitat partitioning or preference by species or groups of fish. This investigation indicated that riffle fish species were partitioned on food and microhabitat preference. There was a distinct tendency for bottom dwelling darters, sculpins, and madtom catfish to be located in riffle head areas where macrobenthic invertebrates may be concentrated. More general feeders, minnows and sunfishes preferred less turbulent, slower flowing, deeper tail water areas. This investigation raises the question whether day/night riffle partitioning is similar and to what extent seasonality affects riffle species composition and feeding guild structure.

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THE STATUS OF THE INSTREAM FLOW ISSUE IN ARKANSAS, 1987

STEVE FILIPEK
Arkansas Game and Fish Commission
P.O. Box 178
Lonoke, AR 72086

and

WILLIAM E. KEITH and JOHN GIESE
Arkansas Department of Pollution Control and Ecology
8001 National Drive
Little Rock, AR 72209

ABSTRACT

Expansion of Arkansas' population with concurrent increases in the state's domestic, industrial, and agricultural water uses and possible out-of-state diversion are placing substantial demands on the state's water resources. In an attempt to address this growing concern, Act 1051 (1985) of the Arkansas legislature was passed requiring the determination of present and future state water needs. A specific area of this mandate was the quantification of instream flow requirements. Basic instream flow needs are maintenance of the aquatic ecosystem and dependent riparian environment. Flow reservation may compliment other instream uses such as recreation, navigation, water quality, and groundwater recharge. However, offstream uses (e.g. irrigation and industry) may compete for these same flows and often at the most critical time of year. In order to answer questions concerning instream flow requirements, over 40 methods of instream flow determination have been developed, the majority in the semi-arid western United States. These individual procedures may be classified into four major methodologies: (1) discharge, (2) single transect, (3) multiple transect, and (4) regression analysis of historical data. Requirements of these four types vary according to necessary level of expertise, time and effort expended, and monetary outlay. In one year, requests for fish and wildlife instream flow needs for approximately 60 stream reaches throughout Arkansas limited the possible options. Modification and further development of a well-known method is outlined as an initial step in the process of quantifying Arkansas' instream flow needs. Examples are given for some of the major river basins throughout the state.

INTRODUCTION

For over 25 years, the western United States has experienced water shortage and appropriation problems. This has been due, in part, to low annual precipitation over large areas and an increasing population which created heavy demands on the limited water resources. As a result, numerous instream flow methods have been developed in that region to plan for the many uses placed on surface water resources. Bayha (1976), summarizing the nationwide water problem, advised eastern states to get ahead of the instream flow problem by formulating plans and finding solutions now.

An instream flow requirement is defined as "the quantity of water needed to maintain the existing and planned in-place uses of water in a stream channel or other water body and to maintain the natural character of the aquatic system and its dependent systems" (Bureau Land Management, 1979). The aquatic and riparian ecosystems and the physical features of the stream are the dependent natural systems. Physical features of a stream include its channel, floodplain, and flow pattern. Some potential uses/needs include maintaining adequate groundwater recharge, navigation, water quality, recreation, and preservation of fish and wildlife populations.

Arkansas has rarely had water quantity problems and legislation granting allocation powers to the Arkansas Soil and Water Conservation Commission (ASWCC) during drought years has seen little use. However, reported plans to pipe surplus Arkansas water to other states as well as possible interbasin transfer of water within the state, have awakened Arkansans to the realization that they may not be water "rich" for long. Declining aquifers and increasing population levels have placed ever higher demands on the state's surface waters for domestic, industrial, and agricultural uses. This same growing human population is utilizing a limited and decreasing stream fishery now more than ever. With increasing angler demands on the stream fishery and increasing diversion demands on the total stream resource, managing agencies such as the Arkansas Game and Fish Commission (AGFC) cannot afford a *laissez faire* approach when it comes to instream flow needs. Instream flow requirements and flow recommendations have become a high priority with natural resource agencies managing stream ecosystems.

It has been calculated that in a normal water year, 69% of the nation's water courses have water available the year around as fish habitat; 17% is usable primarily in spring and summer and 14% is unusable during any part of the year because of low or no flow (Judy *et al.*, 1984). Water quantity problems adversely affect the fish community in 68% of the nation's total waters and 41% of perennial waters. Major water quantity problems include: below optimum flows (32%), occasional low flows (23%), and exessive flow fluctuation (17%). One-half of these waters are adversely affected by natural low-flow conditions. Agricultural diversions adversely affect 14% of all waters.

Excessive demands for water uses were experienced during the drought conditions of 1980, particularly in the delta area of eastern Arkansas. Many streams were literally pumped dry with little concern for the fishery resources. These predictable increases in water demands must be viewed with respect to their effect on all the beneficial uses of the water.

Stalnaker (1981) encouraged fishery and water quality agencies to protect instream resources by aggressively pursuing the establishment of stream flow standards as a parallel effort to water quality standards under the Clean Water Act. He reasoned that stream habitat is very dynamic, changing with the season and the annual water yield.

Therefore, alteration of stream flow not only effects habitat conditions but may also change the relative abundance of fish species. This dynamic nature of the fishery rules out use of historic low flows as a realistic minimum flow. Such a proposal ignores the long-term recovery of a fishery that must occur after a severe drought. Establishing historic low flows as allowable minimum levels would reduce the fishery to perpetual worst case conditions.

For these reasons, various instream flow methodologies have been developed. These plans make it possible to satisfy all water uses during some years, while in other years, certain water uses will be unsatisfied. Past management schemes relying on impoundment and manipulation of streams have been only marginally effective in resolving this problem (Sweetman, 1980). In Arkansas, only a few streams are completely unaffected by water diversion. In some areas these effects are slight but, in others, streams show little similarity to natural flows according to Hines (1975).

A discussion of the legalities of reserving instream flows for fisheries is not within the scope of this paper. However, there are laws providing for protection of fish and wildlife as a part of major project development. One such law is Public Law 85-624, the Fish and Wildlife Coordination Act of 1958 (U.S. Corps of Engineers, 1983). Arkansas statute Section 21-1301 allows the state to exercise some control of allocation and distribution of surplus water from water impoundments by requiring said impoundments "to maintain the normal flow of all streams and preserve the fish therein" (Mays, 1981). Section IV, page 7 of the Arkansas Soil and Water Conservation Commission's *Surface Water Allocation Rule Book* (1982), states that full service priorities, which include domestic use and "instream flow required to maintain the stream ecosystem," will be reserved prior to allocation for diversion. Diversion allocations are prioritized as: agriculture, industry, hydropower, and recreation. Finally, in Amendment 35 to the Arkansas Constitution, the Arkansas Game and Fish Commission is given the responsibility and jurisdiction to conserve and manage all forms of fish and wildlife in the state. When applying this responsibility to instream water resources, the AGFC must consider a holistic approach. This requires protection of sport, commercial, non-game, and endangered or threatened fish species. It also includes conservation and management of aquatic animals, protection of migratory bird habitat, maintenance of riparian vegetation and its associated ecosystem, management and needs of dependent terrestrial wildlife, and accessibility by the public to existing and future stream use areas.

The instream flow issue has been introduced to Arkansas through Act 1051 of the 1985 state legislature which requires the ASWCC to determine present and future water needs of Arkansas. As the coordinating agency, the ASWCC has contracted several federal and state agencies for assistance in this matter. In the arena of instream flows, the ASWCC has asked for recommendations from the U.S. Corps of Engineers (navigation), Arkansas Department of Pollution Control and Ecology (water quality), Soil Conservation Service and ASWCC (agriculture and industry), and the Arkansas Game and Fish Commission (fish and wildlife).

INSTREAM FLOW METHODOLOGIES

The need to obtain practical and defensible instream flow requirements has resulted in the development of nearly 40 methods. Many of these are simply modifications of a few basic techniques to compensate for variation in climates, fish species, and river types. Most fisheries biologists agree that the potential of a stream to support a specific assemblage of fish species depends on the amount of water flowing in the stream; however, the technique used to determine the minimum stream flow varies from region to region and state to state.

Four of the best known procedures to quantify instream flows are: (1) single transect methods, (2) multiple transect methods, (3) multiple regression analysis methods, and (4) discharge methods (Metzger and Haverkamp, 1983). Methods 1 and 2 are field methods requiring varying levels of expertise, time expended, and monetary outlay. The single transect method often utilizes a measurement of wetted perimeter to compare stream discharge and fishery potential.

The multiple transect methods may include wetted perimeter, weighted usable area, and several other habitat rating variables, as well as channel characteristics to predict fish presence and abundance. The IFIM (Instream Flow Incremental Methodology) is a multiple transect method that has proven the most scientific and legally defensible instream flow method available in western states where it was developed. However, the IFIM is expensive and time consuming due to the field work required (Stalnaker and Arnette, 1976). The trade-off is to conduct a few, precise instream flow estimates on major streams or to utilize a relative simple, quick method on numerous streams.

The regression analysis method (Gilbert, 1984) requires a fairly comprehensive stream fish sample database and adequate discharge records over many years. Actual biomass of stream fish communities are regressed against flow measurements when the population samples were collected. Optimal fish populations at specific discharges are the end result.

A request was made for fish and wildlife instream flow guidelines for 56 streams in Arkansas within one year. Use of a labor intensive field technique would not have been logistically possible to meet this request. Major reservations of flow and the establishment of minimum stream levels in the well-watered regions seem better served by broadly applicable and relatively speedy and inexpensive methodologies (Metzger and Haverkamp, 1983). Such methods would enable Arkansas to immediately protect much of its water in a relatively short time while competing offstream demands for that water lie in the future.

The "Montana" method as developed by Tennant (1975) is the best known of the discharge methods and requires no actual field work if precise water flow records are available. With this method, fisheries biologists perform the analysis with the aid of hydrological data provided by the U.S. Geological Survey. Tennant (1975) evaluated his method by using detailed field studies from 11 streams in three states involving physical, chemical, and biological analysis of 38 different flows at 58 cross-sections on 196 stream-miles on both cold and warmwater streams. Results revealed that the condition of the aquatic habitat is remarkably similar on most streams carrying the same portion of the average flow. Similar analysis of hundreds of additional flow regimens near U.S.G.S. gauges in 21 different states during the past 17 years substantiated this correlation on a wide variety of streams. Besides being quick and relatively easy to use, this method assures stream to stream consistency and never produces a zero flow recommendation.

While perfecting his instream flow system and evaluating other techniques, Tennant found that in 86 of 305 instances (28%) in the Missouri River Basin, instream flow criteria modeled from 7Q10's (or historic minimum flow records) resulted in zero flow. In 236 of 305 cases (77%), the 7Q10 was less than 10% of the average flow and was considered by Tennant to be in the severe degredation zone. Criteria from 3-day minimum flow records were worse and historic, all-time, minimum flows would be disasterous causing eventual depletion of the fishery.

Several state and federal agencies have used Tennant's method when time or monetary constraints would not allow use of field transect methods. "The Montana method is a quick, easy methodology for determining flows to protect the aquatic resources on a broad scale and therefore is applicable to regional planning of water uses and needs" (BLM, 1979). Researchers, working on new instream methods to better answer local questions and problems, have found Tennant's method to closely approximate instream flow requirements computed from exhaustive field work. Newcombe (1981) obtained cross-section areas of stream discharges and weighted them in accordance with frequency distribution of water depth and water velocities preferred by life-history stages of native sport fish in the Pacific Northwest. Comparison of his results indicated substantial agreement with Tennant's method.

The Montana method does have inherent limitations which should be understood before it is used. It does not necessarily account for a specific stream's flow fluctuations or seasonal variability characteristics of southeast U.S. streams and does not account for the geometry of the stream channel which can vary in drainges within the same region. However, because of time limitations placed on the agency responsible for required instream flow guidelines, a thorough analysis of this method was done. After careful inspection, the Montana method did not appear totally applicable to Arkansas' instream flow needs because its framework follows hydrologic processes more common to western states. Hydrographs where this method was developed underline the importance of spring and summer snowmelt that provide the majority of water during a single water year. In western climates, winter is not a high flow time of year even though precipitation in the form of snowfall is fairly high. Snowfall is incorporated into the snowpack until the spring and summer months when warming air temperatures begin the thawing and melting process. Arkansas receives its heaviest inflows in the form of rain during winter and spring and experiences a low flow period in late summer to early fall (Fig. 1). This major difference in

Fig. 1. Monthly Mean Flows and Mean Relative Water Temperatures for the Saline River near Rye, Ark.

meterological conditions kept Arkansas biologists from using the Montana method as outlined by Tennant. However, it did not completely negate consideration of the discharge method of instream flow quantification, since discharge is the primary physical factor that characterizes stream environments (Hynes, 1970). The resultant method developed for utilization in Arkansas is outlined and modifications to the Montana method are discussed in the following section.

THE ARKANSAS METHOD

Since the Montana method does not adequately protect certain critical stages in the life cycle of native Arkansas stream fish, a new method utilizing Tennant's basic principles was developed. Average monthly flows, average annual flows, stage-discharge relationships, and stream channel cross-sections were obtained from the U.S.G.S. office in Little Rock. An instream flow method sufficient for Arkansas' fisheries needs evolved which combined: (1) the use of historic hydrologic records for Arkansas streams; (2) many years of field and educational expertise in fisheries biology (including specific fishery needs and habitat requirements); and (3) a knowledge of natural, seasonal processes occurring in streams in Arkansas' different physiographic regions. This method of computing instream flow needs for fisheries in Arkansas will subsequently be referred to as the "Arkansas Method".

The Arkansas method of instream flow determination is based on the premise that the average flow of a stream is a composite of size of the drainage basin, geomorphology of the stream channel, climate, vegetation type and abundance, and related land uses. This flow reflects the average, natural hydrograph of the stream, and the component aquatic fauna and flora which have evolved to "fit" the specific characteristics of that stream. Vannote *et al.* (1980) observed that "over extended river reaches, biological communities are established which approach equilibrium with the dynamic physical conditions of the channel." One of the primary factors affecting physical conditions of the channel is discharge. The fish population inhabiting a particular stream is an indicator of the combined influence of environmental factors which are affected by stream discharge (Wood and Whelan, 1962).

DESCRIPTION OF PHYSICAL/BIOLOGICAL SEASONS IN THE ARKANSAS METHOD OF INSTREAM FLOW QUANTIFICATION

TIME OF YEAR	NOVEMBER THRU MARCH	APRIL THRU JUNE	JULY THRU OCTOBER
FLOW REQUIRED	60% OF THE MEAN MONTHLY FLOW	70% OF THE MEAN MONTHLY FLOW	50% OF THE MEAN MONTHLY FLOW OR THE MEDIAN MONTHLY FLOW
PHYSICAL/BIOLOGICAL PROCESSES INVOLVED	CLEAN AND RECHARGE	SPAWNING	PRODUCTION
NORMAL CONDITIONS	High average monthly flows. Low water temperatures. High dissolved oxygen content.	High average monthly flows. Increasing (preferred) water temperatures.	Low average monthly flows. High water temperatures. Low dissolved oxygen content.
FUNCTION AND/OR RESPONSE	Flushing of accumulated sediment & cleaning out of septic wastes. Spawning areas cleaned & rebuilt by gravel & other substrate brought downriver by high flows. Recharge of ground water (aquifers).	High flows & increasing water temperatures spur spawning response in fish: (1) in channel (2) in overbank or (3) upriver after migration. Feeding also activated by high spring flows.	High water temperatures increase primary, secondary, and tertiary production. Low flows concentrate predators (fish) with prey (invertebrates, forage fish).
LIMITING FACTORS	Reduced flows cause: Decrease in benthic production due to accumulated sediment on substrate. Decrease in fish spawning habitat due to reduced flushing. Decrease in aquifer recharge.	Reduced flows cause: Decrease in spawning egg & fry survival & overall reproduction success of important sport & non-game fish. Weak year classes of important sport, commercial, non-game & threatened fish species.	Reduced flows cause: Water temperatures to increase, decreasing survival of certain fish species. Decrease in wetted substrate & therefore decrease in algae, macroinvertebrates. Decrease in dissolved oxygen due to higher water temperatures; fishkills. Increase concentration of pollutants and sediment in water. Additional decrease in ground water table.

Table 1. Description of physical/biological seasons in the Arkansas method of instream flow quantification.

The Arkansas method divides the water year into three physical/biological units or seasons. These units are categorized by the physical processes that occur in the stream and critical life cycle stages of the fish and other aquatic organisms inhabiting the stream (Table 1). The natural hydrograph of the Saline River at Rye, Arkansas (Fig. 1), indicates November through March is the time of year when increased flows flush sediment laden substrates and septic waste products and bring an influx of inorganic nutrients from the watershed which establish the basic fertility of the stream. Tennant (1975) remarks that 100-200% of average annual flow is good for moving sediment and bedload, and provides for white water types of recreational activities. While Tennant's recommendations appear to be the most widely recognized and used technique in the western states (Reiser *et al.*, 1985), many of the streams it's used on are regulated streams where 200% of the average annual flow can be released at will by the managing agency if the necessary storage capacity is available. Many of Arkansas' streams are not regulated and requests in excess of the average flow for a given month do not appear practical. For this reason, winter flushing flows recommended by the Arkansas Method are often lower than those espoused by Tennant. However, the Arkansas Method flow, 60% of the mean monthly flow (MMF), often is near bank full elevation for many Arkansas streams and should therefore be an effective flow for transporting fine sediments. Recharge of aquifers and groundwater is also an important process occurring during this time.

Seventy percent of the MMF is recommended for fisheries instream flow needs during April through June because it is the primary spawning time for the majority of native Arkansas fish. It is erroneously assumed by some that the late summer low flow period is the only critical time for stream fish populations and, therefore, the only time when instream fisheries requirements need protection. Native fishes must spawn successfully in the spring of each year; otherwise, detrimental effects will be experienced by the population for several consecutive years. Decreases in stream flows contribute to increased mortality by stranding fish eggs and fry or by reducing a sufficient flow of oxygenated water to developing fish eggs or fry. Reduced flows can also result in increased deposition of silt in spawning areas (Peters, 1982). In low gradient streams with expansive floodplains, high water stages may trigger a large portion of the stream fish population to move into backwaters or overbank areas to feed and spawn. The extent of feeding, growth and reproduction is related to the time, coverage, and duration of flooding (Wood and Whelan, 1962). Also, species of native fish such as walleye, white bass, various species of redhorse, and others require high spring flows to migrate upstream to spawn. For these reasons, it is imperative to reserve a high percentage of normal springtime flooding for the fishery. Seventy percent of the MMF often spills onto the flood plain on many Arkansas streams providing necessary spawning habitat and flows.

The final season of this scenario spans July through October when stream flows usually reach absolute minimums and an inverse relationship exists between monthly mean flows and mean water temperatures. Fig. 1 shows this relationship in a typical sine curve. This July-October season is the production time of the biological year when warmer water temperatures accelerate numerous processes in the food chain from bacteria digestion of organic materials to production of plankton, periphyton, macroinvertebrates, forage fish, and predatory fish. However, if water temperatures become too elevated, which can occur with excessive removal of water from a stream, the dissolved oxygen (DO) saturation capacity of water is greatly reduced. Substantial decreases in DO content limit production, growth, and survival of most aquatic life. For example, growth of largemouth bass begins to substantially decrease at DO levels below 4.0 mg/1 and mortality occurs below 1.0 mg/1 (Stuber *et al.*, 1982). Smallmouth bass and other fish species are considerably more sensitive to decreased DO concentrations than are largemouth bass.

During the production season (late summer), stream flows have less tendency to vary compared to other times of the year. For this reason 50% of the MMF could possibly result in a value less than the 7Q10, especially in spring or artesian dominated systems. In these situations the median flow for the monthly period would provide adequate protection, therefore, the minium flow requirement recommended for the production season is 50% of the MMF or the median monthly flow for groundwater powered systems (Table 1). Fifty percent of the MMF approximates the inflection point for the relationship between discharge

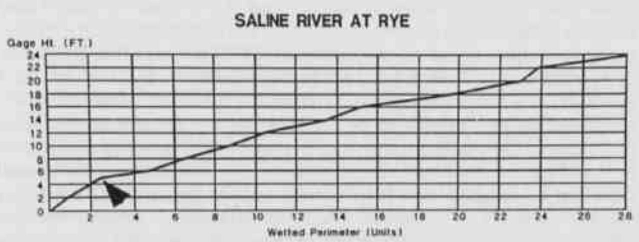

Fig. 2. Relationship Between River Level and Wetted Perimeter for a Cross Section of the Saline River at Rye, AR. Arrow Designates Inflection Point/Minimum Flow for the Low Flow Seasons.

and the wetted perimeter. This inflection point is the basis for most single transect method recommendations. Figure 2 shows this relationship for the Saline River near Rye, Arkansas. In the figure, discharge is represented by the water level gage height. At or below this inflection point (or flow), the change in the relationship between discharge and the wetted perimeter is greatest. This point represents the minimum level a stream should be drawn down since much of the valuable littoral habitat has already been exposed. These flows allow for adequate coverage of the stream substrate or wetted perimeter. Without this magnitude of protection, shoal or riffle areas and sloughs could be exposed, thereby rendering them nonproductive. Stream bank cover for fish would diminish and riparian vegetation and associated wildlife would suffer. Reduced flows would reduce the oxidation capacity of the stream and therefore its ability to assimilate and dilute sewage and other waste products. Concentrations of pollutants and sediments in the water would increase and water quality would be degraded. Extreme low flows result in crowding of fish populations, thereby increasing stress, which can trigger higher levels of fish diseases and parasitic infestations.

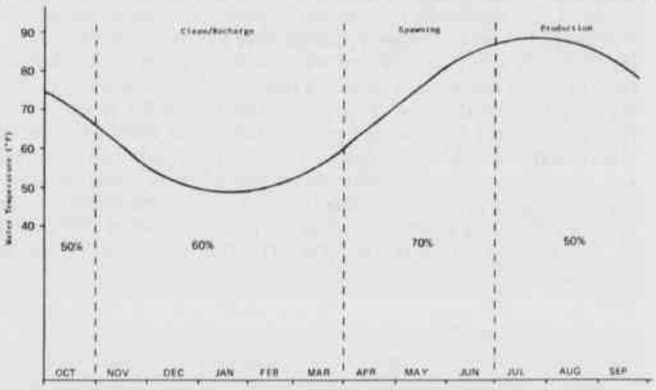

Fig. 3. Temperature vs. Week of Water Year

Fig. 3 illustrates the temperature curve for a typical water year in the Ouachita River near Felsenthal, Arkansas. The instream flow requirements of the Arkansas method are shown on the graph to give an idea of stream water temperature in relation to percent flows necessary for adequate protection of the stream fisheries. Without minimum flows reserved for the fisheries, repetitive abiotic factors such as excessive low flows can control and decimate fish populations (Orth and Maughan, 1980; Layher, 1983).

Although specific stream flow requirements for terrestrial and semi-aquatic wildlife are not addressed, when flow needs for fisheries are met, many instream requirements for these species should be satisfied. Site-specific wildlife problems, such as water level fluctuations during waterfowl season, may require special consideration from professional wildlife biologists. For example, Nichols *et al.*, (1983) showed that the availability of winter water, time of year and duration of inundation may directly affect food utilization, nutrition distribution, annual survival, and recruitment of ducks, particularly mallards. Mallards are the number one harvested duck in Arkansas and the foundation of the multi-million dollar duck hunting "industry" in the state.

SPECIFIC INSTREAM FLOW NEEDS

Figure 4 shows the 12 major river basins in the state where instream flows for fisheries were computed. Tables 2-3 list specific monthly instream flows for the year as computed using the Arkansas method of flow reservation for two streams representing major river basins in the state.

Fig. 4. Map Illustrating 12 Major River Basins in Arkansas.

Table 2. Minimum Instream Flow Requirements for Fisheries by Month for the Ouachita River at Malvern, Arkansas.

MONTH	MONTHLY MEAN FLOW (CFS) 1929 - 1983	INSTREAM FLOW REQUIREMENTS ARKANSAS METHOD (CFS)	INSTREAM NEEDS BY STAGE HEIGHT (FT.)
JANUARY	3,817	2,290	3.6
FEBRUARY	3,442	2,065	3.4
MARCH	3,335	2,001	3.4
APRIL	3,627	2,539	3.8
MAY	3,560	2,492	3.8
JUNE	1,728	1,210	2.7
JULY	1,032	706	2.1
AUGUST	913	592	2.0
SEPTEMBER	1,127	792	2.3
OCTOBER	1,231	932	2.4
NOVEMBER	1,899	1,139	2.6
DECEMBER	2,959	1,775	3.2

Table 3. Minimum Instream Flow Requirements for Fisheries by Month for the Arkansas River at Murray Lock and Dam.

MONTH	MONTHLY MEAN FLOW (CFS) 1928-1984	INSTREAM FLOW REQUIREMENT ARKANSAS METHOD (CFS)
JANUARY	33,520	20,112
FEBRUARY	41,190	24,714
MARCH	50,760	35,532
APRIL	64,960	45,472
MAY	77,490	54,243
JUNE	61,450	43,015
JULY	35,060	24,230
AUGUST	17,450	12,560
SEPTEMBER	17,730	13,820
OCTOBER	24,430	12,320
NOVEMBER	29,010	18,438
DECEMBER	30,730	18,438

ANNUAL MEAN FLOW = 40.270 cfs

Figures 5-6 show monthly mean flows (top line), Arkansas method instream flow (bottom line) and surplus water (shaded area). The minimum stream flows and stream stage heights recommended are guidelines for the ASWCC for minimum values to maintain and protect stream fisheries. Determination of higher flows or stage heights at which ASWCC's water allocation duties begin is not the responsibility of the agencies involved in setting fisheries instream needs.

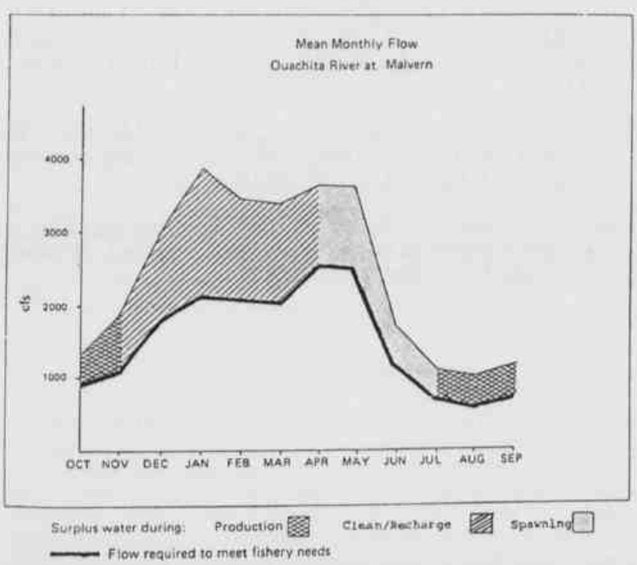

Fig. 5. Minimum Instream Flow Requirements for Fisheries by Month for the Ouachita River at Malvern.

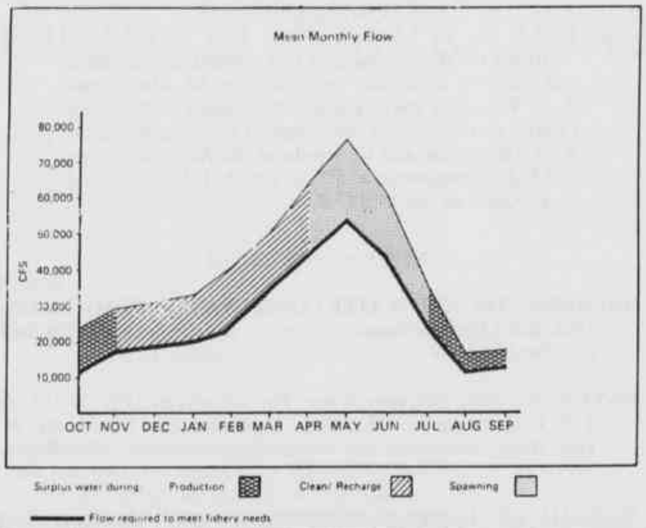

Fig. 6. Minimum Instream Flow Requirements for Fisheries by Month for the Arkansas River at Murray Lock and Dam.

Since only a few sites and instream flow recommendations can be computed, water users above and below the stations specified will need to be advised of minimum instream flow reservations in their area. These will need to be computed on a watershed size basis at the point of interest, or by some other suitable method determined by the administering agency.

Agencies responsible for the conservation and management of the fishery resources should only have to justify that portion of a stream flow actually required to fulfill specific instream needs. Therefore, if fisheries instream needs require a flow of 14,000 cfs in a stream segment and the USCOE requires a flow of 13,000 cfs for navigation purposes at the same time of year, only a flow of 1,000 cfs should have to be justified for the fisheries needs at that time.

Finally, only streams with a 7Q10 value greater than 1 cfs are currently being considered by ASWCC for fisheries instream flow requirements. A large number of streams with 7Q10's less than 1 cfs located in the Ouachita and Ozark Mountains have high water quality and exceptional recreational fisheries. These smaller streams are in as much or greater need of protection as the larger ones. With low or no flow in late summer through early fall, fish populations are often at their tolerance limit. Any water diversion at this critical low-flow period could have devastating effects on the stream's fishery. This matter needs to be addressed in the near future and would seam to be a logical extension of the current instream flow evaluation.

The concept of instream flow reservation in Arkansas is a relatively new problem associated with an increasing population and demands for a limited water resource. All facets of the aquatic and associated terrestrial environment can be affected by the resolution of this issue. Cooperation between coordinating agencies is necessary to insure proper water conservation and utilization on a statewide basis. Since great seasonal variability in surface water availability exists in Arkansas, a concerted effort to store high winter and spring flows for later use during peak irrigation times is necessary. Limiting summer-fall (low flow) pumping/diversion from many state streams will protect the aquatic ecosytem associated with these streams. In the future, wise management of Arkansas' streams through adequate instream flow reservations will benefit domestic water uses, fish and wildlife, agriculture, industry, navigation, water quality, and recreation.

ACKNOWLEDGEMENTS

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DISTRIBUTION AND STATUS OF RARE AND ENDANGERED MUSSELS (MOLLUSCA: MARGARITIFERIDAE, UNIONIDAE) IN ARKANSAS

JOHN L. HARRIS
Environmental Division
Arkansas Highway & Transportation Department
P.O. Box 2261
Little Rock, AR 72203

MARK E. GORDON
304 North Willow, Apt. A
Fayetteville, AR 72701

ABSTRACT

Knowledge of the distribution and population status of freshwater bivalves occurring in Arkansas has increased markedly during the past decade. Sufficient data has become available to delineate species which are rare and/or endangered within the state. Historical and recent records from Arkansas exist for four mussels currently listed as federally endangered species: the fat pocketbook *(Potamilus capax)*, the pink mucket *(Lampsilis orbiculata)*, Curtis' pearly mussel *(Epioblasma florentina curtisi)*, and the turgid-blossom pearly mussel *(Epioblasma turgidula)*. Ten additional mussels which occur or were thought to occur in Arkansas are being considered for federal protection by the United States Fish and Wildlife Service. Several other taxa may warrant protective status.

INTRODUCTION

The state of our knowledge concerning the systematics and distribution of Arkansas freshwater bivalve mollusks has increased and, hopefully, improved considerably since R. E. Call (1895) published his monograph on the Unionidae of Arkansas. Numerous distributional studies have been conducted during the past decade culminating in valuable regional assessments of naiades by Gordon, *et al.* (1980), Gordon (1981), and Johnson (1980). As a result of these investigations, our knowledge of Arkansas mussels is now sufficient to identify those species which are rare or possibly endangered within the state.

Four species known historically from Arkansas are currently recognized as nationally endangered by the United States Fish and Wildlife Service (USFWS, 1982). These species are *Potamilus (= Proptera) capax, Lampsilis orbiculata, Epioblasma (= Dysnomia) florentina curtisi*, and *Epioblasma turgidula*. Ten additional taxa which occur or were thought to occur in Arkansas are currently under review by the USFWS. Available information indicates threatened or endangered listing is possibly appropriate for these species; however, conclusive data on biological vulnerability and threats have not been available (USFWS, 1984). Several additional taxa not included by the USFWS for possible protective listing appear to be rare and perhaps endangered, at least within the boundaries of Arkansas.

MATERIALS AND METHODS

During late 1983, we visited 11 major river systems in Arkansas which were poorly known in terms of the resident mussel fauna or which were considered likely refugia for known endangered species. These sytems included the Spring, Strawberry, Eleven Point, Current, Little (Red River Drainage), Cossatot, Saline (Red River Drainage), Little Red, Caddo, Saline (Ouachita River Drainage), and Ouachita rivers. Surveys were made by collecting dead shells from depositional areas (islands or gravel bars) and handpicking live specimens from the substrate. Muskrat middens provided a valuable source of recently dead shells, especially on the Spring and Eleven Point Rivers. Mask and snorkel were utilized where water clarity permitted, otherwise, specimens were obtained by "grubbing" the substrate for live mussels. Survey methods used by the researchers cited in the Results and Discussion section included handpicking depositional areas, brailing with commercial shellfishing gear, SCUBA diving, and diving with surface based air compressors.

The distribution and status of species discussed in this paper were obtained by compiling data from literature, museum records, government reports, and personal collections. One of us (MEG) has examined over 2000 lots of Arkansas mussels from the University of Michigan Museum of Zoology, American Museum of Natural History, Philadelphia Academy of Natural Sciences, University of Oklahoma Stovall Museum, Harvard University Museum of Comparative Zoology, U.S. National Museum of Natural History, University of Colorado Museum, and University of Arkansas Museum. Distributions were plotted for both relict and live specimens when specific localities were determinable.

Taxa discussed in this paper are divided into three groups: 1) *Federal Endangered Species*, 2) *Species Under Federal Review*, and 3) *Other Species of Concern*. Except for federally protected, endangered species, we followed the terminology and criteria of Miller (1972) and Robison (1974) in defining the status of subject species:

> *Endangered* - actively threatened with extinction. Continued survival unlikely without the implementation of special protective measures;
>
> *Threatened* - not under immediate threat of extinction, but occurring in such small numbers and/or in such restricted or specialized habitat that it could quickly disappear. Requires careful monitoring;
>
> *Extirpated* - eliminated from the subject area;
>
> *Special Concern* - population levels appear secure and localities are widespread enough to ensure that a single catostrophic event would not extirpate the species from the subject area;
>
> *Uncertain* - the taxonomic or distributional data are uncertain or so sparse that no recommendations can be made.

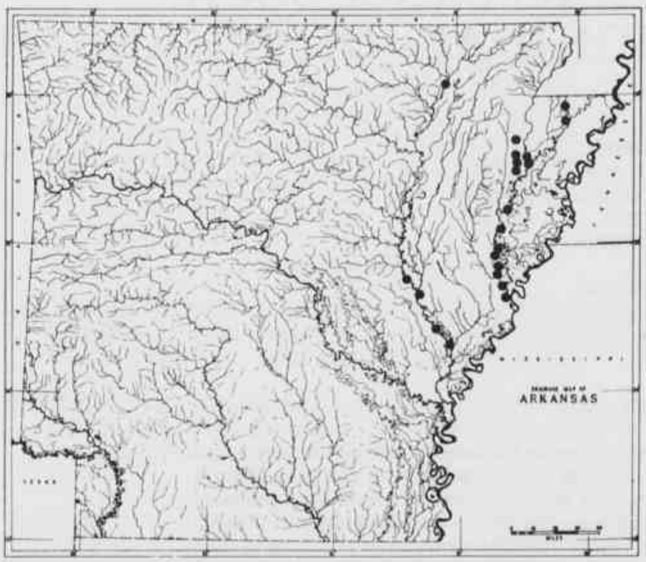

Figure 1. Distribution of *Potamilus capax.*

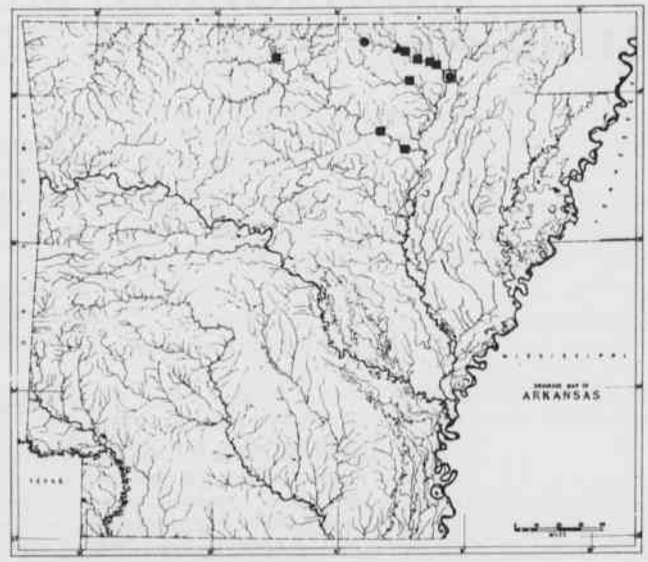

Figure 3. Distributions of *Epioblasma florentina curtisi* (●), *E. turgidula* (▲), and *E. triquetra* (■).

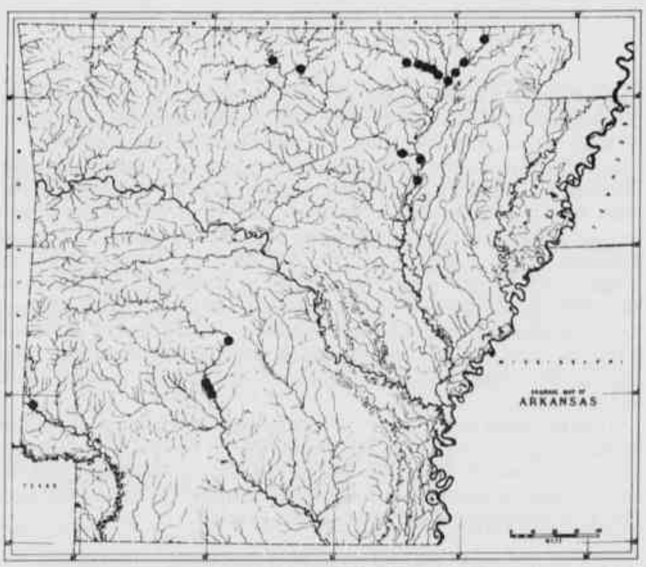

Figure 2. Distribution of *Lampsilis orbiculata.*

Figure 4. Distribution of *Arkansia wheeleri.*

RESULTS

Federal Endangered Species

Potamilus (= Proptera) capax (Green, 1832) — Fat pocketbook pearly mussel. Distribution: Figure 1. *STATUS:* National and State - Endangered

Historically, the fat pocketbook occurred in larger streams throughout the Mississippi and Ohio River systems with verified records from the upper Mississippi River (above St. Louis, Missouri), the Wabash River, Indiana, and the St. Francis River, Arkansas (Dennis, 1985; Ahlstedt and Jenkinson, 1987). Apparently, the St. Francis River supports the last viable population of *Potamilus capax* as no recent records substantiate live specimens from the other systems (Dennis, 1985).

Within the past five years, four separate research projects have been conducted involving the fat pocketbook pearly mussel. Bates and Dennis (1983) sampled 171 sites in the St. Francis River system of Arkansas and Missouri. This included sections of the St. Francis, Castor, Little, Tyronza, and L'Anguille rivers, their tributary ditches and bayous. Based on results of their survey, Bates and Dennis concluded that the only remaining viable population of *Potamilus capax* was located in an eight mile segment of the St. Francis River from Madison, St. Francis County, Arkansas, upstream to Clark's Corner Cutoff. During subsequent surveys conducted in 1984, the fat pocketbook was found at 68 sites from river miles (RMs) 25.8 to 69.0 and in the lower ten miles of Straight Slough (Ecosearch, Inc., 1985). *Potamilus capax* was found to be "the most abundant mussel species in the St. Francis Waterway" and the post-juvenile population size for the St. Francis populations was estimated at 11,000 - 24,000. Habitat for *P. capax* was almost exclusively

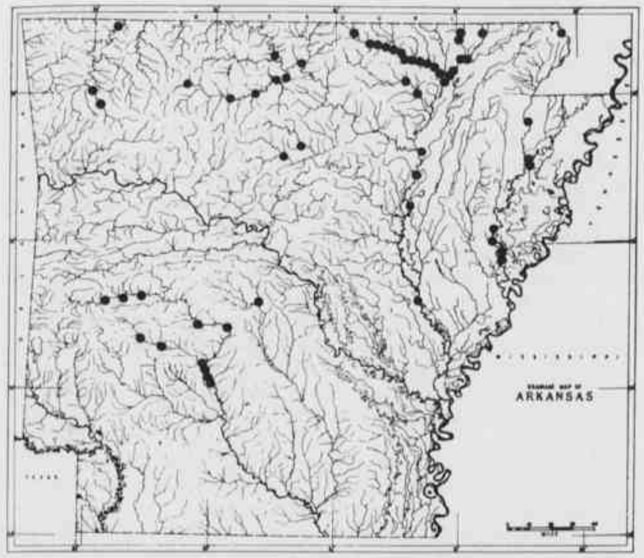

Figure 5. Distribution of *Cyprogenia aberti.*

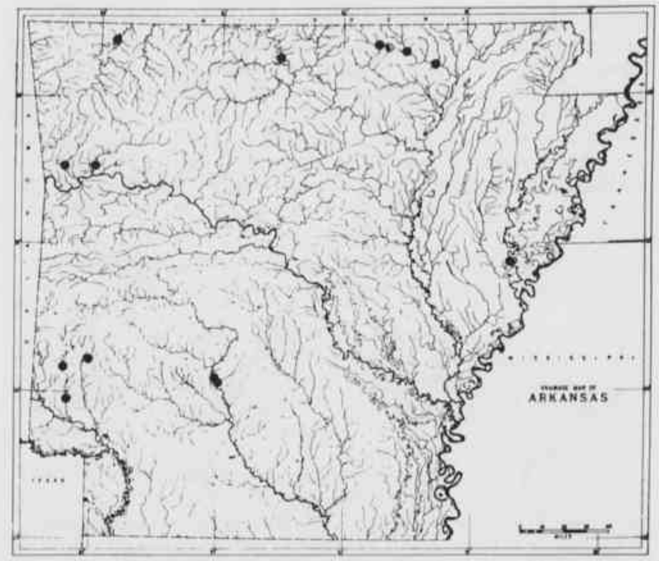

Figure 7. Distribution of *Leptodea leptodon.*

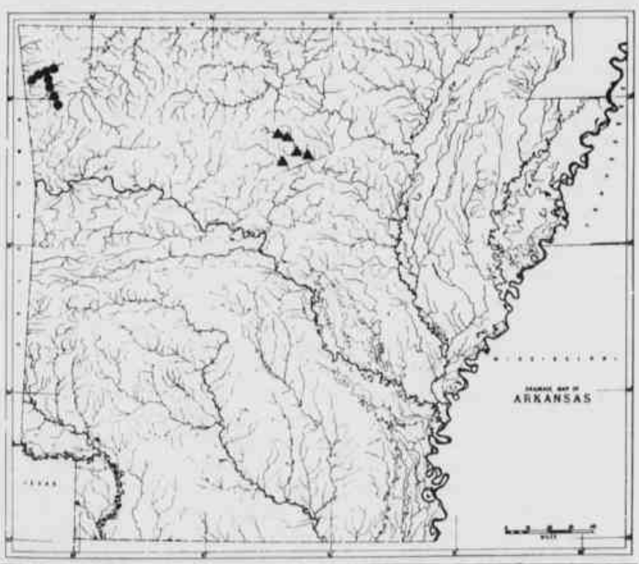

Figure 6. Distributions of *Lampsilis rafinesqueana* (●) and *Lampsilis streckeri* (▲).

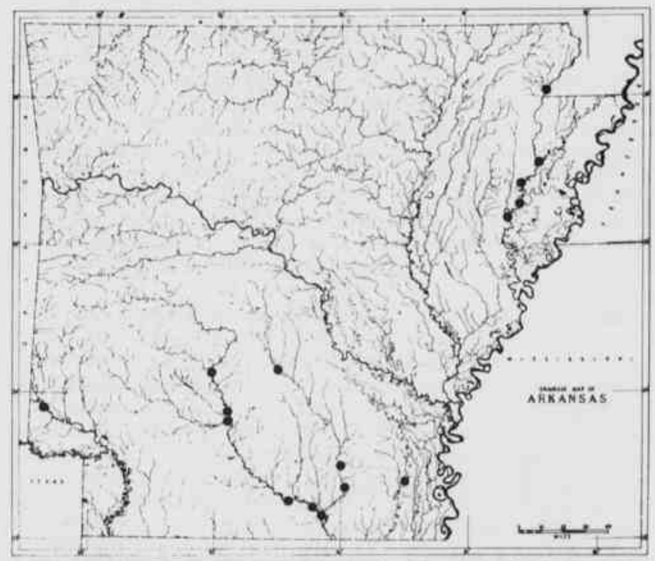

Figure 8. Distribution of *Pleurobema rubrum.*

sand substrate in water depths of 0.1 to 2.0 m.

Construction of an Arkansas Game and Fish Commission boat ramp on the St. Francis River at Madison necessitated relocation of the fat pocketbook population from the construction zone. A total of 512 square meters of river bottom was searched during the relocation project and 7,825 mussels were removed. Eighty-two specimens of *Potamilus capax* were collected representing approximately 1.0% of the mussel population. Most *P. capax* were taken from firmly compacted gravel-sand-shell substrate at depths of 0.5 to 3.5 m (Harris, 1986).

In 1986, a COE sponsored survey documented the distribution and abundance of *Potamilus capax* within the St. Francis River and Floodway system below Wappapello Reservoir (Ahlstedt and Jenkinson, 1987). Approximately 250 river miles were examined and included 144 mainstem and tributary (ditch) sites. *Potamilus capax* was found at 24 sites, seven in the lower St. Francis River and Floodway, three in the St. Francis between Marked Tree and the Siphons Access, and at 14 sites in tributary ditches. Ahlstedt and Jenkinson (1987) concluded that the fat pocketbook inhabits manmade parts of the watershed and is absent in natural areas. *Potamilis capax* was found most often in substrate which contained a mixture of sand, mud, and clay although habitat was highly variable. Summation of all qualitative data for this survey showed the fat pocketbook to comprise 1.0% of the population (142 of 14,606 specimens).

Dennis (1984) and Clarke (Ecosearch, Inc., 1985) outlined programs to aid the recovery of the *Potamilus capax* population in the St. Francis River to a level that is not in imminent danger of extirpation. Specifics included 1) additional surveys to delineate the geographic range of the

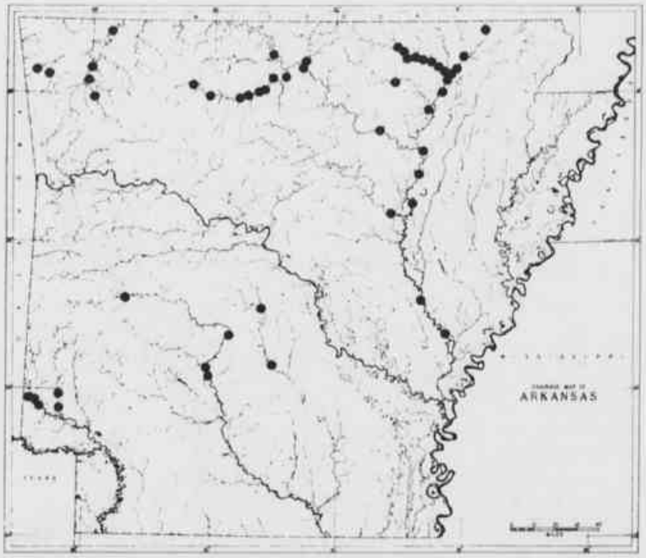

Figure 9. Distribution of *Quadrula cylindrica cylindrica.*

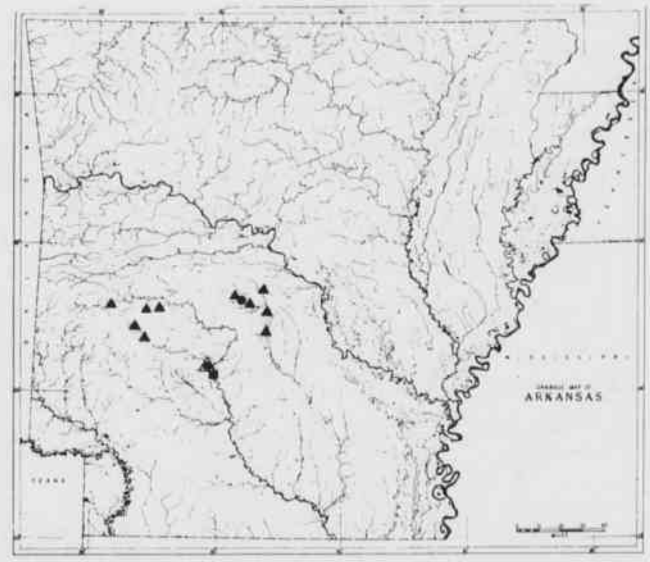

Figure 11. Distribution of *Lampsilis excavata* (●), *Lampsilis powelli* (▲), and *Cumberlandia monodonta* (■).

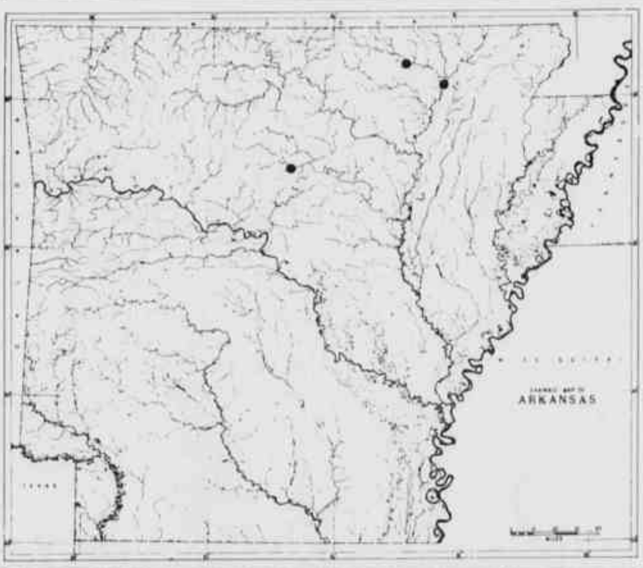

Figure 10. Distribution of *Simpsonaias ambigua.*

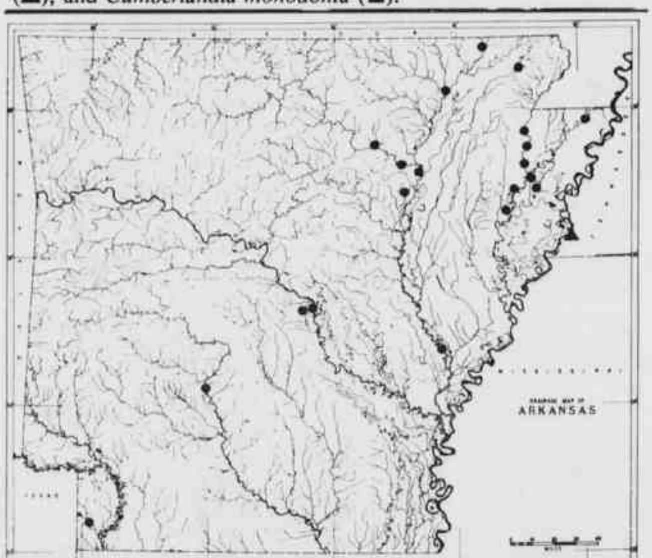

Figure 12. Distributions of *Anodonta suborbiculata* (●) and *Potamilus alatus* (▲).

species, 2) determination of microhabitat parameters of existing populations (i.e. preferred substrate, current velocity, water depth), 3) biological studies to determine reproductive season, reproductive potential, and fish host, and 4) relocation of individuals to suitable habitat at localities with no or few individuals of *P. capax* present. Data obtained by Ahlstedt and Jenkinson (1987) and Harris (1986) indicate that the distribution and population size of the fat pocketbook are larger than previously suspected. Additional surveys are in progress to further define the distribution of *P. capax* with emphasis placed on ditches and tributaries within the St. Francis drainage (Morris Mauney, COE, pers. comm.).

It would seem prudent to initiate biological studies of fish hosts and reproductive parameters while population levels are stable and to determine if feasible transplant sites exist within the historic range of the species. Ecosearch, Inc., (1985), Ahlstedt and Jenkinson (1987), and Harris (1986) have all noted that many *P. capax* appear to strand and die during summer low water levels. Individuals in danger of stranding would be an ideal source of transplant material as they would likely die if not rescued anyway. Dredging activities and water discharge within the St. Francis system should be regulated to avoid adverse impacts to populations defined by the recent surveys.

Lampsilis orbiculata (Hildreth, 1828) — Pink mucket. Distribution: Figure 2. *STATUS:* National and State - Endangered.

Confusion and controversy surround the taxonomy of this species or species complex throughout its range. *Lampsilis orbiculata* and the closely related Higgins' eye pearly mussel (*Lampsilis higginsi* [Lea, 1857]) are very similar in appearance and have variously been considered separate species, subspecies, and the same species (see Gordon, 1981 for literature summary). Johnson (1980) and Gordon, *et al.* (1984) referred Arkansas populations to *Lampsilis higginsi* while Stansbery (in Bogan and Parmalee, 1983), Oesch (1984), and Ahlstedt (1985a) refer to White River drainage, AR and MO, specimens as *Lampsilis orbiculata*. To add to the confusion, Stansbery (Stansbery and Kokai, 1979; Bogan and Parmalee, 1983) considers the *Lampsilis orbiculata*-like form in the Ouachita River drainage to be at least a distinct subspecies and possibly an undescribed species. The senior author of this paper has chosen, perhaps somewhat arbitrarily, to refer to all Arkansas specimens of this complex as *Lampsilis orbiculata*. A thorough, critical systematic analysis of the complex throughout its range is desperately needed.

Lampsilis orbiculata has occurred historically in 25 river systems of the Interior Basin, mainly in the Tennessee, Cumberland, and Ohio River drainages with occasional records from the Mississippi River drainage. Although widespread, the pink mucket has never been found in large numbers from any one site and has usually been considered rare (Ahlstedt, 1985a).

Johnson (1980) listed four localities for this species in Arkansas. Two live specimens of *Lampsilis orbiculata* were recovered using hard hat divers by Stein and Stansbery (1980) from the White River at the site of the new U.S. Highway 67 bridge near Grand Glaise, Jackson County, Arkansas. Additional White River specimens have been noted from the vicinity of Batesville by R. S. Caldwell (pers. comm.) and Dames and Moore (1977) obtained a single specimen (misidentified as *Obovaria olivaria*, redetermined by MEG) from the vicinity of Oil Trough (RMs 261 - 276). Gordon and Harris (1983) found ten additional sites for the pink mucket with live individuals encountered in the Current, Spring and Ouachita rivers. Nowhere were recently dead or live specimens abundant and most sites were represented by single specimens or single valves.

A total of 3,372 mussels were recovered from 1483 m^2 of river bottom during a mussel relocation project in the Spring River, south of Ravenden, Lawrence County, Arkansas (AHTD, 1983). Six specimens, four females and two males, were *Lampsilis orbiculata*. Five of the six were taken in clean rock and gravel substrate while the other individual was found in bedrock and boulders. Water depth was 1.7 - 4.1 m and current velocities ranged 0.3 - 0.6 meters per second.

Gordon, *et al.* (1984) located three individuals of the pink mucket from two localities in the lower Spring River below Imboden, Lawrence County. Two specimens were recovered in approximately 0.7 m of water in gravelly substrate while the third was taken in a 1.0 m deep pool with muddy substrate. Miller and Nelson (1984) collected dead shells of *Lampsilis orbiculata* in the Spring River below Imboden (RM 11.0) and in the Black River at Old Davidsonville State Park (RM 75.2). Miller and Hartfield (1986) found a live pink mucket at each of two locations in the Black River (RMs 75.05 and 80.7). Habitat at RM 75.05 was sand/silt substrate mixed with organic matter with water depth 2.5 - 3.3 m and slow current velocity. The substrate at RM 80.7 was sand and mud with water depth less than 2.0 m and moderate current.

Most recently, Miller and Harris (1987) surveyed dredge spoil piles and the adjacent channel of the White River between Newport and Grand Glaise (RM 254.6 - 230.7) during October 1986 in an attempt to document effects of navigation maintenance dredging on the mussel resources of the river. Shells of *Lampsilis orbiculata* were found at eight of the 12 sites surveyed. There was certainly some indication that pink muckets were killed during dredging activities based on the presence of recently dead shells on fresh (< one year old) spoil piles. During the course of this survey a local commercial shell fisherman allowed us to examine 14 unpaired fresh valves of the pink mucket which were taken from the study area by local shellers. Both SCUBA and brailing techniques were utilized in a mussel bed known to support *Lampsilis orbiculata* (Robert Leisure, pers. comm.) but no live individuals were found.

Lampsilis orbiculata is a source of concern because of the seemingly low numbers within existing populations and continued habitat degradation in rivers sustaining the pink mucket. Gravel removal operations, reservoir discharges, and maintenance of navigation channels in the White and Ouachita rivers appear to be the most serious threats to *Lampsilis orbiculata*. An Environmental Impact Statement has been prepared by the COE for the Ouachita and Black Rivers 9-Foot Navigation project which will allow substantial dredging and bend shortening in the Ouachita River as far upstream as Camden, Ouachita County, Arkansas. Recent newspaper accounts (Arkansas Gazette, 9 April 1987) have reported plans for a similar project to make the White River navigable upstream to Batesville, Independence County, Arkansas. These projects will certainly not improve the status of existing *Lampsilis orbiculata* populations.

Epioblasma florentina curtisi (Utterback, 1916) — Curtis' pearly mussel. Distribution: Figure 3. *STATUS:* National and State - Endangered.

The only recent record for the state is three specimens (recently dead) collected near the mouth of the Spring River (Bates and Dennis, 1983; Ecological Consultants, Inc., 1984). Additional specimens are known from the South Fork Spring River near Salem collected in 1916 by A. J. Brown, an amateur shell collector.

Epioblasma turgidula (Lea, 1858) — Turgid blossom pearly mussel. Distribution: Figure 3. *STATUS:* National and State - Endangered.

The only record for the state was collected from the Spring River at Hardy, Sharp County prior to 1914 (Simpson, 1914; Johnson, 1978; Ahlstedt, 1985b).

Species Under Federal Review

Epioblasma triquetra (Rafinesque, 1820) — Snuffbox. Distribution: Figure 3. *STATUS:* State - Endangered.

Hinkley (1916) and Fuller (1974) provided the two known localities, both from the White River, for *Epioblasma triquetra* before the discovery in 1983 of additional sites by A. C. Buchanan (pers. comm.) in the Spring River and by Gordon and Harris (1983) in the Strawberry and Spring rivers. A single live specimen was discovered in the Spring River at Ravenden by AHTD (1984) and Environmental Consultants, Inc. (1984) found a dead specimen in the Black River at the mouth of the Spring River. This species, as are most *Epioblasma*, was found associated with riffle-shoal type habitat.

Arkansia wheeleri Ortmann and Walker, 1912 — Wheeler's pearly mussel. Distribution: Figure 4. *STATUS:* State - Extirpated?

Historically, this species is known from only three rivers: the Kiamichi in Oklahoma, Little River in southwestern Arkansas, and the Ouachita River in central Arkansas. Johnson (1980) and Clarke (1981) listed two localities for *Arkansia* within Arkansas (one in Little River, one in the Ouachita River). Gordon and Harris (1983) discovered relict shells at two additional sites in Little River and one additional site in the Ouachita River. One of us (JLH) recently collected a relict shell from the Ouachita River at Malvern. The status of this species is currently being surveyed by the USFWS. No viable populations are currently known within Arkansas.

Cyprogenia aberti (Conrad, 1850) — Western fan shell. Distribution: Figure 5. *STATUS:* State - Special Concern.

The western fan shell was considered rare within Arkansas by the COE and was one of the species concentrated on by Bates and Dennis (1983), Ecological Consultants, Inc. (1984), Gordon, *et al.*, (1984) and Ecosearch, Inc. (1985). The species is found in the White, St. Francis, and Ouachita river drainages and is locally abundant in the Spring and Caddo rivers. *Cyprogenia* composed 16.5% (558 of 3372 individuals) of the mussel population in the Spring River at Ravenden (AHTD, 1984). This species seems best suited to medium size rivers or streams that maintain pristine water quality and unaltered substrates. The western fan shell should be considered a key indicator of ecological conditions of streams in Arkansas.

Lampsilis rafinesqueana Frierson, 1927 — Neosho mucket. Distribution: Figure 6. *STATUS:* State - Threatened.

Within Arkansas, this species is restricted to the Illinois River system in the northwest corner of the state. *L. rafinesqueana* is considered locally abundant from second order streams of the system downstream to the Arkansas - Oklahoma line. These populations are possibly threatened by a proposed municipal sewage discharge from the city of Fayetteville.

Lampsilis streckeri Frierson, 1927 - No common name. Distribution: Figure 6. *STATUS:* State - Uncertain.

The type locality of this taxon is the Little Red River at Clinton, Arkansas (Frierson, 1927). Paratypes listed from Onion Creek (Colorado River system), Travis County, Texas appear to be a closely related species, *Lampsilis bracteata* (Gould, 1855). The *streckeri* form has recently been collected from several localities in the Little Red River by Arthur Clarke (pers. comm.) and MEG during an assessment of the distribution, taxonomic status, and population status of this species. Specimens taken from the Little Red River are very similar to and perhaps conspecific with *Lampsilis reeveiana* (Lea), a common species of the White River system (Gordon and Kraemer, 1984).

Leptodea leptodon (Rafinesque, 1820) — Scale shell. Distribution: Figure 7. *STATUS:* State - Threatened.

Most of our records for this species have all been recorded during the present decade. The scale shell occurs in widely disjunct populations and appears to be rare at known localities. The species has been declared endangered in Missouri (Nordstrom, *et al.*, 1977) and Oesch (1984) describes it as a typical riffle shell found in clear unpolluted water with good current.

Pleurobema rubrum (Rafinesque, 1820) — No common name. Distribution: Figure 8. *Status:* State - Special Concern.

This species has been identified as *Pleurobema cordatum pyramidatum* in previous surveys and publications. It appears to be a species which inhabits the larger sections of rivers such as the White, Ouachita, and St. Francis. Ahlstedt and Jenkinson (1987) found it to be relatively common in the St. Francis River between RM 71.5 - 84.3. Harris and Gordon (1985) encountered six live specimens using brailing methods in the Ouachita River at Arkadelphia.

Quadrula cylindrica strigillata (Wright, 1898) — Rough Rabbit's foot pearly mussel. Distribution: Figure 9. *STATUS:* State - Special Concern.

Although listed as occurring in Arkansas by the USFWS (1984), *Q. cylindrica strigillata* is found only in the upper tributaries of the Tennessee River (Bogan and Parmalee, 1983). The subspecies found in Arkansas is the nominate form *Q. c. cylindrica* (Say, 1917). Considerable emphasis has been placed on locating populations of this species by the COE (Ecosearch, Inc., 1985). The species is relatively common in middle to lower portions of the Spring River (Gordon and Harris, 1983) and comprised 2.1% of the mussel fauna in the Spring River at Ravenden (AHTD, 1984). Miller and Hartfield (1986) found the species at four sites in the Black River between RMS 73.2 - 75.1 where it was relatively common. Records for the Ouachita and Little rivers were relict shells and no live specimens have been taken from these sites recently.

Simpsonaias ambigua (Say, 1825) — Salamander mussel. Distribution: Figure 10. *STATUS:* State - Threatened.

Buchanan (pers. comm.) collected several recently dead specimens from a muskrat midden in the Spring River at Imboden and Gordon, *et al.* (1984) found shells deposited on an island in the Black River just upstream of U.S. Highway 63 at Black Rock. An additional locality in the Little Red River at Clinton was noted by Johnson (1980), Gordon et al. (1980), and Clarke (1985).

Epioblasma lefevrei Utterback, 1915 — Lefevre's pearly mussel.

The distribution of this species is listed as Arkansas and Missouri by the USFWS (1984). This species is a synonym of *E. turgidula* (Johnson, 1980; Gordon, 1981).

Other Species of State Concern

Lampsilis excavata (Lea, 1857) — No common name. Distribution: Figure 11. *STATUS:* State - Uncertain.

Johnson (1980) listed the species as occurring in the Saline River at Benton, Saline County. Gordon and Harris (1983) found additional localities in the South and Middle Forks of the Saline River and the Caddo River for specimens referrable to the figure in Johnson, 1980. However, these specimens may represent aberrant individuals of *Lampsilis satura* (Lea, 1852).

Lampsilis powelli (Lea, 1852) — No common name. Distribution: Figure 11. *STATUS:* State - Threatened.

This species is an Arkansas endemic with the type locality restricted to the Saline River at Benton, Saline County (Gordon and Harris, 1985). The species occurs in the upper portions of the Saline and Ouachita rivers and the Caddo River. Stable populations appear present in the South Fork Ouachita River and the South Fork Saline River.

Cumberlandia monodonta Say, 1829 — Spectacle case. Distribution: Figure 11. *STATUS:* State - Extirpated?

This species is known from a single locality in the Ouachita River near Arkadelphia, Clark County (Wheeler, 1918; Johnson, 1980). No live or relict specimens have been collected since.

Anodonta suborbiculata Say, 1831 — Flat floater. Distribution: Figure 12. *STATUS:* State - Special Concern.

Johnson (1980) mapped five localities for this species within Arkansas. Gordon (1982), Gordon and Harris (1983), Ecological Consultants, Inc. (1984), Ecosearch, Inc. (1985), and Ahlstedt and Jenkinson (1987) added 12 additional sites for the flat floater. All records for this species are from near or below the fall line in the Mississippi Alluvial Valley region. The species inhabits slow moving sloughs and backwaters and is typically a lowland species that does not lend itself to frequent collection. It is most often taken during drought from dried ponds or oxbows. We expect this species to be found at additional localities as greater collecting effort is expended during drier months of the year.

Potamilus alatus (Say, 1817) — Pink heel-splitter. Distribution: Figure 12. *STATUS:* State - Endangered (Peripheral)

Previous Arkansas records for the pink heel-splitter have been based on misidentifications of other species, primarily *P. purpuratus* (Lamarck, 1819) (Gordon et al., 1980). Thus, this species has not been previously recorded from Arkansas (Gordon, *et al.*, 1979) although Oesch (1984:179) illustrates its occurrence across the northern half of the state. This species ranges primarily to the north and east of Arkansas. A single specimen was collected by JLH from the banks of the Mississippi River underneath the I-40 bridge at West Memphis, Crittenden County during low flow conditions in January 1981.

CONCLUSION

It is obvious that considerable work remains to better delineate the distributions, biology, and taxonomy of Arkansas mussels. With reference to species discussed in this paper, several trends are apparent. Some species broadly distributed over eastern North America such as *Lampsilis orbiculata* and *Leptodea leptodon* appear to have always been rare and, thus, vulnerable to almost any level of environmental disturbance. Although distributed nationally over a wide geographic area, *Epioblasma triquetra* appears to be following the trend of other *Epioblasma,* in that its numbers appear to be on the decline and populations appear to be small at most localities. Other species such as *Lampsilis powelli* and *Epioblasma florentina curtisi* appear restricted to very small geographic areas with low population numbers. Due to their endemism and presumed restricted environmental tolerances, these species are even more at risk to habitat destruction. *Epioblasma turgidula* may already be extinct (Bogan and Parmalee, 1983). Additional surveys should be undertaken in the Spring River drainage to determine the status of *Epioblasma florentina curtisi* and *E. turgidula* within Arkansas. Sections of the South Fork Spring River, Spring River below Ravenden, Eleven Point River, and also, the Strawberry River would seem to offer suitable habitat to sustain these endangered species.

Two species being reviewed by the USFWS for possible protective listing appear to be worthy of endangered status. If a viable population of *Arkansia wheeleri* is found and *Lampsilis streckeri* is determined to represent a distinct taxon, these species should be listed as endangered as quickly as possible. Two species not under review by the USFWS appear to merit national concern. Due to its restricted range in the upper Ouachita River drainage, *Lampsilis powelli* deserves some consideration for protected status. Further work needs to be done to determine the size of existing populations and to further define the distribution of the species. *Simpsonaias ambigua* remains a rather enigmatic species due to its small size and preferred habitat under large rocks. Additional work is needed on the distribution and biology of this species.

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DISTRIBUTION OF FISHES IN REFERENCE STREAMS WITHIN ARKANSAS' ECOREGIONS

WILLIAM E. KEITH
Department of Pollution Control and Ecology
8001 National Drive
Little Rock, AR 72209

ABSTRACT

The State of Arkansas has been subdivided into six ecoregions based on the homogeneity of land surface forms, potential natural vegetation, soil types and land uses. Reference streams of various sizes, excluding the large rivers, and with the least amount of point source and non-point source disturbances were selected for intensive physical, chemical and biological sampling. These data are to be used to characterize the streams and establish water quality criteria which will protect all stream uses. Fish communities of the reference streams were distinctively different among the ecoregions and can easily be used to characterize the waters of different ecoregions. Although composed of different species, the composition of trophic feeding levels of the fish community was very similar among the ecoregions. The average number of species collected per sample site was similar among the ecoregions; however, the Arkansas River Valley and the Gulf Coastal ecoregions had the greatest species richness and the Delta ecoregion was the lowest in species richness. Species of fish sensitive to environmental change comprised near 50% or more of the community relative abundance in the Boston Mountains, Ozark Highlands and Ouachita Mountains ecoregions. Delta ecoregion fish populations contained less than 1% sensitive species. Comparisons of the ten most abundant species from each ecoregion by use of a similarity index shows very little similarity among the ecoregions. The Ouachita Mountains and Boston Mountains communities were most similar and the Ozark Highlands community versus Delta and Ozark Highlands versus Gulf Coastal were least similar.

INTRODUCTION

The delineation of regions that are distinctly homogeneous has been done by resource managers for decades in an effort to more efficiently manage a variety of natural resources. Many of the early attempts established physiographic regions based on geographic characteristics, regions of similar vegetation type and regions of various land use patterns. These were all single character classifications with specific needs in mind. Later, in an attempt to characterize ecological relationships, several workers incorporated various combinations of multiple characteristics such as soils, climate, water resource, vegetation, land uses and others into ecoregions classifications (USDA Soil Conservation Service, 1981; Bailey, 1976; Warren, 1979).

Most recently, Hughes and Omernik (1981) and Omernik *et al.* (1982) proposed methods for development and uses for ecoregions. The potential uses of these ecoregions include: (1) comparisons of land/water relationships within a region; (2) establish realistic water quality standards for regional rather than a large scale application; (3) location of monitoring and reference sites; (4) extrapolate from site specific studies; and (5) predict effects and monitor environmental changes resulting from pollution control activities (Omernik and Gallant, 1986).

The ecoregions of Omernik (1987) were developed from four small-scale maps of interrelated land characteristics. These include: land uses, land surface forms, potential natural vegetation and soil types. The regions are delineated as the areas of greatest homogeneity. Within each region, the areas which share all of the characteristics that typify the ecoregion are distinguished as the most typical area. Areas which share most but not all of the similar characteristics are designated as generally typical of the region.

The ecoregions within Arkansas and surrounding areas were developed for the U.S. Environmental Protection Agency, Region VI, Dallas and for the Arkansas Department of Pollution Control and Ecology to assist with Arkansas' stream reclassification project. The ecoregions in Arkansas include six distinct regions: (1) Ozark Highlands; (2) Boston Mountains; (3) Arkansas River Valley; (4) Ouachita Mountains; (5) West Gulf Coastal Plains; and (6) Mississippi Alluvial Plain (Delta). These regions are very similar to the natural divisions and sub-divisions of Arkansas as described in *Arkansas Natural Area Plan* (Foti, 1974) and further refined by Pell (1983). The natural divisions of Foti were developed from factors such as: primary vegetation, topography, surface geology, soils and surface hydrology.

Ground reconnaissance and field investigations have resulted in a slight modification of the western segment of the ecoregion boundary between the Arkansas River Valley and the Ouachita Mountains from that purposed by Omernik (1987).

MATERIALS AND METHODS

In order to characterize the physical, chemical and biological features of the biotic environments within each of Arkansas' ecoregions, the Arkansas Department of Pollution Control and Ecology selected a series of streams of varying sizes within each ecoregion for detailed investigation. These reference streams were selected, where possible, within the most typical area of the ecoregion, and only streams with the least amount of point and non-point source disturbances were chosen. A sample site on each stream was established, and both low-flow, high-temperature summertime and steady-state flow, springtime sampling was done. The sampling included detailed measurements of the physical features of the stream, analysis of 18 water quality parameters, a 72-hour continuous record of dissolved oxygen and water temperature, intensive sampling of the stream macroinvertebrate population and a comprehensive fish population sample.

The summer fish population sampling was done with the fish toxicant rotenone or with electrofishing devices. Most of the spring sampling was done with trammel nets of mesh sizes from 2.5 to 8.9 cm. Spring fish sampling was to identify migratory fishes in the area and verify fish spawning activities. The summer sampling identified the total resident fish population and established the relative abundance of each species.

Sample sites with very small or no flow, with reduced visibility into the water and with numerous instream obstructions were sampled with rotenone. If flow existed at these sites, a block net was utilized at the downstream limit of the sample area and the rotenone was detoxified with potassium permanganate below the sample area. Areas sampled ranged from about 0.1 to 0.4 ha.

Electrofishing gear was used at sites which had substantial flow, high visibility into the water and where much of the stream could be waded by workers in chest-waders. A gasoline powered generator with 3500 watt A.C. output was used as a power source. The electrodes were energized directly from the generator. Swift flowing riffle areas were blocked with a seine and stunned fish were allowed to drift into the seine. Sampling was done in an upstream direction and the sample areas were usually from 0.4 to 1.6 km in length. All areas that could be efficiently worked were sampled until it became apparent that all existing habits had been sampled and the fish species and their relative abundance was well established by the sample.

All fishes possible were dipped from the water and preserved in 10% formalin for later identification and enumeration. When large numbers of the same species were observed while electrofishing, only an occasional "dip" sub-sample was made but notes on the species abundance were recorded. Each fish species from all summer samples was given a relative abundance value as described below:

4 — Abundant — Species or age group collected easily in a variety of habitats where species expected; numerous individuals seen with consideration of sampling gear limitations and expected abundance of such species; a dominant species of the species group.

3.5 — Common to Abundant

3 — Common — Species or age group collected in most areas where such species would exist; individuals frequently seen and apparently well established in the population; one of the more frequent species of the species group.

2.5 — Present to Common

2 — Present — Species or age group collected with enough frequency to indicate the likely presence of an established population but definitely a subordinate species in the species group.

1.5 — Rare to Present

1 — Rare — Species or age group represented by only one or very few individuals in the population; more than likely a remnant, migrant or a displaced species.

Values are assigned to the adult, intermediate and young age group of each species; therefore, the maximum value for a species is 12 and the minimum is 1.

These values were determined from the number of fish in each species size group, field observations of fishes which were not collected, general knowledge of fish species life history, selectivity of the sample gear and limitations existing at the sample site. Extensive efforts were not made to determine an accurate separation of the young and intermediate age groups of each species. These determinations were based on the presence or absence of a variety distinctive size groups. All calculations of percent of the total community were made with the relative abundance values.

RESULTS AND DISCUSSION

General location of each sample site on the selected reference streams within Arkansas' six ecoregions are shown in Figure 1. A list of the reference streams with the size of the watershed and the stream gradient at the sample site is given in Table 1. Also included are the

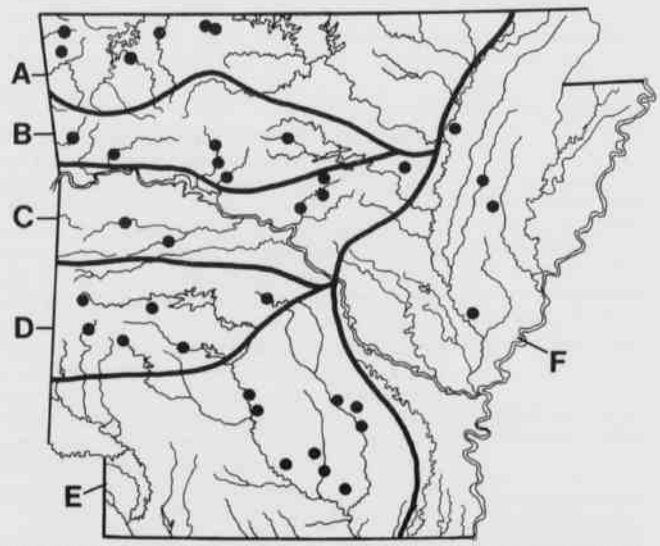

Figure 1. Reference stream sample sites within Arkansas Ecoregions with locations of sample sites on reference streams.
A - Ozark Highlands;
B - Boston Mountains;
C - Arkansas River Valley;
D - Ouachita Mountains;
E - Gulf Coastal Plains;
F - Mississippi Alluvial Plains (Delta)

Table 1. List of reference streams within each ecoregion with watershed size, stream gradient and flows at sample sites.

Stream	Watershed Size (km²)	Stream Gradient(m/km)	Summer Flow(M³/s)	Spring Flow(M³/s)
OZARK HIGHLAND ECOREGION				
South Ford Spavinaw	46.8	4.8	0.04	0.51
Flint Creek	49.4	3.7	0.14	0.81
Yocum Creek	143.0	3.4	0.16	4.86
Long Creek	478.4	1.3	0.29	5.49
War Eagle Creek	683.8	0.8	0.75	3.06
Kings River	1367.6	0.9	1.46	7.56
BOSTON MOUNTAINS ECOREGION				
Indian Creek	122.2	6.1	T	0.57
Hurricane Creek	130.0	6.3	T	0.90
Archey Creek	278.2	2.7	0.02	3.66
Illinois Bayou	325.0	2.4	0.03	4.41
Lee Creek	436.8	2.9	0.11	9.00*
Mulberry River	969.8	2.6	0.19	9.00*

ARKANSAS RIVER VALLEY ECOREGION				
Mill Creek	44.2	2.6	0	0.30
No. Cadron Creek	54.6	1.9	T	0.30
Ten Mile Creek	127.4	1.5	T	3.15
Dutch Creek	286.0	0.7	0.02	2.10
Petit Jean River	626.6	0.7	0,09	9.00*
Cadron Creek	800.8	0.1	0.45	15.00*
OUACHITA MOUNTAINS ECOREGION				
Board Camp Creek	49.4	5.3	0.08	0.59
Little Missouri River	78.0	5.5	0.12	0.77
South Fork Quachita	119.6	1.3	0.20	1.01
Cossatot River	312.0	7.6	0.52	2.92
Caddo River	756.6	2.5	4.02	15.00*
Saline River	938.6	0.8	1.59	12.00*
GULF COASTAL ECOREGION				
E. Fork Tulip Creek	119.6	0.7	0.16	1.68
Cypress Creek	189.8	0.8	0.32	4.50
Whitewater Creek	59.8	0.5	0	0.07
Big Creek	153.4	0.5	0	0.02
Derrieusseaux Creek	384.8	0.7	0	6.00
Freeo Creek	405.6	0.6	0	0.48
Hudgins Creek	486.2	0.3	0	9.00*
L'Aigle Creek	603.2	0.5	0	5.66
Moro Creek	1172.6	0.3	0	10.50
DELTA ECOREGION				
Boat Gunwale Slash	59.8	0.1	0.09	6.90
Second Creek	156.0	0.2	0.23	4.95
Village Creek	504.4	0.1	4.01	1.05
Bayou DeView	1196.0	0.1	5.73	15.00*

T = Less than 0.01

*Flow estimated

stream flows which existed during the spring and summer sample periods. The range of watershed sizes among all sites is from 44.2 to 1367.6 km². Stream gradients are from 0.095 to 7.6 m/km.

Fish habitat was measured at each site during the summer sampling along numerous stream transects. Instream fish cover such as brush, logs, debris, undercut banks, aquatic vegetation and low-overhanging vegetation was measured directly along each transect and converted to percent of stream width. Stream substrate was also measured along each transect. Both the Delta and Gulf Coastal ecoregions are dominated by instream fish habitat such as brush, logs and debris. The Arkansas River Valley is highly variable in the type of fish habitat; however, from all sample sites, approximately 30% of the fish habitat is similar to that of the Delta and Gulf Coastal region and about 70% is dominated by substrate types which provide desirable fish cover. The Boston Mountains, Ozark Highlands and Ouachita Mountains ecoregion streams are heavily dominated by fish habitat provided by substrate. These differences in fish habitat among the ecoregions produce distinctly different fish communities.

The distribution of fishes within the five major fish families of the State are shown for each ecoregion in Figure 2. The Delta and Gulf

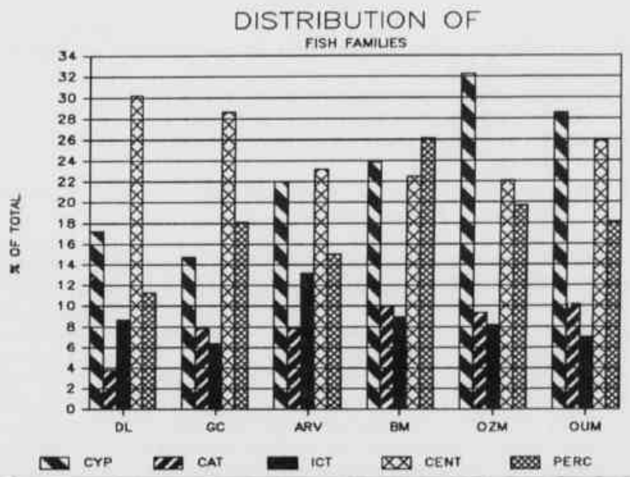

Figure 2. Distribution of fishes within the fish families of Cyprinidae (CYP), Catostomidae (CAT), Ictaluridae (ICT), Centrarchidae (CENT) and Percidae (PERC) for reference streams within each ecoregion.

Coastal ecoregions are distinctively dominated by the Centrarchidae. The Arkansas River Valley is also dominated by Centrarchidae but Cyprinidae is only slightly sub-dominant. Percidae dominates the Boston Mountains fishes but are followed closely by Cyprinidae and Centrarchidae. The Ozark Highlands are strongly dominated by Cyprinidae followed by Centrarchidae and Percidae. Similarly the Ouachita Mountains communities are dominated by Cyprinidae although not as distinctively as in the Ozark Highlands.

The secondary trophic feeding level (marcroinvertebrate feeding fishes) dominates the fish communities of all regions. These comprise 70 to 80% of the relative abundance values. Primary feeders normally make up less than 10% of the community and carnivores constitute 10 to 15% of the community. Primary feeding fishes are least abundant in the Gulf Coastal ecoregion where two samples contained no primary feeders. They are most abundant in the Ozark Highlands. This region also contains the highest levels of nitrogen in the water of the reference streams.

A list of Arkansas fishes which are sensitive to slight to moderate environmental changes were developed from a concensus of knowledgeable ichthyologist. These species make up less than 0.2% of the relative abundance value of all Delta ecoregion communities. Gulf Coastal and Arkansas River Valley fish communities contain approximately 10 to 15% sensitive species. In contrast, sensitive species make up about 50% or more of the communities in the Ozark Highlands, Boston Mountains and Ouachita Mountains ecoregions. Over 66% of the Ozark Highlands fishes are sensitive species.

The average number of species collected per site is very similar among the ecoregions. However, the total number of species collected per ecoregion was as follows: Arkansas River Valley 75, Gulf Coastal 66, Ouachita Mountains 61, Boston Mountains 60, Ozark Highlands 60, and Delta 51. Although it is realized that not all species present within each ecoregion were collected, it is felt that the majority of the more common species within the least-disturbed streams were identified. Areas inadequately sampled within the ecoregions were the large rivers.

The relative abundance value for each species was added for all reference streams where it occurred within each ecoregion and the species were listed in descending order of abundance within the region (ADPC&E 1987). The similarity index from Odum (1971) was modified to use these relative abundance values as follows:

$$SI = \frac{C}{A+B+D} \times 1000$$

SI = similarity index (range from 0 to 100; 100 = identical populations)
A = total relative abundance value of sample A
B = total relative abundance value of sample B
C = sum of relative abundance values of species common to both samples
D = sum of difference in relative abundance values of species common to both samples

Only the ten most abundant species from each ecoregion were subjected to the index for comparison, but all possible comparisons among the six ecoregions were made. The results are shown in Table 2. The greatest similarity exist between the Ouachita Mountains and the Boston Mountains fishes. The least similarity is between the Ozark Highland versus Gulf Coastal and between the Ozark Highlands versus Delta fishes. It is apparent from the similarity indices that there is very little similarity of the 10 most abundant fishes from each of the six ecoregions within the State. This substantiates the distinctiveness of these ecoregions as reflected in the fish communities of the least-disturbed streams.

Table 2. Similarity indices from comparisons of relative abundance values of the ten most abundant fish species of all ecoregions.

	ECOREGIONS				
	BOSTON MTNS.	OZARK HIGHLAND	AR RIVER VALLEY	DELTA	GULF COASTAL PLAINS
OUACHITA MTNS.	62	32	21	11	11
BOSTON MTNS.		39	40	10	10
OZARK HIGHLAND			19	9	9
AR RIVER VALLEY				36	29
DELTA					58

CONCLUSIONS

Fish communities of least-disturbed reference streams within Arkansas' six ecoregions are distinctive and can be used to characterize a segment of the biota of each region. The ten most abundant species from each ecoregion are substantially dissimilar and the relative abundance of fishes within the major fish families is characteristically different among the ecoregions. The greatest species diversity was found in the Arkansas River Valley ecoregion and was a result of a great diversity of stream types. The Delta ecoregion showed the lowest fish species richness. The composition and proportion of sensitive fishes within the ecoregions is distinctive, particularly between the upland and lowland type regions. It is apparent that fish communities are sufficiently distinctive to be used to characterize waters of the various ecoregions, to establish specific communities to be protected and to monitor for environmental changes.

ACKNOWLEDGEMENT

This project was part of a wide scope project funded under Section 205(j) of the Clean Water Act and administered through the Environmental Protection Agency, Dallas Region. The field work was performed by numerous members of the Water Division of the Arkansas Department of Pollution Control and Ecology and assisted by Fisheries Biologist from the Arkansas Game and Fish Commission.

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EFFECTS OF STOCK TYPE AND PLANTER EXPERIENCE ON THE TIME REQUIRED TO PLANT LOBLOLLY PINE SEEDLINGS

R.A. KLUENDER and J.L. YEISER
Agricultural Experiment Station
University of Arkansas at Monticello
Monticello, AR 71655

ABSTRACT

Inexperienced workers planted container-grown and bare-root seedlings of loblolly (*Pinus taeda* L.) on a rocky, upland site near Batesville, AR in a comparison of planting speed and survivability. Planting-speed depended on the type of seedling planted and the amount of planting experience. Significantly less time was required to plant an acre with container-grown than bare-root seedlings. Experience increased the consistency and speed of planting for both seedling types.

INTRODUCTION

Seedling planting speed varies with the number of seedlings to be planted per acre, physical site factors, and conditions that impede the movement of workers on the site. Physical site factors include terrain (slope and roughness), soil type and soil moisture. Factors that impede worker movement on a site include the tree tops and limbs left from harvest, as well as stumps, holes and ruts. Experience of the planting crew has been recognized as one of the most significant factors in planter productivity. When inexperienced crews are employed, a "start-up" period or time of reduced planting productivity is present. This occurs while workers are learning the job, organizing themselves into effective crews and generally getting up to speed physically.

Recently, large scale production of container-grown seedlings has made their use operationally feasible. Additionally, Guldin (1982) reported that some crews in the south were able to plant 25% more container-grown then bare-root seedlings per man-day. This was done by using plug-shaped dibbles. Planting speed for bare-root seedlings was reported by Kluender *et al.* (1985) and Izlar (1980). This paper presents: 1) the planting speed and survival of bare-root and container-grown seedlings planted by inexperienced workers, 2) probable time required to plant an acre in the Ozark Highlands under good conditions, and 3) the variability of planting rate.

METHODS

Container-grown seedlings were grown approximately five months in Styroblock® containers (No. 8) prior to planting. Bare-root (1-0 stock) seedlings were grown as normal planting stock. Both seedling types were grown by the Arkansas Forestry Commission at the Baucum Nursery in North Little Rock. After planting, bare-root seedlings averaged 7.4 inches and container-grown seedlings 6.2 inches in height.

The selected study site was located on Waugh Mountain, six miles northwest of Batesville, AR. The study design consisted of 13, 0.4 acre plots in each of three randomized blocks. One-half of each plot was planted with bare-root or container-grown seedlings resulting in 39 pairs of observations.

Inexperienced workers performed the planting operation. All seedlings were planted in mid-March when moderately warm temperatures, and adequate soil moisture existed. Also, at that time, there was minimum risk from deep freezing of roots in the soil. Container-grown seedlings were planted with special dibbles designed for the number eight Styroblock® container. Bare root seedlings were planted with KBC planting bars and standard dibbles.

Planting crews consisted of eight workers. Workers planting bare-root seedlings carried their own planting bags with seedlings. Container-grown seedlings were slightly more difficult to handle and required two of the eight team members to act as seedling handler serving six planters.

At the beginning of the observed planting period, each worker started planting a row by himself. When a worker came to the end of a row, he moved to the next free row and began planting again, without a break. Near the end of a plot, workers all worked on the last row together. When a plot was finished, workers proceed to the next plot without a break. Time to plant a complete plot was recorded and the recorded time subsequently expanded to a planting-speed per acre.

Workers planted seedlings eight feet apart in rows spaced at eight foot intervals (680 seedlings per acre). Planting quality was constantly checked. Workers were recalled to improperly planted trees to plant them correctly. After several such recalls, quality of planting ceased to be a problem. In addition, a stocking check was conducted at one year to insure that there was not excessive mortality attributable to poor planting technique and that seedlings were planted as prescribed.

An F test was run on the ratio of planting-speed variance from the first and second, and the second and last third of the planting-speed observations. This was done to determine if planting-speed variance decreased significantly as experience was gained.

An analysis of variance (ANOVA) was used to test for differences in planting-speed by planting stock type as workers gained experience. The dependent variable, planting-speed, was modeled as a function of the planting stock type (seedling type), with acres planted (experience) as a co-variate.

Toward the end of the observed planting time it became apparent that a consistent planting rate has been reached. When this occurred the last four observations, which had little variation between them, were averaged, to obtain a sustainable planting-speed.

RESULTS

Average planting-speeds for both seedlings types are presented in Table 1. Average planting-speed for the container-grown seedlings was slightly faster than the bare-root seedlings, but the variance of the container-grown seedlings was slightly higher than the bare-root. However, for both seedling types, as the number of acres planted increased, the number of hours required to plant an acre decreased (Fig. 1). This increase in planting-speed can be attributed to learning the psycho-motor skills required to do the job of planting, and "getting in the swing" of manual labor. Also, variability in planting speed for both container-grown and bare-root seedlings decreased as more acres were planted. This was due to better organization of the planting crews,

Table 1. Bare-root and container-grown planting speed expressed as average man-hours required to plant one acre

SEEDLING STOCK	MEAN	MINIMUM	MAXIMUM	STD DEV	N
BARE ROOT	9.75	5.75	13.88	1.68	39
CONTAINER	8.48	5.66	13.50	1.81	39

as well as increased planting experience with time.

The stocking check at the end of the first year revealed that 94.4% of the bare-root and 97.5% of the container-grown seedlings had been properly placed and had lived. Although there was only a 3.1% difference in stocking level between the two seedling types, the difference was significant at the 0.05 level (Duncan's Mean Separation). The extremely high stocking check results indicated that both seedling types had been planted correctly and at the proper spacings.

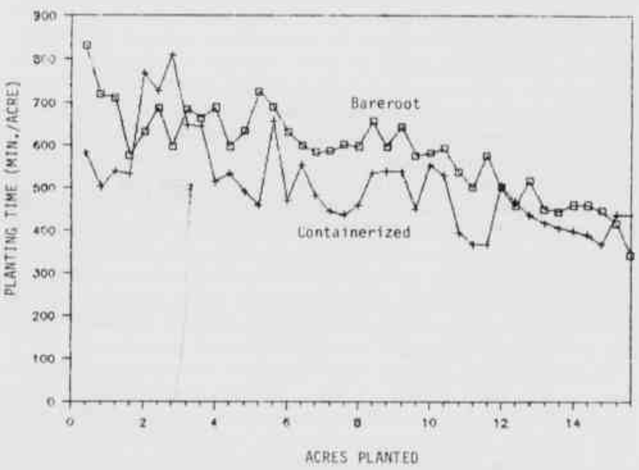

Figure 1. Time required to plant one acre with bare-root or containerized loblolly pine seedlings.

The greatest decrease in planting-speed variation came between the first and second thirds of observations for the bare-root stock. Planting-speed variance decrease for the container-grown seedlings occurred less quickly, and extended for a longer period. The variance decrease for both planting methods was significant at the 90% level. In summary, high variance in planting-speed can be expected in the earliest part of a planting operation, but after a period of time, variance in planting-speed will decrease significantly and a reasonably smooth rate of planting can be expected after workers learn the job.

The analysis of variance (ANOVA) showed that only planting method (seedling type) and acres planted (experience) were significant at the 0.05 level.

The average estimated sustainable planting-speed was 6.95 hours per acre for bare-root seedlings and 6.52 hours per acre for container-grown seedlings. The estimated sustainable rate was reached after the crews had planted about 6.5 acres per crew, or 0.8 acres on an individual basis.

APPLICATION

The average time required to plant an acre of bare-root seedlings in this study was slightly higher (9.75 hours per acre vs. 7.93 hours per acre) than reported by Kluender *et al.* (1985). However, the post-training sustainable planting-speed from this study (6.95 hours per acre) was below that reported by Kluender *et al.* (1985).

The "learning curves" for planting bare-root and container-grown seedlings presented here are results that apply to crews with no prior experience in tree planting. Such a condition is likely to occur when a consultant or landowner employes casual laborers to plant small acreage on non-industrial tree farms or possibly on larger holdings. How fast a worker acquires planting skills will vary with terrain, soil type, climate, and abilities of laborers. The estimated sustainable rates that individuals can achieve will vary with the same factors that influence the learning curve.

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BOTANICAL EVIDENCE FOR HOLOCENE MOVEMENT OF ROCK STREAMS IN ARKANSAS

S. MARIE LOOKINGBILL
Instructor
Central Junior High School
Springdale, AR 72764

MALCOLM K. CLEAVELAND
Research Associate
Tree-Ring Laboratory
Department of Geography
University of Arkansas
Fayetteville, AR 72701

MARGARET J. GUCCIONE
Assistant Professor
Department of Geology
University of Arkansas
Fayetteville, AR 72701

ABSTRACT

Botanical studies of rock streams on the western half of Rich Mountain and on the north slope of Mt. Magazine in Arkansas question the common presumption that such streams require periglacial conditions to form, and are now inactive relict features in this area. Trees along the margins of the streams examined show abundant evidence of trauma resulting from Late Holocene movement, in the form of bent and tilted stems. Cross sections of trees demonstrate marked eccentric growth associated with tilting and cambial trauma associated with corrasion by rocks. That this damage is not the result of excessive snow loading is indicated by the lack of such stressed trees away from the stream margins. Stressed growth and shortened lifespan of trees on the Rich Mountain rock stream margins is shown by the small diameter (less than 15 cm) of most, while older and larger trees are found on higher slopes away from the stream.

These rock streams are indicated to be moving, active features, not stabilized relicts of the Pleistocene. Further study would permit more testing of this hypothesis and the establishment of a chronology of movements in the last century.

INTRODUCTION

White (1981) defines a block stream as an elongate body of rocks extending farther downslope than across slope; occurring on mountainsides or in the heads of ravines; overlying solid or weathered rock, colluvium, or alluvium; and existing above or below treeline. In this report block streams are referred to as rock streams.

It is commonly assumed that periglacial mass-wasting processes produce rock streams (White, 1976), including those found in the Appalachians (Hupp, 1982), the St. Francois Mountains of southeastern Missouri (Peltier, 1950), and the Ouachita Mountains of west-central Arkansas and east-central Oklahoma (Stone and McFarland, 1979). The periglacial conditions of semipermanent snow fields and numerous freeze-thaw cycles causes rocks to loosen from the cliff faces. These blocks are transported downslope by creep, solifluction, gelifluction, or a combination of these processes. After emplacement, fine materials are removed by rain and snow meltwater. When conditions favorable to the formation and downslope movement of these rock streams no longer exist, they become stable, relict features, presumably of Pleistocene age.

Mass wasting has been proposed as the general process responsible for the formation of rock streams. Rapid mass wasting processes include slab failure, rock avalanche, and rockfall. Slab failures are the common form of weathering on steep walls in hard rock. The release of lateral confining pressures permits the opening of joints which cut across geological structures or bedding planes. The result is a mass of closely fitting masonry whose strength is entirely derived from friction between blocks (Selby, 1982). Rock avalanches result when well-jointed rocks lose internal cohesion. Rockfalls are confined to the removal of individual and superficial blocks from a cliff face. Rock avalanches and rockfalls are considered to be important processes in the formation of the rock streams on Mt. Magazine and Rich Mountain. Groundwater seepage, ice crystal formation, and ice wedging contribute to the formation of separated blocks by infiltration and expansion along bedding surfaces and vertical fractures. Eventually, the collapse of large sections of the cliff occurs and forms the rock streams (Vere, 1986).

Rock streams may creep downslope or they may surge. Surging is sudden movement or an increase in the rate of movement of rock streams. Substrate movement associated with surging may create noticeable and datable changes in growth patterns of woody vegetation (Shroder, 1978; 1980). In contrast to rapid movement, rock creep involves long-term, slow deformation which is imperceptible except to observations of long duration.

Many attempts to determine if slope movement is occurring and to date movement utilizing dendrochronology and other botanical methods have been made (LaMarche, 1968; Shroder, 1978, 1980; Hupp, 1983, 1984). Dendrochronology has been used to date rock avalanches (Butler *et al.*, 1986), fault movement (Page, 1970; LaMarche and Wallace, 1972) and volcanic activity (Smiley, 1958; LaMarche and Hirschboeck, 1984). Dendrochronology is superior to the radiocarbon technique for the exact dating of young geological events in part because dendrochronological dates do not have uncertainty (expressed as "plus or minus" error parameters) associated with them (Claque *et al.*, 1982).

Many different internal and external, structural and morphological changes occur in trees because of downslope movement. Mass movement events can cause permanent changes in external tree morphology such as inclination or tilting of stems, shearing stress on roots and stems, corrasion scars or bark removal, burial of stems, exposure of roots, inundation, and denudation or the production of bare ground (Shroder, 1978). Tilting of trees is the most common morphologic change on Mt. Magazine and Rich Mountain.

Immediate environmental change is reflected in internal structure and morphology, affecting annual growth rings of trees (Shroder, 1978, 1980; Hupp, 1984). Abrupt tilting of a tree results in subsequent rings that are wide on one side of the trunk, in contrast to the opposite side where the same rings are relatively narrow. When this pattern of eccentric rings appears after years of relatively concentric ring production, the date of the onset of the eccentric growth is usually within one year of the event that caused the tilting (Hupp, 1984).

This botanical investigation of rock streams on Mt. Magazine and Rich Mountain was undertaken to determine: 1) if these rock streams are static, relict Pleistocene periglacial features or, 2) if they have moved recently or are presently moving, and, if so, what is the rate of movement (steady or surging). This investigation included observations of tree morphology along rock-stream margins, examination of selected tree cross sections, and comparison with a local tree-ring chronology.

SITE DESCRIPTION

Mt. Magazine is located in the Arkoma foreland basin in west-central

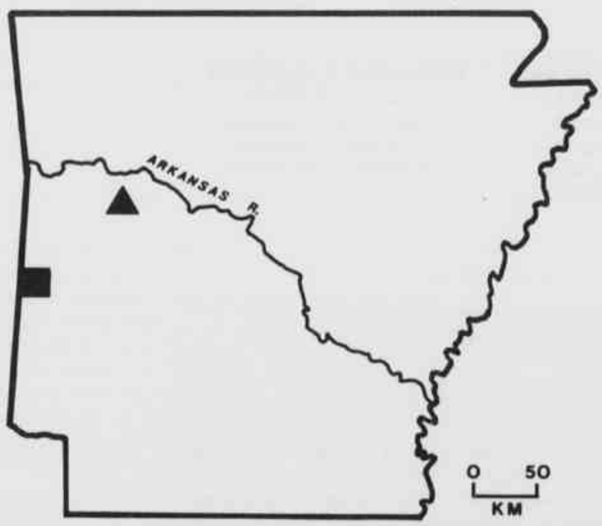

Figure 1. Map of Arkansas showing locations of rock streams studied. Triangle: Mt. Magazine; Rectangle: Rich Mountain.

Arkansas (Fig. 1). The caprock is Savanna Sandstone, a Pennsylvanian deltaic deposit. The moderately thick-bedded, gray sandstone is relatively resistant to weathering. A more or less continuous cliff up to 30 meters (m) high surrounds the uppermost slopes of the mountain (Vere, 1982). Underlying the Savanna Sandstone is the McAlester Formation, a unit that is less resistant to weathering and enables tree cover to develop on its slopes.

Below the cliff face and extending downslope for several hundred feet in some places, are numerous boulder-covered, vegetation-free surfaces (Fig. 2). These are rock streams. The largest rock stream occurs on the north side of Mt. Magazine (Vere, 1982) and is the study site.

Figure 2. Looking downslope from the cliff at the head of the Mt. Magazine rock stream. A lower section of the rock stream is in the center background, separated from the upper section by a levee-like area.

The upper and most extensive portion of the rock stream is immediately below the cliff face. It is approximately 100 m long by 100 m wide and has an average slope of 27 degrees. The lower portion of the stream is more elongate and not as wide (approximately 230 m long and 15 to 30 m wide) as the upper portion (Vere, 1982). The slope decreases to between 2 and 14 degrees.

Rich Mountain and Black Fork Mountain are located along the Arkansas-Oklahoma border in the Ouachita Mountains (Fig. 1). Both mountains are elongate, east-west trending ridges composed of the Pennsylvanian Jackfork and Stanley Formations. The Jackfork Formation includes beds of resistant, thickly-bedded, gray sandstone and easily weathered shale. The steep north-facing slope of Rich Mountain and south-facing slope of Black Fork Mountain are composed of a cliff of Jackfork Sandstone at the mountain crest underlain by the Stanley Shale, an easily weathered unit. Elongate rock streams occur beneath these cliff faces or in ravines farther down the mountain slopes.

The rock stream examined here occurs in a ravine part way down the mountain on the north-facing slope of Rich Mountain, along Oklahoma Highway 1 (Fig. 3). As seen at Mt. Magazine, forest vegetation is developed on a boulder-rich substrate on either side and above and below the rock stream. Beyond this area, normal forest vegetation is developed on a relatively boulder-free substrate.

Figure 3. Looking upslope from the toe of the Rich Mountain rock stream.

Unlike Mt. Magazine, however, normal forest vegetation is developed on a boulder-rich substrate from above the rock stream to the crest of the mountain. This vegetation includes all age classes of trees and some understory species. The block substrate has accumulated a sufficient amount of interstitial, fine-grained material to support tree growth. Also in contrast to Mt. Magazine, a cliff face is not present at the head of the ravine. However, small outcrops and abundant rubble does occur parallel to the slope near the crest of Rich Mountain, indicating a resistant bed of sandstone is present. This unit is the presumed source of the rock stream. Lobate features with lateral and terminal levees were observed in the ravine above the rock stream and may indicate that movement has occurred as debris flow (Selby, 1982).

METHODS

Field work consisted of noting the morphology of trees adjacent to the rock streams and locating trees that showed stress, such as leaning or bending. Three samples were taken for laboratory analysis. The trees selected were bent at least twice and were not over 10 centimeters (cm) in diameter. One sample was taken on Mt. Magazine and the other two samples were taken on Rich Mountain. Finally, tree diameters at 1.6 m height were measured at three sites adjacent to the rock stream on Rich Mountain. Each measurement was taken within a plot having approximately a 6.0 m radius.

Laboratory work consisted of sample preparation, species identification, and tree-ring analysis. The stem cross sections were sanded to a smooth finish with consecutively finer grades of sandpaper, starting at 120 grit and finishing with 400 grit. The genus and species, where possible, were identified by wood anatomy (Panshin and de Zeeuw, 1970) and bud and bark morphology (Harlow *et al.*, 1979). The tree rings were examined with a binocular microscope at 7 to 30X magnification in the Tree-Ring Laboratory of the Geography Department, University of Arkansas, Fayetteville. Ring boundaries were marked; rings were counted; and ring widths were measured using a computerized tree-ring measurement system (Robinson and Evans, 1980). This data was compared to the standard tree-ring index chronology for white oak *(Quercus alba)* from Black Fork Mountain, Arkansas (Stahle *et al.*, 1985) for crossdating purposes (Stokes and Smiley, 1968).

RESULTS

Tilting of trees is the most common morphologic change seen in trees on Mt. Magazine and Rich Mountain. Tilting is recorded in tree growth by eccentric ring development, by the production of anatomically distinct reaction wood on the upper side of hardwoods, and by bent trunks (Fig. 4) as the tree subsequently grows upright again (Shroder, 1978). Single abrupt inclination events generally produce easily dated changes in ring growth. Gradual or long-term multiple inclinations produce compound trunk curvature as well as complex reaction wood which may be very difficult to date (Shroder, 1978).

Figure 4. A bent tree (foreground) growing near the bottom of the upper section of the Mt. Magazine rock stream.

A bent holly tree (*Ilex* sp.) was sampled on the western margin of the upper portion of the Mt. Magazine rock stream. The cross section of the sample has concentric rings for the first two years, followed by very eccentric rings (Fig. 5). This could be caused by the tilt evident near the base of the trunk. The eccentric growth occurs along at least

Figure 5. Cross section of holly tree sampled at Mt. Magazine. Note highly eccentric growth along several axes, indicating several episodes of tilting in different directions. The wood belongs to the diffuse-porous group. Each division of the scale is 1.0 cm.

two different axes, indicating that the tree was tilted in at least two directions at different times. The rings become very eccentric and very difficult to distinguish in the outer five rings of tree growth. This might be attributed to competition from surrounding trees or trauma affecting the root system. Several abrupt reductions in growth (Fig. 6) suggest that other traumas occurred and one may be recorded by the second bend in the tree.

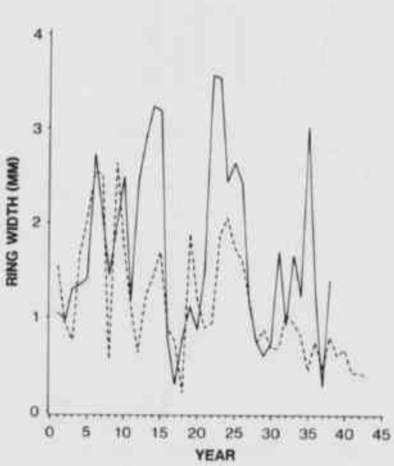

Figure 6. Radial measurements of the holly sample from Mt. Magazine along two lines marked in Fig. 5. Some of the outer rings are missing on one radius.

The cross section of black locust *(Robinia pseudoacacia)* collected at site D at the toe of the rock stream on Rich Mountain has concentric rings the first two years, followed by eccentric rings (Fig. 7). This change in growth, as well as a bend near the base of the tree, may have been caused by tilting. The cambium has died at one point on the radius (Fig. 7), evidence of corrasion or impact injury at that point. As a possible consequence of this trauma, ring 13 and subsequent rings (Fig. 8) are very small and discontinuous around the circumference of the stem.

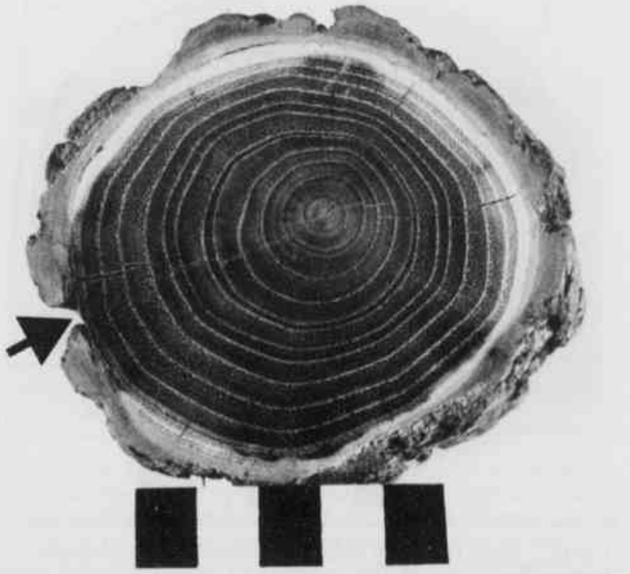

Figure 7. Cross section of the black locust sampled at site C on Rich Mountain. This tree has ring-porous wood. Note the cambial wound (arrow) indicating direct trauma to the tree severe enough to destroy the cambium at that point. Each division on the scale is 1.0 cm.

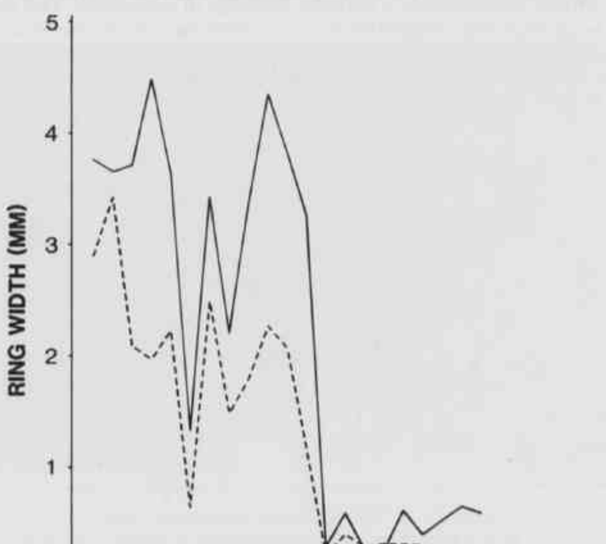

Figure 8. Radial measurements of the black locust sample from Rich Mountain. The abrupt reduction in growth at ring 13 may reflect the cambial injury seen on the cross section (Fig. 7). Some of the outer rings are missing from one radius.

The cross section of the persimmon tree *(Diospyros virginiana)* collected at site B on the western edge of the Rich Mountain rock stream formed concentric rings the first seven years, followed by somewhat eccentric rings (Fig. 9). Ring 8 has a dark layer that could be evidence of trauma. An abnormally abrupt reduction in growth after the fifth ring (Fig. 10) may be associated with tilting or injury. This trauma may also be recorded as a bend near the base of the tree that is the result of tilting. The last rings were very difficult to distinguish because growth was extremely slow, possibly a sign of injury.

Figure 9. Cross section of the persimmon sampled at site B. This tree has semi-ring-porous wood. Each division of the scale is 1.0 cm.

Tilted trees are common on the vegetated, boulder-rich margins of the rock streams of both Mt. Magazine and Rich Mountain. Most of the trees on Mt. Magazine are leaning or bent, some several times. One tree, noted but not sampled, had eight bends. These bends are evidence of catastrophic tilting and subsequent renewed vertical growth. It is possible that the pervasive malformation could result from snow and frost damage. However, drastically malformed trees appear to occur more frequently in the vicinity of the rock streams, an argument for downslope movement of these materials.

In contrast to Mt. Magazine, a large portion of the vegetated, boulder-rich surface above the rock stream on Rich Mountain supports normal forest vegetation. It remains unclear why some portions of rock streams accumulate deposits of fine-grained materials adequate to support vegetation. Boulder size and age of the deposit may be two contributing factors. The forest on Rich Mountain consists of a wide range of stem sizes and ages, while Mt. Magazine appears to have only smaller and/or younger trees. Some of the oak trees on Rich Mountain resemble the oaks sampled on Black Fork Mountain that attain ages of 300 years or more (Stahle *et al.,* 1985). All age classes, including the oldest,

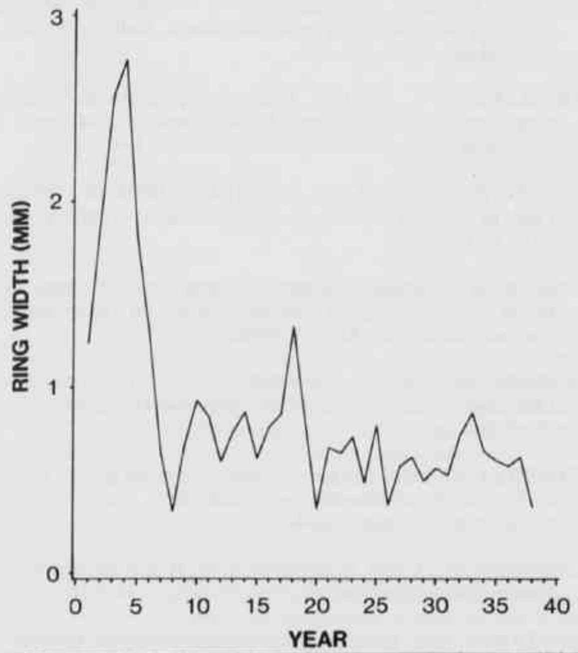

Figure 10. Radial measurement of the persimmon sample (Fig. 9) from Rich Mountain.

Figure 11. Several of the bent trees growing in the area above the Rich Mountain rock stream.

exhibit external morphological characteristics (Fig. 11) associated with an unstable substrate, such as abrupt bends in their stems (Shroder, 1978, 1980).

Quantitative measurements of tree diameter at three sites on the lateral margins of the lowest part of the Rich Mountain rock stream demonstrate a dominance of smaller trees (Table 1) with a greater abun-

Percent of Trees in Diameter Classes

Site	Diameter Classes (Cm) 2-8	9-15	16-25	26-33	34-40	41-60	No. Trees Measured
B	33	17	25	8	17	0	12
C	34	28	14	10	7	7	29
D	55	41	0	4	0	0	22

Table 1. Frequency of diameter classes of trees at three sites on the margin of the Rich Mountain rock stream. The classes were adjusted from even widths on the basis of apparent natural break points in the distribution.

dance of small trees near the toe of the rock stream at Site D (Fig. 12). Somewhat larger trees occur at sites B and C (about 20 m west of site B), higher on the lateral margins of the rock stream than site D. This suggests that the site at the toe of the rock stream is exposed to more

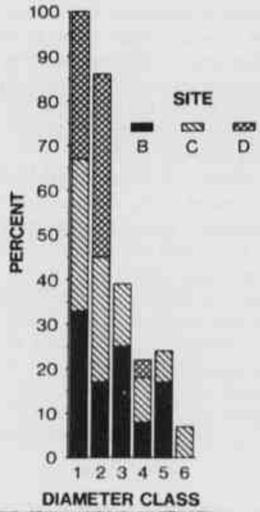

Figure 12. Graph of the trees in different diameter classes at sites B, C, and D. The classes are as shown in Table 1.

stressful conditions, or the trees are younger, while sites higher on the lateral margins of the rock stream are subject to less growth stress, or those trees attain greater ages.

Trees sampled on Rich Mountain in this study were compared to a white oak *(Quercus alba)* tree-ring chronology compiled by Stahle *et al.* (1985) from trees on nearby Black Fork Mountain, Arkansas. Because the trees examined in this study are young, and show highly variable growth patterns that seem to be influenced more by site disturbance than by climate, crossdating, *i.e.,* the matching of climatically controlled growth patterns (Stokes and Smiley, 1968), is extremely difficult. In addition, growth of the outer rings in all three samples is so suppressed that there are missing rings, rendering any one-to-one match impossible.

CONCLUSIONS

Rock streams exist on some mountains in Arkansas and Oklahoma where a relatively resistant, massive sandstone unit forms a cliff face above a less resistant shale unit. These rock streams are elongate bodies of coarse sandstone blocks commonly oriented approximately parallel to the slope. These blocks are derived from the cliff of resistant sandstone by mass wasting. The rock streams are similar to active features in alpine areas (White, 1976), and therefore have been considered to be relict features formed in a periglacial regime during the Pleistocene (Stone and McFarland, 1979).

There is botanical evidence for movement of the rock streams in approximately the past century. The central portion of the rock streams does not support vegetation because insufficient fine-grained material has accumulated. The botanical evidence is collected from the margins where vegetation is present. Tree growth in this area may also result from less frequent and violent mass movement compared to the central portion of the rock stream.

The evidence for rock stream movement during the life span of a tree includes external tree morphology, eccentric annual ring formation, and corrasion of the bark and cambium, resulting in abnormal ring formation or cambial death. Tree morphology on Mt. Magazine suggests that slope materials along the rock stream margins at this site are not stable and movement downslope occurs catastrophically or in surges. Many trees have multiple bends and a large number of trees are affected, although most do not attain a diameter greater than 15 cm. In contrast, the upper margin of the Rich Mountain rock stream has many mature trees. The presence of fine-grained materials upslope of the rock stream may facilitate movement as debris flows. Many of the trees above and along the lateral margins of the rock stream show morphologic evidence of movement. Therefore, slope materials at this site have moved relatively recently.

Cross sections of selected bent trees at both sites support the hypothesis of unstable slopes. All three samples examined have eccentric tree rings. These result from tilting, probably caused by active slope movement. One sample also exibits evidence of mechanical damage to the stem, probably the result of direct damage to the stem and/or root system of the tree by moving rocks.

This study demonstrates that botanical evidence can substantiate, and potentially date, movement along the margins of rock streams. These data support the hypothesis that Holocene movement occurs and that the rock streams are not stable relict features. Further study and many more samples (Butler *et al.*, 1987) are needed to accurately date the downslope movement, to determine if movement within and among the rock streams are synchronous or are isolated and sporadic events, and to establish the recurrence interval. Trees at the margins of the rock streams should be compared to trees growing in the areas between rock streams where the predominant mass-movement mechanism is creep. These more stable trees can be used to construct a tree-ring chronology and accurately date movements on the adjacent rock streams.

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FUR TRADE RECORDS FROM ARKANSAS FACTORY, ARKANSAS POST, LOUISIANA TERRITORY, 1805-1810

PAUL J. POLECHLA, JR.[1]
Zoology Department
University of Arkansas
Fayetteville, AR 72701

ABSTRACT

The United States government established a trading house at Arkansas Post in 1805 on the north bank of the Arkansas River in the newly purchased Louisiana Territory. The goal of this trading house was to foster good relations with the Quapaw tribe and other indigenous peoples. John B. Treat and his successors operated the post and meticulously recorded the number, value, and species of pelts traded. Tabulation of these records, which have been preserved in the National Archives, revealed that 9 or 10 species contributed a total of about 44,000 hides, worth approximately $18,000. White-tailed deer *(Odocoileus virginianus)* pelts comprised the largest volume and percentage (83%) of the total value of the fur harvest, and black bear *(Ursus americanus)* was second largest in both categories. Because these two species were also prized for their meat and lard, they were primary targets of hunters. Although the river otter *(Lutra canadensis)* and beaver *(Castor canadensis)* compromised only a small fraction of the total fur harvest, their pelts brought the highest prices. The raccoon *(Procyon lotor)* had one of the lowest-priced pelts, but more of its pelts were harvested than for the otter and beaver combined. Bobcat *(Lynx rufus)*, fox *(Urocyon cinereoargenteus* and/or *Vulpes vulpes)*, mountain lion *(Felis concolor)*, and red wolf *(Canis rufus)* made up the remainder of the total harvest. Competition from private entrepreneurs, political opposition, and a slump in the international fur market forced the Arkansas Post to liquidate its assets and close in 1810. The lesson from this period underscores the needs to properly handle furs, limit harvest season, and establish stable fur markets.

INTRODUCTION

Many lessons can be learned about the management of furbearing game mammals by examining early fur trade records. The North American continent in general and Arkansas in particular have a rich heritage of fur trade, commemorated by such authors as Phillips (1916) and Hafen (1982). Much of the fur trade literature focuses on the James Bay, Hudson Bay, Great Lakes, Rocky Mountains, and Pacific Coast regions (Phillips, 1961; Hafen 1982; Francis and Morantz, 1983). Occasionally a few authors (Lewis *et al.*, 1807; Arthur, 1982; Lowery, 1974; Foley and Rice, 1983) address the role of the south-central United States in the fur trade. Information on the fur trade in Arkansas, however is limited to a few basic, but interesting, accounts (Holder, 1951; Johnson, 1957; Sealander, 1979; Dickinson, 1985; Golden, 1985). The importance of Arkansas Post to the early fur trade of the region is well known, but Arkansas Post is mentioned only in passing in chronologies of mammals of the region.

After the establishment of a fur trading post by Henri De Tontis' followers near the confluence of the White, Arkansas, and Mississippi rivers, the dominion of the region was transferred from the French (Faye, 1943), to the Spanish (Faye, 1944), and back to the French (Mitchell and Calhoun, 1937). Beginning in 1796, the newly established United States government established official fur trading outposts, called "Factories." After the U.S. government purchased the Louisiana Territory from France in 1803, several Factories were established in the new territory.

The political ideology of the reigning administration was that a good trade rapport with Indian tribes would allow for safe infiltration by a burgeoning American populace into the ancestral home of the native Indians. An officially sanctioned government Factory, called the Arkansas Factory, was established.

Although much has been published on the political and socioeconomic history of Arkansas Post (Plaisance, 1952; Johnson, 1957; Bearass and Brown, 1971), no thorough analysis or compilation of Arkansas Factory fur harvest has been published. The purpose of the present study is to determine the characteristics and faunal composition of the fur trade records of the Arkansas Factory, Arkansas Post, Louisiana Territory, *circa* 1805-1810 and the factors effecting it.

MATERIALS AND METHODS

I examined the National Archives Microfilm Publication's Microcopy No. 142, entitled "Records of the Bureau of Indian Affairs, Record Group 75; Records of the Office of Indian Trade; Arkansas Factory." The number of pelts of each species of fur-bearing mammal were tabulated from the "Journal." The common and scientific names of mammals of Sealander (1979) were used. The number of pelts was cross-tabulated with the "Ledger and Invoice Book" and the "Letter Book." The sources cited in the introduction were used to supplement the interpretation of the fur harvest.

RESULTS

Tabulation of the trade records from 1805 to 1810 revealed that nine or ten species contributed a total of 23,001 hides, valued at $18,158.40 (Table 1). White-tailed deer *(Odocoileus virginianus)* pelts comprised the largest percentage of the total volume (89.03%) and value (82.86%). There were 122 fawn and 20,356 adult deer pelts, made up of 17,652 "shaved" pelts (i.e., with hair removed) and 2,704 "unshaved" pelts. Black bear *(Ursus americanus)* pelts ranked second in percentage of total volume (5.46%) and value (8.91%). The remaining species each had 3% of the total volume of pelts and 4% of the total value.

Although the river otter *(Lutra canadensis)* and beaver *(Castor canadensis)* comprised only a small percentage of the total volume (1.20% and 1.13%, respectively) and value (3.66% and 3.77%, respectively), these pelts brought the highest price per skin ($2.56 and $2.48, respectively). The raccoon *(Procyon lotor)* had one of the lowest-priced pelt values ($0.19), but more of its pelts were recorded than for the otter and beaver combined.

Bobcat *(Lynx rufus)*, fox *(Urocyon cinereoargenteus* and/or *Vulpes*

[1]Current address: Department of Life Sciences, Eastern New Mexico University, Portales, NM 88130.

Table 1. Volume and value of pelts traded at Arkansas Factory, Arkansas Post, Louisiana Territory between 1805-1810 (data from National Archives).

Common Name	Species	No. of Skins	Price/ Skin	Lbs. of Skins†	Price/ Lb.†	Total Value	
White-tailed Deer (Total)	Odocoileus virginianus	20,478	$0.73	45,158	$0.33	82.86%	$15,045.40
White-tailed Deer (Hair Shaved)	Odocoileus virginianus	17,652	0.75	37,177	0.35	---	13,169.43
White-tailed Deer (Hair Unshaved)	Odocoileus virginianus	2,704	0.68	7,981	0.23	---	1,848.27
White-tailed Deer (Fawn)	Odocoileus virginianus	122	0.23	---	---	---	27.70
Black Bear	Ursus americanus	1,257	1.29	---	---	8.91	1,617.50
Beaver	Castor canadensis	276	2.48	571	1.20	3.77	685.25
River Otter	Lutra canadensis	260	2.56	---	---	3.66	664.50
Raccoon	Procyon lotor	620	0.19	---	---	0.67	120.80
Bobcat	Lynx rufus	56	0.19	---	---	0.06	10.55
Fox (Grey or Red)	Vulpes or Urocyon	43	0.21	---	---	0.05	8.90
Mountain Lion (Panther)	Felis concolor	9	0.50	---	---	0.02	4.50
Red Wolf	Canis niger	2	0.50	---	---	0.01	1.00
GRAND TOTAL		23,001					$18,158.40

* Expressed in French weight.
1.0 French lb. = 1.079 English lb. = 0.490 kg.

vulpes), mountain lion *(Felis concolor),* and "wolf" pelts are probably assignable to the red wolf *(Canis niger)* and not to the coyote *(Canis latrans),* sometimes referred to as the "prairie wolf" (Gipson, Sealander, and Dunn, 1974).

Skins of adult deer and beaver were weighed in French pounds (1 French lb = 1.07 English lb = 0.49 Kg), a custom left over from the earlier period of French dominion. An average shaved skin weighed 1.032 Kg per skin (n = 17,652), whereas an average unshaved deer skin weighed 1.446 kg (n = 2,704). A bear skin weighed an average of 1.014 kg (n = 276). All other pelts were graded by quality and size and were purchased by the skin.

DISCUSSION

There are several explanations for the characteristics of the trade at the Arkansas Factory. Deer and bear pelts comprised the largest percentages of total volume and value. Because these two species were also prized for their meat and lard (Johnson, 1957), as well as for their pelts, they were primary targets of hunters. Venison and bear meat were staple fare of the early Arkansas diet (Schoolcraft, 1821). Rendered bear lard, called manteca (Spanish for butter), was sought after because it did not turn rancid like other oils used for cooking (Holder, 1951; Dickinson, 1985). Manteca was traded through private enterprises (Holder, 1951) and not through the Arkansas Factory. The fat from each prime bear could produce up to 25 gallons of oil, worth $20 (Johnson, 1957). Most deer pelts were shaved to remove lard and were tanned for leather articles (Phillips, 1961). Unshaved deer and bear hides were in demand for robes and for bed and floor coverings (Phillips, 1961).

In the colder climates of higher latitudes and altitudes, beavers developed longer, denser, and more lustrous fur. The pelts with darker shades of brown commanded the highest market price for European hats (Arthur, 1928; Sandoz, 1964) rather than the straw-colored pelts of the southern beavers. Therefore pelts from the region were in low commercial demand compared with the northern and Rocky Mountain beaver (Phillips, 1961). Beavers were also trapped for their castor gland, for making perfume, and for their flesh and tails, which were roasted (Schoolcraft, 1821; Peterson, 1914). In spite of the color, the price per southern beaver pelt was higher than other pelts trapped in the area, except for otter. Otter pelts commanded the highest price per pelt on the Arkansas Factory market due to the superior durability and density of the pelage (Polechla, 1987). Otter pelts were fashioned into robes and other garments.

Several other furbearing species are known to have occurred in the region, but were noticeably absent from the Arkansas Factory trade. They include the muskrat *(Ondatra zibethicus),* elk *(Cervus elephus),* and buffalo *(Bison bison).* (Holder, 1951; Sealander, 1979). These species were occasionally traded in 1822 at Spadre Factory, Arkansas Territory (Johnson, 1957). However, elk and bison were not numerous in the region, and muskrat pelts were not in high demand on the European market a that time (Peterson, 1914; Phillips, 1961). Similarly, there was no market for mink *(Mustela vison)* from the region (Holder, 1951). These facts seem to explain the absence of these species from the Arkansas Factory trade record.

Examination of months of Arkansas Factory transactions show that over 50% of the hides were traded during the late spring, summer, and early fall months and stored until shipment. These records also indicate that young mammals (e.g., cubs and fawns), as well as adults, were killed and traded, demonstrating that there was a year-round harvest of some species. Seton (1929) noted that beaver were also taken throughout the year.

Joseph Saul, a U.S. government trading agent in New Orleans who received furs from the Arkansas Factory, was very critical of Factor John Treat's policy of keeping furs during the warm seasons:

> The United States will loose considerably by damaged skins this season....It is pretty universal....to order their agents never to ship skins for this Market later than from the 1st or 10th of April, which will arrive in May, after which all shipments from this post are at an end....We have no convenience to keep them over the Season, and the price falls too low to sell.

The factory's operation depended upon a unique association of rugged individuals. *Couriers de bois* (French for runners of the woods), were a combination of trappers, hunters, and traders, who travelled up the tributaries of the White and Arkansas rivers and the Delta bayous. Equipped with supplies advanced on credit, the couriers traded with natives for furs and collected their own. Although the bulk of the Arkansas Post trade was with the Quapaw and Osage, other Indian people, such as the Delaware, Shawnee, Cherokee, and Choctaw tribes, traded with the engages (Johnson, 1957). Chickasaw and Creek crossed the Mississippi, hunted, and probably traded in present-day Arkansas.

The Indians usually used snares, dead falls, and bows and arrows to capture their quarry (Swanton, 1946), whereas white hunter-trappers of that era used homemade, long-spring, steel-jawed traps and flintlock riffles to capture game. The harvested animals were skinned and their pelts dired as thoroughly as possible. When the couriers had a canoe load of pelts, they floated downstream until they reached Arkansas Post. It was here that the Factor graded the furs according to quality and size and traded merchandise for them. Manufactured goods, including rifles, hunting supplies, knives, kitchen utensils, cloth, equestrian gear, and an assortment of beads and trinkets, were shipped from Pittsburgh down the Ohio River to the Mississippi River and then to Arkansas Post. The last leg of the journey was routed through the White River Cutoff or up the Arkansas River at its confluence to the Mississippi River. A typical transaction included a multitude of trade items.

As described by John B. Treat, pelts were stored in an existing, rented "House for the Factory...about 30 feet by 15, containing two rooms, and those raised six feet from the ground, the under part being perfectly close, with square Timber, being occupied as a Skin House, it being dark and cook, and therefore well adapted to that purpose." Because rent for the skin house was expensive, Factor Treat planned to build a new one. A drought during a crucial period of construction prevented the lumber from being floated from the dense swamp to the building site. The high cost of skilled carpentry labor and a low project budget caused construction to proceed at a slow pace. The much needed new "Store House and Skin Room" was completed in 1810 (the year the Factory closed) not in time to be used for government factories.

While in storage, the hides often became damaged by "worms", probably the larvae of beetles (Dermestidae) or moths (Tineidae) Borror, DeLong, and Triplehorn, 1976). Traditionally, Indians stored a dried bird, such as a "martin" (Hirundinidae) or "fisher" *(Ceryle alsyon)* with the hides to supposedly repel the insect larvae (Swanton, 1946).

After a number of hides had been collected, they were bailed together in packs. The Factor hired boatmen to take the fur cargo on a flat-bottom barge down the Arkansas and Mississippi Rivers to government agents in New Orleans. Enroute pelts were often damaged due to the vagaries of the arduous passage. The only available boats often leaked. Torrential rains and water that seeped through cracks in bilges soaked the uncovered pelts and caused them to decay. Joseph Saul, New Orleans government agent, strongly advised the traders to wrap the pelts with bear-skin tarpaulins (inside out to protect the pelts from water and insect damage) because "the last eleven packs...were nearly all spoiled." Damaged pelts were salvaged at a mere 2.5 cents per pound for glue.

Undamaged pelts were sold through public auction or other means. Government agents collected the proceeds to be used to defray costs of the War Department. Buyers loaded their furs onto sea-going vessels and shipped them to New York for tanning and to London for garment manufacturing, sales, and distribution (Phillips, 1961).

Despite the hardships, Factor John Treat was optimistic during the first couple of years of the Factory's operation. In the spring of 1806, the total shipment of furs from the entire settlement of Arkansas Post was 975 packs of fur, of which the Arkansas Factory shipped 61 packs. Bright and Morgen, the dominant private fur-trading company, shipped 267 packs that same spring. Arkansas Factory was ranked fourth of 15 trading interests. The second leading interest traded a little more than 100 packs in that season.

In 1807, Arkansas Factory hauled its highest volume of pelts. From that time on, Factory trade declined. Stiff competition came from French, British (e.g., Michilimackinac and John Forbes and Co.), and Spanish trading companies of the Mississippi and Gulf Coast Region, in addition to the legal and illegal private American entrepreneurs (Phillips, 1961). The bulk of the Osage tribe fur trade, which annually amounted to $20,000 (Lewis *et al.*, 1807), went to the merchants of St. Louis, such as Manuel Lisa (of Spanish and Indian descent), August and Pierre (Sr.) Choutaeu (of French descent), and William S. Williams (of American descent) (Hafen, 1982; Foley and Rice, 1983). Fur trade historians (Phillips, 1961) have suspected that competitors of Arkansas Factory received the valuable furs, such as bear, beaver, and otter, and Arkansas Factory competed only for the less valuable deer skins. The modest success of Arkansas Factory was further eroded by European socioeconomic conditions, which created a glut of deer skins on the market (Phillips, 1961).

Other negative influences, in addition to the poor fur handling practices, have been blamed for the downfall of the Factory. The first two Factors suffered from ill health (attributed to the inhospitable climate) and had to be replaced. Treat became ill and was replaced in September, 1808, by James Waterman. The unseasonably cold winter that year severely restricted mobility, trapping, and trading. In July 1810, Waterman grew ill and was replaced by Samuel Treat, the brother of John Treat. The unseasonably cold winter of 1808 severely restricted mobility, trapping, and trading. Because all U.S. Factories were under the supervision of the War Department, stationed in distant Philadelphia and New Orleans, letter communication and cargo transportation was exceedingly slow to the frontier trading posts.

The decline was also due to government mismanagement. At first, the private Bright and Morgan Company was given a monopoly on the private Arkansas Post fur trade. Factor Treat realized that this was detrimental to the government's interests, but the War Department erroneously encouraged Treat to license more private traders, further hampering Arkansas Factory's commercial success. The existing trade regulations prohibiting illicit trade could not be enforced by the small number of troops stationed at Arkansas Post (Plaisance, 1952). Private traders actively lobbied on the local, regional, and national levels against a potential government fur-trade monopoly.

When the Factors attempted to expand their trade, the War Department effectively stifled the innovations. Treat reported that he had sent a party of five traders to an encampment of Cherokee and Delaware people at the confluence of the Black and White Rivers. John Shee, Superintendent of Indian Trade, War Department, Wrote to Treat, cautioning him against future unsanctioned enterprises such as that. When the Osage tribe requested that Treat establish a post north of the Arkansas River among their camps, Treat declined the offer and wrote, in 1808, to John Mason, who had replaced Shee as superintendent, "It might appear improper for my being any further troublesome [sic] on a subject offering so great advantage to the whole Establishment of Indian Trade as he has already at different times been pointed out."

On September 1, 1910, Samuel Treat received a letter from Mason ordering him to close Arkansas Factory and liquidate its assets. Although Arkansas Factory, Arkansas Post, Louisiana Territory, was short lived (1805-1810), it did allow for infiltration of American colonists into the region.

CONCLUSIONS

The history of Arkansas furbears from 1805 to 1810 directly relates to current furbears management in Arkansas. The knowledge gained from this historical analysis should be applied to present situations and the mismanagement not repeated. Unrestricted year-round harvest and removal of young and adult mammals may significantly reduce Arkansas furbearer populations. Improper fur handling (i.e., subjecting hides to elements and insects) and keeping raw hides during warm months results in low quality and market price. Extreme fluctuations in fur supply and demand should be avoided by establishing a stable market.

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PHYSIOGRAPHY AND HYDROLOGY OF THE UPPER SALINE RIVER, SALINE AND GARLAND COUNTIES, ARKANSAS

JOHN D. RICKETT
Biology Department
University of Arkansas at Little Rock
Little Rock, AR 72204

ABSTRACT

The Saline River is one of two significant river systems in Arkansas that does not have a major impoundment. In the interest of continuing this status, this project was conducted. Thirty-five sites on the four major and six minor tributaries of the upper saline River, Saline and Garland Counties, Arkansas, were visited a total of 58 times between 24 January 1985 and 21 November 1986. Habitat quality was assessed by measuring twelve physicochemical features and flow parameters, analyzing substrate composition and describing stream morphometry. Physicochemical measurements were within the limits of good quality habitat, and most of the readings were quite low. Representative sites on the four major tributaries had pool/riffle ratios between 1.1 and 2.9, whereas a comparison site on the Saline main stem downstream from Benton had a ratio of 4.1. Lower ratios represent a nearly equal length of pool vs. riffle thus offering an optimum number of niches for occupation by a stable ratio of forage to predatory fish species. There was a wide variety of refugia within the habitat for the temporary escape and protection of forage species, but some sites lacked such refugia for the Ouachita madtom because sand and silt had settled into the substrate interstices. Substrate composition was highly variable. Riffles contained pieces of many sizes from sand to large rock (up to 30 cm dia.). Average percent in each size group were >17mm = 58% (range 0-90), 6.3-16mm = 24% (range 0-60), 1.0-6.2mm = 9.4% (range 0-50), 0.5-0.9mm = 3.5% (range 0-10), <0.5mm = 2.4% (range 0-7) and other = 3.7%. Pools usually contained areas of sand, leaf/detritus beds, bedrock or slabrock and rock. Average stream flow parameters were depth = 0.253m (range 0.04-0.55), velocity = 0.557m/s (range 0.16-1.01), width = 9.486m (range 2.0-32) and discharge (Q) = 1.34cms (range 0.042-5.28). Upper reaches of the stream were well shaded with steamside vegetation including sweet gum, black willow, willow oak, water oak, sycamore, blackgum, river birch, buttonbush and alder. Lower reaches were less shaded. By early September many stream channels were somewhat choked with water willow, and abundant algae grew in the shallower pool areas.

INTRODUCTION

The upper Saline River is comprised of four main tributaries that begin in western Saline County and eastern Garland County. It is one of two major rivers in Arkansas that does not have a major impoundment. Several studies of a specific nature have been conducted in this area, but none have attempted to pull a variety of information together and identify attributes that would specifically favor its preservation. Holistic description of the upper Saline River is not attempted in this paper, but perhaps it will be a beginning.

Numerous fish collections have been made in the area, resulting in or contributing to the description of new species, populations deserving of special concern or unique or interesting community structure. Birdsong and Knapp (1969) described the creole darter *(Etheostoma collettei)* as occurring over much of southern Arkansas and northern Louisiana, but the Saline River seems to be its region of greatest abundance. Taylor (1969) described the Ouachita madtom *(Noturus lachneri)* as an endemic species from a few specimens taken entirely within the upper Saline River system. Robison (1974) listed the Saline River as one of the few locations for both the taillight shiner *(Notropis maculatus)* and the colorless shiner *Notropis perpallidus)*.

This paper describes, in a general way, the major physicochemical, hydrological and watershed features and attempts to relate these to the needs of the fish and benthic communities and possible recreational use. More detailed and lengthy study is needed to fully characterize the river, its hydrology and watershed and its biotic community.

DESCRIPTION OF THE AREA

The watershed from which the Saline River arises includes 1391 km² of pine-hardwood forest, some clear-cut areas and areas influenced by man, such as stock farming, light industry and limited housing development. The four major tributaries comprises 354 km of waterway (Figure 1). For purposes of comparing the tributaries, the confluence of the

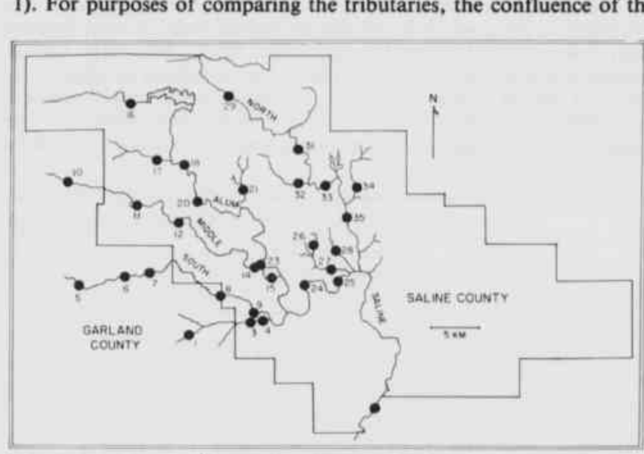

Figure 1. Collecting sites for physiography and hyrology data on the upper Saline River system, Saline and Garland Counties, Arkansas, 1985-86.

Alum and Middle Forks is considered to be the beginning of the Saline River proper, and second-order status is assigned to the four main tributaries because of their habitat similarities. The Alum Fork is longest and drains the largest area, followed by the North Fork (Figure 2, Table

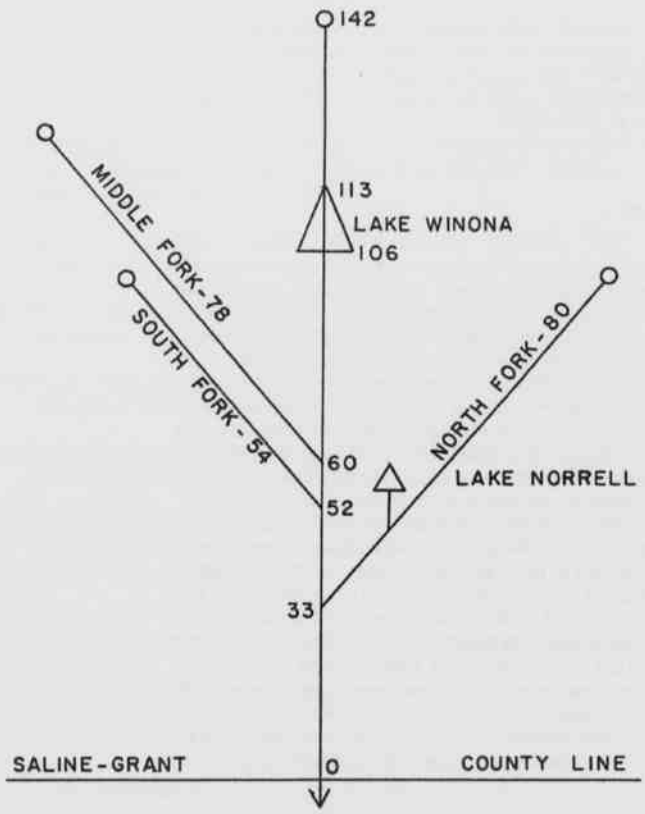

Figure 2. Schematic diagram with distance relationships of the four major tributaries of the upper Saline River system, Saline and Garland Counties, Arkansas.

1). Minor tributaries are assigned first-order status except Williams and Moccasin Creeks, which technically are second-order streams because they connect to the third-order Saline River, but their habitat characteristics are more similar to the first-order streams sampled. Lake Winona, far up on the Alum Fork, is a 555 ha water supply reservoir

Table 1. Upper Saline River drainage areas and tributary length by county.

Counties	Saline	Garland	Perry	Pulaski	Total
DRAINAGE AREA (km^2)					
North Fork	353	--	2.6	5.1	361
Middle Fork	133	138	2.6	--	274
South Fork	105	220	--	--	325
Alum Fork	428	2.6	--	--	431
TRIBUTARY LENGTH (km)					
North Fork	80	--	--	--	80
Middle Fork	52	26	--	--	78
South Fork	27	27	--	--	54
Alum Fork	130	12	--	--	142

for Little Rock, whereas Lake Norrell is a 167 ha water reservoir for Benton and is located on Brushy Creek, a small tributary of the North Fork. Although these impoundments may act as filters for migrating fish (e.g. darters), their effects should be very local within the watershed.

MATERIALS AND METHODS

Data collections were made during 58 visits to 30 sites (Figure 1, Table 2). Physicochemical tests were done on site with a HACH DR/EL analysis kit (Hach Chemical Co., Ames, IA), which are based on pro-

Table 2. Physiographic and hydrologic data collecting sites in the upper Saline River system, Saline and Garland Counties, Arkansas, 1985-86.

Site	Location	Date(s)[a]
1	Ten Mile Creek, T2S,R17W,S29	(86)5/13,10/3
3	Ten Mile Creek, T2S,R16W,S19	(85)1/24;(86)9/19
4	Ten Mile Creek, T2S,R16W,S19-20	(86)3/12
5	South Fork, T1S,R19W,S35	(86)8/29
6	South Fork, T2S,R18W,S5	(86)5/22
7	South Fork, T1S,R18W,S34	(85)2/28
8	South Fork, T2S,R18W,S3	(86)9/26
9	South Fork, T2S,R16W,S18	(86)5/30,8/2,9/19
10	Middle Fork, T1N,R19W,S28	(86)5/16
11	Middle Fork, T1S,R18W,S3	(85)2/28,8/2
12	Middle Fork, T1S,R17W,S21	(85)6/13;(86)5/29
14	Middle Fork, T1S,R16W,S30	(86)6/24,8/2
15	Middle Fork, T1S,R16W,S32	(86)11/21
16	Alum Fork, T2N,R18W,S29	(85)5/17,6/29;(86)6/17
17	Little Alum Fork, T1N,R18W,S13	(86)5/14,8/22
18	Alum Fork, T1N,R17W,S18	(85)3/7,11/6;(86)1/31,2/28, 4/11,6/20,8/22
20	Alum Fork, T1N,R17W,S29	(85)4/18;(86)9/5
21	Lee Creek, T1N,R17W,S25	(85)4/18
23	Alum Fork, T1S,R16W,S30	(86)6/24,8/2,11/21
24	Alum Fork, T2S,R16W,S2	(85)5/16;(86)7/3,8/1
25	Alum Fork, T2S,R15W,S6	(86)9/12
26	Williams Creek, T1S,R16W,S23	(86)6/12
27	Williams Creek, T1S,R15W,S30	(85)3/14
28	Moccasin Creek, T1S,R15W,S19	(85)3/27
29	North Fork, T2N,R17W,S16	(85)3/7
31	North Fork, T1N,R16W,S10	(86)5/27
32	Dog Creek, T1N,R16W,S27	(85)3/27
33	North Fork, T1N,R16W,S25	(86)10/17
34	Caney Creek, T1N,R15W,S28	(85)3/14
35	North Fork, T1S,R15W,S8	(85)5/10,10/25;(86)1/17, 2/18,4/1,4/24,5/22,8/8

[a]Pattern for dates: (year)month/day.

cedures in Standard Methods (Rand *et al.*, 1976). Following is a list of specific methods used for the tests: pH—colorimetric-spectrophotometric method; turbidity—spectrophotometric method; D.O.—Winkler-azide titration method; total hardness—ManVer II titration method; total alkalinity—titration method; O-phosphate— ascorbic acid method; nitrate-nitrogen—cadmium reduction method; nitrite-nitrogen—diazotization method; sulfate—SulfaVer IV titration method; and iron—1,10-phenathroline method. Substrate was analyzed by shaking scoops of material through a graded sieve set and measuring the volume of each size category by displacement. Stream velocity was measured with a General Oceanics Model 2031 flowmeter, whereas other morphometric features were recorded by measurement and observation. Stream discharge (Q) was calculated with the formula Q = dwv (mean depth × width *x* mean velocity) (Reid and Wood, 1976:75). Pool morphology (length, mean width and mean depth) was measured to determine the pool residence time, whereas respective lengths of pools and riffles were used to calculate the pool/riffle ratio. The division between pool and riffle was arbitrarily set at the point where velocity was less than 0.05 m/s.

RESULTS AND DISCUSSION

Chemistry

Individual physicochemical measurements are given in Table 3, whereas arithmetic means by month are given in Table 4. All tests except temperature and turbidity showed considerable variation among the sampling sites. Water temperature varied mostly with seasons (Figure 3) ranging from 7 to 27 C, whereas the turbidity was between 0 and 50 FTUs. The highest turbidities were measured when a tributary was flooded following a rain. Dissolved oxygen ranged from 6.6 to 13.2 mg/1, whereas pH readings were between 6.2 and 8.5. Dissolved oxygen was greater during the winter months with little difference between 1985 and 1986. pH was lowest during January and February 1985 (6.7) and gradually rose to 7.7 during the same months in 1986, then declined to 7.2 during April through June 1986. Hardness measurements ranged from 10 to 100 mg/1 and were highest during the fall and winter. Alkalinity readings were between zero and 75 mg/1 but didn't seem to exhibit any seasonality. Phosphate ranged between 0.05 and 1.15 mg/1 with no apparent change due to season alone.

Table 3. Physicochemical data from the upper Saline River system, Saline and Garland Counties, Arkansas, 1985-86.

Date	Site	Air temp (C)	H2O Temp (C)	Turb (FTU)	pH	D.O. (mg/1)	Tot Hard (mg/1)	Tot Alka (mg/1)	O-Phos (mg/1)	NO3-N (mg/1)	NO2-N (mg/1)	Sulfate (mg/1)	Fe (mg/1)	Q (cms)
24 Jan 85	3	19	9	1.5	7.2	13.2	40	10	.19	1.5	.015	9	.06	.419
28 Feb	11	15	10	8	6.6	11.5	60	35	.75	1	.025		.07	3.444
28 Feb	7	14	10	2	6.2	12	70	10	.18	1.4	.19			1.843
7 Mar	18	21	10	6	6.9	10.9	40	5	.21	1	.017		.04	2.974
7 Mar	29	20	9	0	6.4	11.5	30	0	.18	1.3	.031		.07	.351
14 Mar	27	20	12	50	8.5	10.8	90	50	.22	.7	.013		.06	2.072
14 Mar	34	22	13	24	7.6	10.3	80	33	.14	1.3	.014	12	.21	2.57
18 Apr	21	25	19	0	7.6	8.6	75	70	.91	1.2	.02		.07	.6
18 Apr	20	26	20	0	7	8.6	38	30	.42	1	.022	12	.04	.96
10 May	35	21	20	0	7.4	8.5	54	40	.65	1.3	.017	11	.15	1.211
16 May	24	28	20	0	6.8	8.6	62	50	.4	1.8	.042	11	.18	5.28
17 May	16	30	21	0	6.7	9.2	10	5	.22	1.4	.057	5	.07	.281
29 Jun	16	34	23	5	6.5	6.9	12	10	.26	1.7	.13	6	.04	.2
25 Oct	35	24	20	8	7.4	7.5	70	48	.21	1.1	.015	10	.04	.48
6 Nov	18	21	14	7	7.3	9.1	58	37	.47	1.8	.028	8	.05	.536
17 Jan 86	35	14	11	4	7.4	12.6	60	30	.5	.6	.017	12	.13	.473
31 Jan	18	18	7	0	8	12.5	78	38	.82	.2	.005	7	.01	.238
18 Feb	35	25	12	2	7.5	11.2	60	30	.19	.7	.027		.04	2.52
28 Feb	18	2	10	10	7.8	11	70	20	.11	.8	0	9	.02	.397
1 Apr	35	26	21	6	7.2	9.8	35	20	.48	.8	.017	6	.01	1.563
11 Apr	18	21	19	10	6.7	9.4	53	7	.1	.4	.011	0	.22	2.623
24 Apr	35	27	17	6	7.2	10.8	38	20	.14	.5	.005	2	.13	4.838
13 May	1	32	20	0	6.4	8.8	20	10	.2	.5	.007	6	.04	.112
14 May	17	29	20	2	7.6	8.6	65	37	.12	.6	.018	11	.2	.072
16 May	10	29	23	2	7.3	8.6	30	24	.29	.9	.088	14	.18	.252
22 May	35	23	19	9	7.1	9	32	15	.12	.4	.015	6	.15	2.298
22 May	6	28	22	0	7.2	8.6	42	30	.26	1.1	.024	7	.08	.81
27 May	31	25	21	7	6.8	9.2	20	3	.17	.5	.009	10	.28	1.285
29 May	12	30	23	6	7.6	8.8	58	47	.24	.5	.017	11	.25	2.496
30 May	9	32	24	4	7.8	9.6	59	40	.07	.6	.034	9	.3	.733
12 Jun	26	27	24	8	8	8.8	100	75	1.15	.4	.039	9	.14	.426
17 Jun	16	31	27	4	6.3	8.2	10	2	.14	.6	.025	7	.17	1.287
20 Jun	18	33	25	4	7.2	9	32	27	.12	.9	.058	5	.26	.692
24 Jun	23	34	26	0	7.4	8.4	40	37	.16	.5	.022	5	.23	.593
24 Jun	14	35	27	7	7.6		62	46	.07	.4	.021	8	.21	.995
3 Jul	24	35	27	10	7.8	8.4	58	50	.13	.5	.008	5	.15	1.94
22 Aug	18	36	27	5	7.8	9.2	48	35	.08	.5	.037	5	.02	.144
22 Aug	17	36	25	0	8.1	9.6	80	59	.14	.95	.033	13	.07	.079
29 Aug	5	28	24	7	7.3	9.2	46	25	.05	.35	.012	1	.17	.123
5 Sep	20	29	24	4	7.1	6.6	40	30	1.1	.8	.014	2	.06	.202
12 Sep	25	30	26	4	7.8	9.4	50	50	.15	1.1	.03	5	.07	.785
19 Sep	3	33	27	0	7.1	8.8	34	27	.1	.7	.031	7	.03	.094
19 Sep	9	32	27	4	7.8	9.4	48	40	.16	.5	.018	8	.05	.277
26 Sep	8	32	26	8	7.8	8.2	52	50	.26	.4	.001	5	.03	.154
3 Oct	1	31	22	0	6.4	8.8	18	12	.11	1.3	.011	11	.05	.042
17 Oct	33	23	17	8	7.1	9	55	45	.07	.4	.008	9	.04	.048
21 Nov	15	16	11	1	8.2	11	68	50	.2	1.3	.047	8	.05	.969
21 Nov	23	16	11	3	7.6	10.2	75	40	.07	.5	.002	9	.04	.646

Table 4. Means of physicochemical measurements by month in the upper Saline River, Saline County, Arkansas, 1985-86.

	MONTHS										
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
N	3	4	4	5	10	6	1	3	5	3	3
pH	7.53	7.02	7.35	7.14	7.15	7.17	7.80	7.73	7.52	6.97	7.70
D. O.	12.8	11.4	10.9	9.4	9.8	8.3	8.4	9.3	8.5	8.4	10.7
Hard.	59	65	60	48	44	43	58	58	.45	48	67
Alka.	26	24	22	29	30	33	50	40	39	35	42
Phos.	0.50	0.31	0.19	0.41	0.27	0.32	0.13	0.09	0.35	0.13	0.25
NO3-N	0.77	0.98	1.08	0.78	0.91	0.75	0.50	0.60	0.70	0.93	1.20
NO2-N	.012	.060	.019	.015	.032	.049	.008	.027	.019	.011	.026
Sulfate	9.3	9.0	12	5.0	10	6.7	5.0	6.3	5.4	10	8.3
Iron	.067	.043	.095	.094	.188	.175	.150	.087	.048	.043	.047

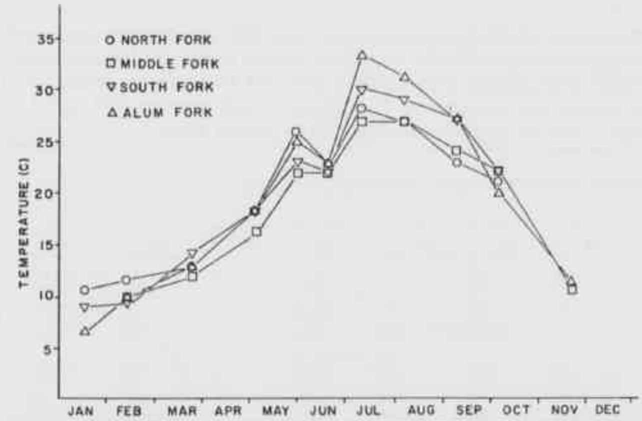

Figure 3. Average monthly water surface temperatures in the four major tributaries of the upper Saline River system, Saline and Garland Counties, Arkansas, 1985-86 (data from this study).

in 1985 than in 1986. Nitrite-nitrogen varied sporadically from zero to 0.19 mg/1. The highest values were obtained on 28 Feb and 29 Jun 85, whereas the lowest readings were obtained on 28 Feb, 31 Jan and 24 Apr 86. Sulfate generally ranged between zero and 14 mg/1 with no season oriented variation. Iron concentrations ranged from 0.01 to 0.30 mg/1 with eight of the nine highest occurring between 11 April and 24 June. Twelve of the 14 lowest measurements occurred between 19 September and 1 April.

Some interesting comparisons among the four major and several minor tributaries occurred (Table 5). Between the Alum Fork and its minor tributaries (Lee Creek and Little Alum), the latter exhibited generally higher pH, hardness, alkalinity, phosphate and sulfate readings. Curiously, the site above Lake Winona on the Alum Fork measured very low hardness and alkalinity and rather low pH, whereas the Little Alum Fork tributary, arising from supposedly a very similar geologic formation nearby, had rather high readings. Conversely, the only significant tributary of the South Fork, Ten Mile Creek, exhibited generally lower pH, hardness and alkalinity than the South Fork itself. These variations seem to be correlated with the relative amounts of limestone exposure in the watershed — the Little Alum Fork arises in an area containing some Womble shale (Phil Kehler, UALR Earth Science Dept.), which contains a small amount of limestone. Large areas which were recently clear-cut occur in the watershed of the upper Alum Fork, and smaller areas which were recently clearcut lie in the watershed of Ten Mile Creek. Although these clearcut areas are being recolonized rapidly, for some length of time the quality of the runoff will be affected. Most of these tributaries begin as seeps rather than springs of sudden appearance, so it is unlikely that any differences are related to the origin. The upper Alum Fork may depend more heavily on surface runoff for stream maintenance than Ten Mile Creek or Little Alum Fork because it became spatially interrupted (probably subsurface) during July and August 1986. The Little Alum and Ten Mile Creek never ceased measurable flow. The tendency for broken flow is not limited to the upper Alum Fork (Robison and Harp, 1985) but still creates a situation of special concern for many species.

Table 5. Means of physicochemical measurements by tributary in the upper Saline River, Saline County, Arkansas, 1985-86.

	TRIBUTARY					
	Alum	Alum-trib	Middle	South	South-trib	North
N	17	4	5	6	4	10
pH	7.24	8.05	7.46	7.35	6.78	7.24
D. O.	9.20	9.28	10.2	9.50	9.90	9.94
Hardness	46	82	56	53	28	51
Alkalinity	28	58	40	32	17	28
Phosphate	0.29	0.58	0.31	0.16	0.15	0.26
Nitrate-N	0.91	0.77	0.82	0.72	0.90	0.81
Nitrite-N	0.030	0.025	0.040	0.046	0.016	0.016
Sulfate	6.3	11.0	10.2	6.0	8.2	8.7
Iron	0.098	0.108	0.152	0.126	0.045	0.114

Substrate

Table 6 gives substrate analysis data. Although there was considerable variation among the sites, the largest particle size group (> 16 mm) was dominant with an average of 58%. The other size groups had means

Table 6. Substrate composition and stream flow parameters in the upper Saline River system, Saline and Garland Counties, Arkansas, 1985-86.

		Percent in each size group (mm)					Stream flow (m)			
Date	Site	>16	6.3-16	1.0-6.3	0.5-0.9	<0.5	mD	mV	W	Q(cms)
1/24/85	3	67	20	12	0.5	0.5	0.23	0.35	5.2	0.419
2/28	11	50	25	19	3.0	3.0	0.48	0.41	17.5	3.444
2/28	7	0	42	50	3.0	5.0	0.27	0.35	19.5	1.843
3/07	29	90	6	2	1.0	1.0	0.18	0.26	7.5	0.351
3/07	18	70	17	12	1.0	0	0.31	1.01	9.5	2.974
3/14	27	(no substrate analysis)					0.37	0.70	8.0	2.072
3/14	34	(no substrate analysis)					0.42	0.68	9.0	2.570
3/27	28	40	50	3	1.0	6.0			(est.	0.100)
3/27	32	5	5	-90% slabrock/bedrock-					(est.	0.300)
4/18	21	50	25	15	5.0	5.0	0.40	0.50	3.0	0.600
4/18	20	85	0	0	2.0	3.0[a]	0.20	0.80	6.0	0.960
5/10	35	35	52	8	4.0	1.0	0.24	0.58	8.7	1.211
5/16	24	10	60	20	7.0	3.0	0.32	0.66	25.0	5.280
5/17	16	20	18	2	-60% slab/bed-		0.15	0.75	2.5	0.281
6/13	12	40	40	10	8.0	2.0			(est.	1.000)
8/02	11	(no substrate analysis)					0.20	0.50	3.0	0.300
10/25	35	80	10	7	3.0	0	0.30	0.40	4.0	0.480
11/06	18	(no substrate analysis)					0.17	0.70	4.5	0.536
1/17/86	35	70	20	5	4.0	1.0	0.22	0.43	5.0	0.473
1/31	18	90	7	2	0.5	0.5	0.17	0.28	5.0	0.238
2/18	35	90	7	2	0.5	0.5	0.40	0.70	9.0	2.520
2/28	18	90	6	3	1.0	0	0.18	0.38	5.8	0.397
3/12	4	(no substrate analysis)					0.18	0.68	24.0	3.020
4/01	35	60	30	7	2.0	1.0	0.11	0.49	29.0	1.563
4/11	18	75	18	5	1.0	1.0	0.31	0.94	9.0	2.623
4/24	35	30	40	15	10	5.0	0.24	0.63	32.0	4.838
5/13	1	80	10	5	3.0	2.0	0.07	0.40	4.0	0.112
5/14	17	60	15	15	6.0	4.0	0.06	0.30	4.0	0.072
5/16	10	30	50	10	5.0	5.0	0.05	0.42	12.0	0.252
5/22	35	45	30	10	8.0	7.0	0.23	0.54	18.5	2.298
5/22	6	60	25	10	3.0	2.0	0.27	0.60	5.0	0.810
5/27	31	70	15	7	5.0	3.0	0.22	0.73	8.0	1.285
5/29	12	60	10	15	10	5.0	0.48	0.52	10.0	2.496
5/30	9	80	15	2	2.0	1.0	0.13	0.47	12.0	0.733
6/12	26	80	16	3	0.5	0.5	0.22	0.43	4.5	0.426
6/17	16	95	5	0	0	0	0.55	0.52	4.5	1.287
6/20	18	80	10	7	2.0	1.0	0.19	0.52	7.0	0.692
6/24	23	65	25	4	3.0	3.0	0.14	0.77	5.5	0.593
6/24	14	50	35	8	4.0	3.0	0.14	0.79	9.0	0.995
7/03	24	40	40	10	5.0	5.0	0.44	0.42	10.5	1.940
8/22	18	72	20	5	2.0	1.0	0.10	0.38	3.8	0.144
8/22	17	40	40	10	5.0	5.0	0.05	0.45	3.5	0.079
8/29	5	65	30	3	1.0	1.0	0.06	0.41	5.0	0.123
9/05	20	74	18	4	2.0	2.0	0.14	0.16	9.0	0.202
9/12	25	55	32	7	4.0	2.0	0.17	0.42	11.0	0.785
9/19	3	40[b]	40	10	6.0	4.0	0.05	0.47	4.0	0.094
9/19	9	60	25	8	4.0	3.0	0.09	0.56	5.5	0.277
9/26	8	10	60	15	9.0	6.0	0.12	0.16	8.0	0.154
10/03	1	65	20	8	4.0	3.0	0.08	0.26	2.0	0.042
10/17	33	20[c]	50	20	5.0	5.0	0.04	0.24	5.0	0.048
11/21	15	62	28	4	3.0	3.0	0.19	0.34	15.0	0.969
11/21	23	76	16	4	2.0	2.0	0.17	0.38	10.0	0.646

[a]Other material such as clay.

[b]These values are for the upper one-third; the lower two-thirds of the riffle had 70-20-6-2-2 percent in the respective substrate categories.

[c]These values for riffle 1; riffle 2 values follow: 45-35-15-3-2.

of 24% (6.3-16 mm), 9.4% (1.0-6.2 mm), 3.5% (0.5-0.9 mm), 2.4% (<0.5 mm) and 3.7% (other, including bedrock, slabrock and clay). The replicate substrate analyses at a given site were somewhat variable as was the composition as one progressed downstream. Headwater areas were typified with a greater percentage of larger rocks (100-300 mm), which provided a greater number of under-rock or "on the leeward side of the rock" niches. The favored habitat of the Ouachita madtom *(Noturus lachneri)* was substrate dominated by larger (60-140 mm) rocks with little or no silt deposition, leaving numerous cavities available for temporary refugia (Rickett, 1986). The slabrock/bedrock areas were obviously difficult to colonize by fish or macrobenthos. The substrate at most sampling sites was relatively free of silt, except at sites 7, 24 and 25. A bridge was being built near site 7, and a large amount of loose soil had washed into the stream. Furthermore, during a non-sampling visit on 20 Aug 85, evidence of the passage of a large construction machine through the stream channel was readily observed.

Stream Flow

Discharge (Q) measurements are given in Table 6, whereas Figure

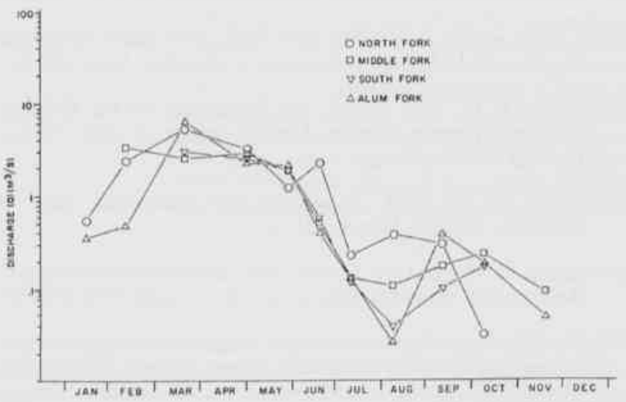

Figure 4. Average monthly discharges (Q) at selected sites on the four major tributaries of the upper Saline River system, Saline and Garland Counties, Arkansas, 1985-86 (data from this study).

4 shows seasonal variation. During the spring of the year the Alum and Middle Forks exhibited about the same discharge with the South and North Forks slightly less, except when water was being released from Lake Norrell for pick up by the Benton public water system or to relieve pressure on the lake. During the dry part of the summer the Alum Fork was often the smallest of the four, particularly within ten river miles downstream of Lake Winona. A very recent visit (25 Jul 86) to site 16 (above Lake Winona) revealed a stream with no perceptible flow and only small pools remaining. It was not uncommon for about any portion of the stream to experience a ten-fold variation between sustained spring flow and dry summer flow. The lower North Fork probably experienced less variation because of sustained flow efforts by the Benton water works utility.

As expected flow patterns and discharge varied with the seasons, and resident species have adapted to the pattern. Evidence of flooding was recorded indicating the depth in some reaches varied by a factor of 20. Localized streamside flooding occurred, but the flood channel was steep in most places and held most of the flood waters.

Stream Hydrology

Morphometric and flow variables were measured during a period of lowest expected levels (1,2 Aug 86) to determine the minimum natural flow (Table 7). There was more variability of measurements taken in pools than riffles. The five numbered sites exhibited typical headwater

Table 7. Summary of hydrological data on the upper Saline River system, Saline County, Arkansas, 1986.

	Site					
Variable	14	24	35	9	23	Saline[a]
Date	8/2	8/1	8/8	8/2	8/2	8/1
Discharge (Q)(m^3/s)	0.282	0.476	0.216	0.248	0.156	0.375
Riffle volume (m^3)						
Range--low	3.6	18.2	7.0	5.9	4.8	116
Range--high	85.0	50.2	20.4	45.1	27.8	215
Mean	28.6	34.3	14.7	19.9	14.6	166
Pool volume (m^3)						
Range--low	26.2	230	16.6	10.6	32.3	137
Range--high	579	1740	197	7570	1643	13,644
Mean	260	630	68.8	1546	482	8,708
Residence time (min)						
Range--low	1.6	8.1	1.3	0.7	3.4	7.1
Range--high	34.2	60.9	15.2	510	175	607
Mean	15.4	22.1	5.3	104	51.3	388
Riffle length (m)						
Range--low	7.5	12.0	15.0	12.5	6.0	36.0
Range--high	55.0	76.0	39.0	48.0	41.0	104
Total	180	190	137	180	132	286
Mean	29.9	38.0	22.8	30.0	22.0	71.6
Pool length (m)						
Range--low	11.5	31.0	7.5	8.0	11.5	18.0
Range--high	71.0	168	49.5	332	106	646
Total	199	410	146	530	260	1,183
Mean	33.2	82.0	24.4	88.4	43.3	394
Riffle velocity (m/s)						
Range--low	0.22	0.42	0.20	0.15	0.36	0.20
Range--high	0.47	0.62	0.65	0.52	0.53	0.32
Mean	0.34	0.49	0.37	0.28	0.45	0.26
No. riffles measured	6	5	6	6	6	3
No. pools measured	6	5	6	6	6	3
Stream length meas.	379	600	283	710	734	1,469
Pool/riffle ratio	1.1	2.2	1.1	2.9	2.0	4.1

[a]Unnumbered site on the Saline River 2 km west of Tull on the Saline-Grant County line, approximately 8 km downstream from Benton.

characteristics of shorter pools and more riffles per linear distance, whereas the Saline site was located in the transition zone to a lowland stream (longer pools and fewer riffles). The pool depth in the headwater area varied more widely ranging up to (estimated) four meters, while the maximum pool depth in the lowland region was 1.6 m. Close to the Alum Fork site (23) was a pool with the greatest volume (approximately 32,000 cu m) primarily because its depth averaged about two meters. The North Fork site (35) also had a large pool nearby which was made more extensive by a beaver dam. Most of the headwater pools were much smaller.

Pool/riffle ratios varied from 1.1 at the Middle Fork site to 4.1 at the Saline site. The lower pool/riffle ratios (around 1.0) indicate a more even stream occupation by pools and riffles, which should be the ideal arrangement for optimum dispersal of niches and maximum development of community feeding resources. If our primary interest is in pool dwellers, and most game fish are, certainly numerous resources exist in the pool itself, but additional items are available from the adjacent riffle. As populations of riffle dwellers reach maximum density, some are forced to move out of the riffle, quite often downstream into the next pool where they become available as food to pool-dwelling fish.

Considering physicochemical and substrate characteristics and stream hydraulics, the Saline River exhibits much variation which provides numerous transition zones within which significant changes occur.

Although it has not been confirmed for this headwater region, different areas within it should exhibit varying diversities of species. Statzner and Higler (1986) argue that the highest diversities should occur in transition zones of stream (such as braided channel areas or the simultaneous confluence of two or more tributaries).

Vegetation

The predominant tree species along the stream were water oak *(Quercus nigra),* willow oak *(Q. phellos),* sweet gum *(Liquidambar styraciflua),* blackgum *(Nyssa sylvatica),* black willow *(Salix nigra),* sycamore *(Platanus occidentalis)* and river birth *(Betula nigra).* Shrubs such as buttonbush *(Cephalanthus occidentalis)* and alder *(Alnus serrulata)* were also common. Headwater areas of the streams were usually extensively shaded (up to 80 percent), which facilitated the input of allochthonous nutrients and retarded solar heating of the water. Lower sections lacked heavy streamside shading because the pools were typically wider and longer. The allochthonous deposition of sweetgum aggregate fruits and alder fruits into the stream should be particularly important because these products apparently serve as refugia for caddisfly larvae and other small invertebrates until decomposition of them is well advanced. Water willow *(Dianthera americana)* was recorded at all sampling sites and reached maximum profusion in early September. In some areas its growth choked riffles and occupied large portions of shallow areas of pools. Algae, predominantly greens and bluegreens, also occupied some shallow pool areas in early September, particularly in the South Fork.

CONCLUSIONS

All areas of the upper Saline River system exhibited characteristics of a typical headwater stream. Clearcutting forested portions, construction and agricultural runoff seemed to be the three major human impacts to this diverse watershed. Physicochemical measurements indicated high water quality, and in most areas the riffle substrate composition offered a variety of microhabitats and refugia for macrobenthos and riffle-dwelling fish species. A clear distinction between pool and riffle existed, and the pool/riffle ratio was slightly more than unity indicating nearly equal division of the stream into these two major habitat types. Both pools and riffles contained numerous microhabitats which were occupied by a wide diversity of organisms (Rickett, MS in prep.). Streamside vegetation was varied and provided abundant shading and deposition of allochthonous materials. Because the Ouachita madtom *(Noturus lachneri),* endemic to the Saline River headwaters, requires clean water and open substrate cavities, the present quality of the stream and its watershed should be carefully protected. Unfortunately much of the watershed is presently owned or managed by parties who may be less concerned about protection.

ACKNOWLEDGEMENTS

Appreciation is extended to the Arkansas Natural Heritage Commission for providing financial assistance to this project and to Steve Killian and Gene Templeman who assisted with field work.

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A SPECTROPHOTOMETRIC ASSAY FOR THE ENZYME CATALYZED REACTION OF 4-NITROQUINOLINE 1-OXIDE WITH GLUTATHIONE

J. STEVEN STANLEY and ANN M. BENSON
Department of Biochemistry
University of Arkansas for Medical Sciences
Little Rock, AR 72205

ABSTRACT

4-Nitroquinoline 1-oxide (4NQO(is a toxic and carcinogenic compound that has been reported to be subject to conjugation with glutathione (GSH). This reaction may proceed non-enzymatically or be catalyzed by GSH transferases. The non-enzymatic rate for this reaction has been reported to be very high. The purposes of this investigation were to develop a spectrophotometric assay for the reaction of 4NQO with GSH and to determine whether the rate for the enzyme catalyzed reaction was significant relative to the non-enzymatic reaction. The absorbance spectrum of 4NQO in phosphate buffer exhibited a maximum at 365 nm. Reaction of 4NQO with GSH was accompanied by a shift to 353 nm and an absorbance increase which was maximal at 350 nm. The formation of product could be quantitated from the increase in absorbance at 350 nm, where the change in the millimolar extinction coefficient was 7.20 mM^{-1} cm^{-1}. Although the non-enzymatic reaction of 4NQO and GSH proceeded rapidly at or above pH 8, at physiological pH this reaction was largely enzyme dependent. In an assay system containing 0.1 mM 4NQO, 1 mM GSH, and 0.1 M potassium phosphate, at 25°C, the conjugation of 4NQO with GSH by mouse liver cytosol was optimal at pH 6.5 - 7.5. At pH 6.5 and 1 mM GSH, a GSH transferase purified from mouse liver catalyzed the reaction of 4NQO with GSH with a maximum velocity of 156 μmoles/min per mg of protein. The K_m for 4NQO was 35 μM. The high activity of liver cytosol in promoting the reaction of 4NQO with GSH and the high affinity of the purified GSH transferase for 4NQO suggest that enzymatic catalysis of this reaction may be of considerable significance in vivo.

INTRODUCTION

4-Nitroquinoline 1-oxide (4NQO) is a toxic and carcinogenic compound that has been shown to cause tumors of the lung, forestomach, glandular stomach, mouth, esophagus, liver and skin of rodents (Ito, 1981). Both enzymatic and non-enzymatic conjugations of 4NQO with glutathione (GSH) have been reported (Al-Kassab *et al.*, 1963; Chasseaud, 1979). This reaction, shown in Figure 1, has been described as an addition-elimination reaction resulting in the formation of a thioether (Chasseaud, 1979). Two types of assays for the rate of reaction of 4NQO and GSH have been described. Varnes and Biaglow (1979) noted that both an increase in absorbance at 354 nm and the appearance of a fluorescent band at 420 nm appeared to accompany the formation of a GSH-quinoline 1-oxide conjugate. Changes in fluorescence in the 420 nm to 3000 nm range were used to quantitate the reaction of GSH and 4NQO. The absorbance increase at 354 nm was consistently observed, whereas the fluorescence at 420 nm was in some cases not detected. A causal relationship between the formation of product and the appearance of fluorescence at 420 nm appears not to have been established. Al-Kassab *et al.* (1963) measured the reaction of 4NQO with GSH by quantitation of the nitrite released. The non-enzymatic reaction was very rapid under the assay conditions used (pH 8.0, 6 mM GSH), and this imposed severe limitations upon the ease and applicability of the assay procedure. Nevertheless, these investigators were successful in demonstrating catalysis of the reaction by rat liver cytosol. The GSH transferases, a family of cytosolic detoxication enzymes, catalyze the conjugation of numerous xenobiotics with GSH (Jakoby and Keen, 1977; Habig, 1983). However, it has not been clear whether these enzymes may have a significant role in promoting the reaction of 4NQO with GSH, in relation to the rate at which this reaction occurs non-enzymatically.

The present investigation had two purposes — to develop a quantitative spectrophotometric assay for the reaction of 4NQO with GSH, and to establish whether the rate for the enzyme-catalyzed reaction was significant relative to the non-enzymatic reaction.

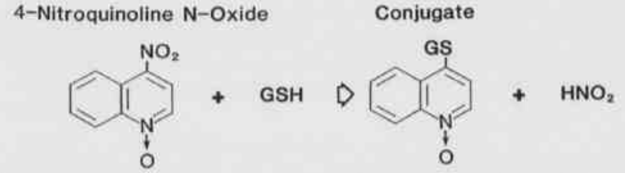

Figure 1. The conjugation of 4NQO with GSH.

MATERIALS AND METHODS

Aldrich Chemical Company supplied the 4NQO. Sigma Chemical Company supplied the GSH. Preparation of mouse liver cytosol and of a purified GSH transferase was performed by methods that have been described previously (Pearson *et al.*, 1983). The GSH transferase isozyme, GT-8.8b, yielded a single coincident peak of enzyme activity and protein on preparative isoelectric focusing and a single Coomassie blue staining band after electrophoresis in polyacrylamide gels under denaturing conditions. In those assays catalyzed with mouse liver cytosol, 2 μl of 10-fold diluted cytosol were used. This represents 9.5 μg of protein in the 1 ml assay system. Spectrophotometric measurements were made on a Beckman DU-6 spectrophotometer with kinetics accessory. Product formation was linear with time and with enzyme concentration under the assay conditions used in these studies. Protein concentrations were measured by the method of Lowry *et al.* (1951).

RESULTS

The absorbance spectrum of 4NQO in phosphate buffer at pH 6.5 and 25 °C exhibited a maximum at 365 nm (Fig. 2). Addition of GSH (6mM) to 4NQO (0.1 mM) yielded an increase in absorbance and a shift in the maximum to 353 nm. No further change was seen after 150 minutes. In the presence of mouse liver cytosol, 1.0 mM GSH, and 0.1 mM 4NQO, the identical spectral changes were observed. Figure 2 shows the spectrum of 4NQO and the spectrum of the product after complete enzymatic reaction with GSH. The difference spectrum (Fig. 3) shows that the maximum change in absorbance occurred at 350 nm. Product formation could be quantitated from the change in the millimolar extinction coefficient (△E) at 350 nm, which was 7.2 $mM^{-1}cm^{-1}$. The dependence of the enzymatic and non-enzymatic reaction rates on pH was examined at 25 °C in an assay system containing 1.0 mM GSH, 0.1 mM 4NQO, and 0.1 M potassium phosphate. The enzymatic reaction was catalyzed by mouse liver cytosol. Figure 4 shows how these reaction rates were affected as the pH was increased from 5 to 8. The

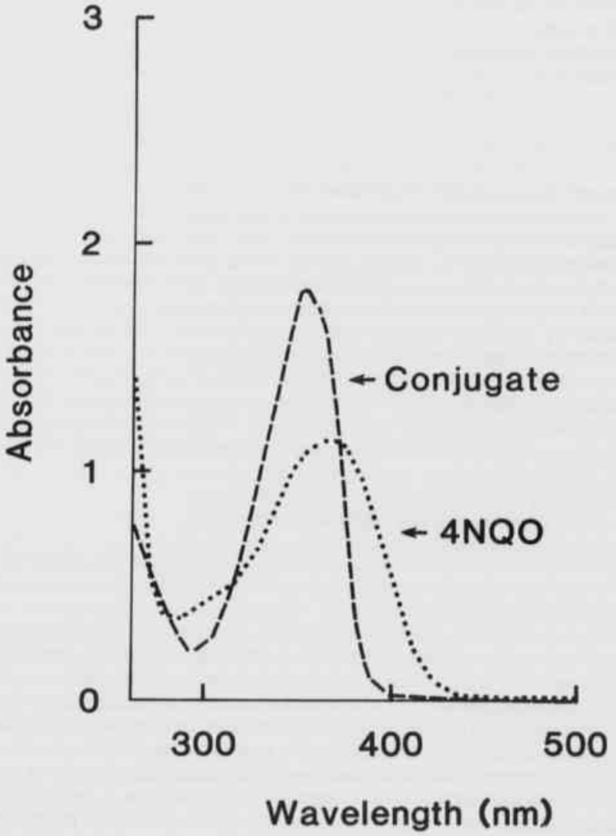

Figure 2. Absorbance spectra of 0.1 mM 4NQO and of the product formed by its complete enzymatic reaction with GSH (1 mM). Samples and blanks were in phosphate buffer, pH 6.5, at 25 °C and contained 0.2 μl of mouse liver cytosol.

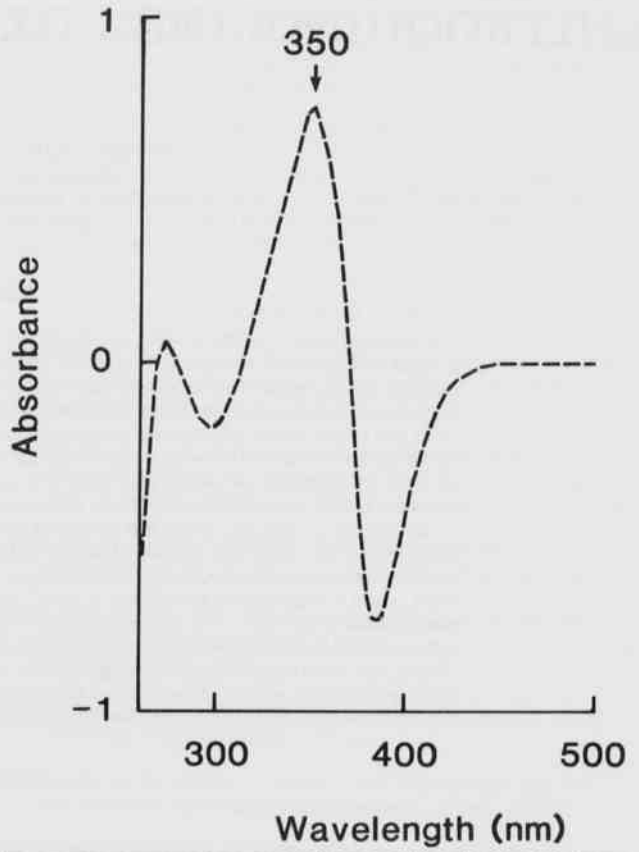

Figure 3. Difference spectrum of the reaction product of 4NQO and GSH, vs. 4NQO. The concentrations and conditions were as described in the legend to Fig. 2.

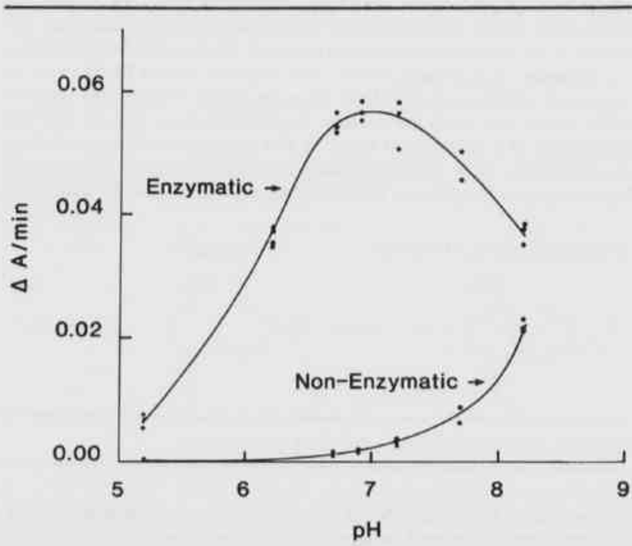

Figure 4. Enzymatic and non-enzymatic reactions of 0.1 mM 4NQO with GSH (1 mM) at 25 °C as a function of pH. The enzymatic reaction was catalyzed by 0.2 μl of mouse liver cytosol.

optimum enzymatic rate occurred between pH 6.5 and pH 7.5. The non-enzymatic rate rose with pH, increasing most rapidly above pH 7.7.

Some of the kinetic characteristics of the enzyme catalyzed reaction between 4NQO and GSH were examined, using a GSH transferase isozyme that had been purified to apparent homogeneity from mouse liver cytosol. The concentrations of 4NQO and GSH were optimized. The standard 1 ml assay system contained 0.1 M potassium phosphate, pH 6.5, 1.0 mM GSH, 0.05 mM 4NQO, and 0.06 μg of enzyme. The reaction was initiated by the addition of the 4NOQ in 10 μl of ethanol. The concentration of 4NQO was varied between 0.05 mM and 0.003 mM for the kinetics studies. The purified GSH transferase catalyzed the reaction of 4NQO and GSH with high efficiency. Kinetic analysis (Fig. 5) revealed that the enzyme had a K_m for 4NQO of 35 μM. The maximum velocity was 156 μmol/min per mg of GSH transferase.

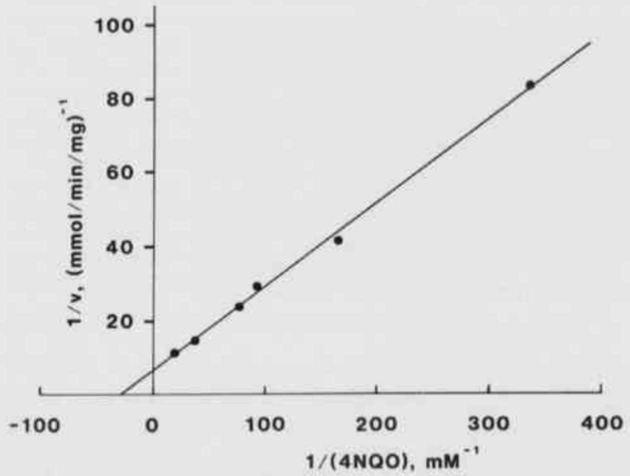

Figure 5. Double reciprocal plot of 4NQO concentration vs. initial velocity of the reaction of 4NQO with GSH (1 mM) in phosphate buffer at pH 6.5 and 25 °C. The reactions were catalyzed by a GSH transferse that had been purified from mouse liver cytosol.

DISCUSSION

The spectrophotometric assay described above is a rapid and convenient method for quantitating the reaction between 4NQO and GSH. The sensitivity was far greater than that obtained by measurement of nitrite released (Al-Kassab *et al.*, 1963), and product formation could be monitored continuously. Results obtained by application of this assay method showed that the non-enzymatic reaction of 4NQO with GSH increased with pH and became quite substantial at pH 8. However, in the most prevalent physiological pH range the role of glutathione transferases in promoting the reaction between 4NQO and GSH is clearly of much greater quantitative significance than the non-enzymatic reaction.

ACKNOWLEDGEMENT

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EFFECTS OF BLUE TILAPIA/CHANNEL CATFISH POLYCULTURE ON PRODUCTION, FOOD CONVERSION, WATER QUALITY AND CHANNEL CATFISH OFF-FLAVOR

LES TORRANS and FRAN LOWELL[1]
Department of Agriculture
University of Arkansas at Pine Bluff
Pine Bluff, AR 71601

ABSTRACT

Channel catfish *(Ictalurus punctatus)* monoculture ponds stocked with 10,000/ha of mixed-size catfish were compared to ponds stocked additionally with blue tilapia *(Tilapia aurea)*. Ponds stocked with 5000/ha young-of-the-year blue tilapia produced 236 kg/ha less catfish, but tilapia biomass increased by 1020 kg/ha, averaging 233 g/fish. Ponds stocked with sexually mature tilapia in April to provide forage to the catfish had increased catfish production but a poorer food conversion radio. Ponds stocked with sexually mature tilapia in June or July had catfish production and FCR's similar to the controls. Dissolved oxygen was significantly lower than the controls in all polyculture treatments. Zooplankton biomass and secchi disc visbility were significantly lower than the controls in three of four polyculture treatments. Chlorophyll *a* was slightly, but not significantly, less than the controls. The major benefit of tilapia/catfish polyculture was the reduction of channel catfish off-flavor. Catfish in polyculture treatments were off-flavor 8.3% of the times sampled, compared to 62.5% for catfish reared in monoculture. The addition of tilapia to catfish ponds is a practical, effective means of reducing the incidence of off-flavor in channel catfish.

INTRODUCTION

Commercial catfish farmers were facing difficult times in 1982. Feed prices and energy costs were extremely high, and pond-bank prices for channel catfish averaged only $0.55/pound, compared to the previous five year average of $0.61/pound (USDA National Agricultural Statistics Service, 1986). Many Arkansas catfish farmers were searching for additional fish species and/or production methods that could increase their net income.

Polyculture, the rearing of two or more aquatic species together in a pond, is a production technique used to increase overall fish production and profits (Dupree and Huner, 1984). Fish species that feed low on the food chain, such as plankton feeders or detritivores, are especially suitable as companion species with channel catfish in that they do not compete directly with catfish for feed. They consume the plankton bloom and bottom sediments, normally unusable and unwanted byproducts of intensive catfish culture. The result of polyculture is an increase in net fish production without a proportional increase in production costs (Dunseth and Smitherman, 1977; Torrans and Clemens, 1981).

Unfortunately, most secondary foodfish species that are suitable in polyculture for biological reasons, such as bigmouth buffalo *(Ictiobus cyprinellus)*, silver carp *(Hypophthalmichthys molitrix)* or bighead carp *(Aristichthys nobilis)*, are unsuitable for practical reasons — they have a comparatively low market value and require more than one year to reach market size. It is difficult to incorporate species such as these into an applied polyculture system with channel catfish, given the management normally practiced on commercial catfish farms. Most catfish farmers currently maintain a stock of mixed-size channel catfish, periodically "top off" the larger marketable catfish during the growing season, and restock smaller fingerlings (Dupree and Huner, 1984). A secondary species would therefore have to be separated by hand from the catfish at each partial harvest once it became too large to pass through the grading seine. This makes polyculture impractical on large commercial farms with existing management. However, polyculture could be economical if the secondary species reached market size in a single season (eliminating numerous hand-sortings) and/or had a high value (justifying the expense of extra labor).

A fish species that reduced channel catfish production costs or risks would also increase the net income of catfish farmers. A catfish food conversion ratio improved by the addition of forage fish, or better water quality (higher dissolved oxygen levels, for example) resulting from the addition of a secondary species would mean more profits for the farmer.

We felt that blue tilapia *(Tilapia aurea)*, an exotic Cichlid (Suffern, 1980) could be used in several ways to improve the economics of fish farming in Arkansas. They are an excellent foodfish with high value (Crawford *et al.*, 1978; Anon., 1986) that do well in polyculture with channel catfish (Dunseth and Smitherman, 1977; Williamson and Smitherman, 1975). What was not previously known was how large tilapia could grow in a single season in Arkansas. If tilapia could grow to market size in one season, hand-sorting during numerous partial harvests would not be a major problem. The tilapia would be large enough to be held in a grading seine only during the last partial harvest of the growing season, by which time they would be marketable. The value of the tilapia at that time could be high enough to justify the labor of separating them from the catfish (Anon., 1986).

Tilapia could also be an excellent forage fish for channel catfish. The ideal forage species has been defined as a species that is 1) prolific, 2) stable in abundance, 3) trophically efficient, 4) vulnerable to predation, 5) non-emigrating, and 6) innocuous to other species (Ney, 1981). Although blue tilapia have not been previously studied as a forage fish in catfish ponds, they appear to meet all of the criteria. In addition, since they are a tropical species that die when the water temperature falls below 7 °C, it is easy to control their distribution, both on and off the fish farm.

Finally, tilapia are facultative filter-feeders (Drenner *et al.*, 1984; McBay, 1961), as well as bottom grazers (McBay, 1961; Williamson and Smitherman, 1975; Spataru and Zorn, 1976), and could improve the water quality in catfish ponds. The use of so-called "sanitary fish"

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[1]Present address: B. W. Baruch Institute for Marine Biology and Coastal Research, University of South Carolina, Columbia, SC 29208.

to improve water quality in commercial culture ponds and water reservoirs is practiced in Israel (Dupree and Huner, 1984). *Tilapia aurea* have been credited with reducing organic matter in Israeli reservoir bottom sediments, and also reducing objectionable taste and odor in water (Leventer, 1981). While objectionable taste and/or odor of the water is not itself a problem in channel catfish ponds in the United States, the absorption of odorous compounds by channel catfish is a serious problem.

The frequency and severity of "off-flavor" in pond-raised channel catfish has increased dramatically in recent years, and is generally related to increased feeding rates (Brown and Boyd, 1982). It is estimated that over 50% of the commercial catfish ponds in Mississippi and Alabama contain catfish that are "off-flavor" during the growing season (Armstrong *et al.*, 1986). Off-flavor is currently the most serious economic problem faced by the catfish industry. The annual economic impact of off-flavor in Mississippi alone is $25-75 million (Anon., 1987).

Geosmin is produced by actinomycetes and blue-green algae (Medsker *et al.*, 1968; Safferman *et al.*, 1967), and has been shown to be a major cause of off-flavor in channel catfish (Lovell and Sackey, 1973). Since tilapia consume and digest blue-green algae (Moriarty, 1973), and also forage on the sediment surface where actinomycetes grow, there is reason to believe that tilapia raised in polyculture could be effective in reducing off-flavor in channel catfish.

The purpose of this study was to evaluate blue tilapia as both a secondary food fish and as a forage fish in channel catfish ponds. We expected that this polyculture combination would result in increased net fish production, improved food conversion ratios, and better water quality, as reflected by dissolved oxygen, the plankton biomass and the incidence of channel catfish off-flavor.

MATERIALS AND METHODS

Nine 0.1 ha earthern ponds at the University of Arkansas at Pine Bluff Agricultural Experiment Station were stocked in March 1982 with mixed-size channel catfish, *Ictalurus punctatus*, averaging 164 g (5 g to 600 g) at the rate of 10,000 fish/ha. Three of the ponds served as catfish monoculture controls. Three of the ponds were also stocked with 5000 young-of-the-year blue tilapia/ha averaging 6.1 g on June 30, to evaluate the foodfish potential of blue tilapia. The last three ponds were stocked on April 25 with sexually mature (approximately one-year-old) blue tilapia at a rate of 30 females and 30 males per hectare. It was anticipated that these adult tilapia would begin spawning in May and continue to spawn throughout the summer. This could provide a large biomass forage-size tilapia for the catfish, perhaps improving the catfish food conversion ratio (FCR).

Nine ponds were similarly stocked in April 1983 with 10,000 mixed-size channel catfish/ha that averaged 194 g (5 g to 600 g range). As in 1982, three of the ponds were maintained as catfish monoculture controls. Three of the ponds were stocked on June 1 with sexually mature blue tilapia at a rate of 30 females and 30 males per hectare. Three of the ponds were stocked on July 6 with sexually mature blue tilapia at a rate of 90 females and 30 males per hectare. Different stocking rates and/or dates of adult tilapia were used in the two forage treatments this year as a result of what was learned the previous year.

Zooplankton dry weight, chlorophyll *a* (an estimate of phytoplankton density), dissolved oxygen concentration (at dawn), and secchi disc visibility were determined weekly for all ponds in 1982 using standard techniques (American Public Health Association *et al.*, 1980). Zooplankton biomass and secchi disc visibility were determined weekly in 1983, and dissolved oxygen was determined daily.

The fish were fed a 32% protein floating pelleted feed six days/week both years. The feeding rate was adjusted in a manner normally used on commercial catfish farms. When water temperatures were low (10° to 20°C) in the spring, fish were fed as much as they would eat in a 15-minute period. As fish metabolism and surface feeding activity increased in relation to rising water temperatures, the quantity fed was increased accordingly up to a management-imposed limit of 45 kg/ha/day. This limit on maximum daily feeding rate was established to minimize the need for emergency aeration (Cole and Boyd, 1986; Tucker *et al.*, 1979). Feed consumption decreased in late October as water temperatures declined, and ceased completely in early November.

Larger catfish were partially harvested or "topped off" from all ponds five times both years by seining and removing all catfish longer than 40 cm (approximately 600 g). This was done to simulate the harvesting practices on commercial catfish farms (Dupree and Huner, 1984) where the standing crop of catfish is periodically reduced to the level where maintenance and growth requirements of the standing crop are met by the management-imposed limit on feeding rate. All ponds were drained and completely harvested each year after feeding ceased in November.

One food-size catfish was randomly chosen from each partial harvest and "taste-tested". An unseasoned filet was cooked in a microwave oven, and each cooked sample was smelled, tasted and rated as to flavor by a minimum of three experienced tasters. Samples were categorized as "off-flavor" if they had an objectionable odor or taste, or "on-flavor" if there was no objectionable odor or taste.

Statistical analyses were conducted using ANOVA, Duncan's multiple range test and T-Test (Barr *et al.*, 1979).

RESULTS AND DISCUSSION

Net Production and FCR

The net catfish production over the two-year study ranged from 2916 kg/ha to 3991 kg/ha (Table 1). This was higher than the average reported fish production from commercial catfish farms in Arkansas of 2524 kg/ha (Arkansas Crop and Livestock Reporting Service, 1986). The lowest catfish yield and poorest catfish food conversion ratio (FCR) occurred when tilapia fingerlings were stocked in 1982 to produce a secondary foodfish crop (tilapia foodfish treatment, Table 1). Although the net catfish production was not significantly lower than the catfish monoculture treatment that year, the FCR was significantly poorer when only the catfish net yield was considered. However, an additional 1020 kg/ha of tilapia foodfish averaging 233 g were also produced in this treatment. When the tilapia foodfish production was added to the catfish produced, both the total yield of marketable fish (3936 kg/ha) and the FCR (1.40:1) were significantly better than the control treatment (ANOVA, $P < 0.05$). Assuming the catfish in this polyculture treatment converted feed as well as the controls (1.60:1), the 1020 kg/ha of tilapia produced consumed only 935 kg/ha of feed, for an FCR of 0.92:1. While tilapia grew to a marketable size in a single season, and the economics of this polyculture system appear favorable, we believe that there are a number of practical constraints to the successful application of this technology. Tilapia are difficult to harvest by seining alone, and a complete harvest would (and did) require total pond draining in the fall. Even if farmers found this acceptable, the entire tilapia crop would have

Table 1. Stocking, net catfish yields and incidence of catfish off-flavor of catfish monoculture and catfish/tilapia polyculture ponds in 1982 and 1983 (means of three replicate ponds per treatment).

Year	Treatment	Date tilapia stocked	Number tilapia stocked/ha	Amount fed (kg/ha)	Net yield (kg/ha)	FCR	Percent of samples off-flavor (N)
1982	Catfish Monoculture	-	-	5037 b[1]	3152 ab	1.60 b	67 (12)
1982	Tilapia Forage	April 25	30F+30M[3]	6451 a	3476 a	1.86 a	0 (12)
1982	Tilapia Foodfish	June 30	5000[2]	5601 ab	2916 b	1.92 a	0 (12)
1983	Catfish Monoculture	-	-	6237 a	3990 a	1.57 a	58 (14)
1983	Tilapia Forage	June 1	30F+30M[3]	6519 a	3991 a	1.64 a	13 (15)
1983	Tilapia Forage	July 6	90F+30M[3]	6117 a	3655 a	1.68 a	20 (15)

[1] Values in the same column followed by different letters are significantly different at the p=0.05 level. Data analyzed by year.
[2] Six- to seven-week old fingerlings averaging 6.1 g.
[3] Approximately one-year-old, sexually mature fish.

to be marketed in a relatively short time period. Few restaurants would be willing to introduce a new menu item that is only available seasonally (Pers. comm., Larry Joiner, Farm Fresh Farms, Inc.). Since the major constraint to tilapia foodfish production appeared to be marketing, not production, further research on tilapia foodfish/catfish polyculture was not conducted in 1983.

The ponds stocked with sexually mature tilapia in 1982 (tilapia forage treatment, Table 1) had a slightly higher net catfish production, but a significantly poorer FCR than the control treatment. Since the adult tilapia had been stocked in late April, they were able to begin spawning as early as May (Torrans and Lowell, 1985). Fry produced early in the year were large enough to eat whole pellets by late July, and thus competed directly with the catfish for feed for approximately three months. By the time the water was cold enough for the catfish to effectively catch and eat the tilapia (October), tilapia from the early spawns were too large (approximately 150 g to 200 g) to be consumed by the catfish. Thus, significantly more feed was given to the forage treatment over the growing season, little forage benefit was returned to the catfish, and a significantly poorer FCR resulted (Table 1). While these results were not all positive, we felt that further research on the forage benefit of tilapia was warranted. We believed that an increased stocking rate of adult tilapia and/or a later stocking date would result in an improved FCR.

Neither of the forage treatments in 1983 differed significantly from the catfish monoculture control with respect to either net catfish production or FCR (Table 1). We believe that the poorer FCR of the 1982 forage treatment was largely due to the date that the adult tilapia were stocked that year. The earlier (April 25) stocking of mature tilapia in the 1982 forage treatment, and the subsequent large size attained by the tilapia offspring, resulted in the significantly poorer FCR (1.86:1) seen in the forage treatment that year.

Overall catfish production in 1983 averaged 3879 kg/ha. Since the FCR of the catfish monoculture control treatments were nearly identical both years (1.60:1 and 1.57:1 in 1982 and 1983, respectively), we believe that the higher overall production in 1983 may be due to the greater average weight of the catfish stocked in 1983 (194 g average in 1983 versus 164 g in 1982). The greater initial fish biomass would have resulted in more feed being fed early in the season, prior to reaching the management-imposed limit on the feeding rate.

Water Quality

There were no significant differences in chlorophyll *a* between the polyculture and monoculture treatments in 1982 (Table 2). *Tilapia aurea* are size-selective phytoplankton grazers which selectively feed on particles larger than 25 μm (Drenner *et al.*, 1984). A selection pressure such as this on the phytoplankton community can result in a shift in the species composition to smaller, more rapidly reproducing species, rather than a reduction in overall phytoplankton biomass. In fact, heavy fish predation on the zooplankton has been shown to result in an overall increase in chlorophyll *a* (Burke and Bayne, 1986; Smith, 1985).

While differences in phytoplankton biomass were not detected, the zooplankton biomass was significantly lower than the control in both polyculture treatments in 1982. Both 1983 polyculture treatments had a reduced zooplankton biomass, however the difference was significant only in the treatment stocked with tilapia on June 1 (Table 2). A reduced zooplankton biomass in the polyculture ponds was expected, and at least partially accounts for the low (0.92:1) apparent FCR of tilapia. *Tilapia aurea* are escape-selective zooplankton predators that suppress populations of zooplankton with limited escape abilities (Drenner *et al.*, 1984). Other species with similar feeding strategies have also been shown to reduce the zooplankton biomass when raised in polyculture with channel catfish (Burke and Bayne, 1986; Torrans and Clemens, 1981).

The secchi disc visibility (a measure of water clarity) was less than the controls in all four polyculture treatments, and this difference was significant in three of the four treatments (Table 2). Since the reduced water clarity cannot be explained by increased zooplankton or phytoplankton biomass, we believe that it may be due to increased turbidity resulting from the tilapia foraging on the sediment surface for organic detritus and benthic invertebrates (McBay, 1961; Williamson and Smitherman, 1975).

Table 2. Comparison of four water quality parameters between catfish monoculture (control) ponds and catfish/tilapia polyculture ponds during 1982 and 1983. Values given are means ± SE (N) for the time period after the tilapia were stocked. Treatment means were compared to the control by sample date (Paired T-Test). Asterisks mark values that are significantly different from zero (*P < 0.05; **P < 0.01).

Year	Treatment	Zooplankton dry weight (mg/L)	Chlorophyll a (μg/L)	Oxygen (mg/L)	Secchi disc visibility (cm)
1982	Control[1]	3.16±0.46 (55)	47.2±7.8 (86)	4.97±0.26 (86)	11.6±0.6 (85)
	(From April 25)	**	N.S.	*	*
	Tilapia forage (Stocked April 25)	1.46±0.41 (57)	40.0±4.3 (87)	4.30±0.22 (87)	9.6±0.4 (87)
	Control[1]	3.08±0.46 (52)	34.4±3.3 (60)	4.87±0.30 (60)	13.0±0.6 (60)
	(From June 30)	**	N.S.	**	**
	Tilapia foodfish (Stocked June 30)	1.53±0.30 (54)	32.1±3.5 (58)	3.45±0.29 (59)	11.2±0.5 (60)
1983	Control	2.92±0.42 (47)	-	3.96±0.11 (313)	10.4±0.4 (48)
	(From June 1)	*		**	N.S.
	Tilapia forage (Stocked June 1)	1.74±0.19 (46)	-	3.54±0.10 (315)	9.5±0.5 (48)
	Control	2.91±0.56 (35)	-	3.90±0.13 (250)	10.6±0.5 (39)
	(From July 6)	N.S		*	**
	Tilapia forage (Stocked July 6)	1.91±0.25 (36)	-	3.13±0.11 (251)	8.2±0.3 (39)

[1] Two mean values are given for the control treatment each year since different time periods are being compared.

Dissolved oxygen, perhaps the most important water quality parameter from a commercial production standpoint, was significantly lower in all polyculture treatments when compared to the controls (Table 2). The dissolved oxygen concentration measured at dawn averaged 0.4 mg/L to 1.4 mg/L less in the polyculture treatments. This was unexpected and certainly undesirable from a production standpoint, although production and FCR's were apparently unaffected by it. The reduced oxygen concentrations may have been due in part to the increased turbidity, which could reduce photosynthesis, or to the respiration of the increased fish biomass.

Off-flavor of Channel Catfish

The most important finding of this study was the reduced incidence of off-flavor in channel catfish reared in polyculture with blue tilapia. None of the catfish from the polyculture treatments were off-flavor in 1982 (Table 1), compared to a 67% incidence of off-flavor in the catfish monoculture ponds. Catfish fromt he two 1983 polyculture treatments were off-flavor 13% and 20% of the time (Table 1), compared to 58% for the catfish reared in monoculture that year. Overall, the incidence of catfish off-flavor averaged 8.3% for the tilapia/catfish polyculture treatments, versus 62.5% for the catfish monoculture controls. To our knowledge, this represents the first management technique shown to be effective in reducing the incidence of off-flavor in pond-raised channel catfish.

The dynamics of off-flavor in channel catfish are poorly understood. A variety of "off-flavors" have been detected in channel catfish, including "sewage", "stale", "rancid", "metallic", "mouldy", "petroleum", "weedy", and "musty-muddy". Only the "musty-muddy" flavor has been tied to specific compounds, namely geosmin (trans, 1, 10,-dimethyl-trans-9-decalol) and 2-methylisoborneol (Lovell, 1983).

Geosmin and methylisoborneol are produced by actinomycetes and certain blue-green algae (Medsker *et al.*, 1968; Safferman *et al.*, 1967; Silvey, 1966). However, a simple correlation between the presence of specific organisms in the water and catfish off-flavor has not been established (Armstrong *et al.*, 1986). It is likely that the production of odorous compounds results from only certain combinations of interactions of organisms and environment (Silvey, 1966).

With this in mind, it is impossible to say with certainty exactly what caused the reduced incidence of catfish off-flavor observed in our study. The tilapia may have directly reduced the blue-green algae populations by filter-feeding, or affected the actinomycetes by foraging on the sediment for detritus and benthic invertebrates. They may have indirectly influenced the system by consuming "fines" or feed normally wasted by the catfish, or by increasing the turbidity of the water.

Our data indicate that tilapia/catfish polyculture is effective in reducing the incidence of off-flavor in pond-raised channel catfish. If these findings are consistent across a large geographical area, it could result in multi-million dollar savings to the industry.

CONCLUSIONS

1) The production of tilapia foodfish in polyculture with channel catfish could be economical if tilapia can be marketed. Major constraints are that tilapia are difficult to harvest by seining, and they would have to be marketed in a relatively short time period in the fall.

2) Tilapia produced as forage for catfish had no affect on overall catfish production and FCR when the adult tilapia were stocked no earlier than June 1. Earlier stocking resulted in increased catfish production but a poorer FCR.

3) All polyculture treatments had significantly lower dissolved oxygen concentrations than the controls. While this had no observable effect on catfish food conversion, it may increase the overall risk of fish losses due to oxygen depletion. The polyculture treatments had a reduced zooplankton biomass and were more turbid, but had similar chlorophyll *a* concentrations to the controls.

4) Catfish raised in polyculture with tilapia had a significantly lower incidence of off-flavor than did catfish raised in monoculture. This management practice could provide a significant economic benefit to the catfish farming industry.

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A CARTOGRAPHIC TREND ANALYSIS OF FURBEARER HARVEST DISTRIBUTIONS IN ARKANSAS

RENN TUMLISON, MARK TRAIL
Oklahoma Cooperative Fish and Wildlife Research Unit
and Department of Zoology
Oklahoma State University
Stillwater, OK 74078

and

V. RICK McDANIEL
Department of Biological Sciences
Arkansas State University
State University, AR 72467

ABSTRACT

Average by-county fur harvest for the last nine harvest seasons (1977-1985) was used as data points to be interpolated using nearest neighbor algorithms in computer-assisted trend analyses. COMPLOT maps were produced which represented a surface of harvest densities drawn over a map of Arkansas. Twelve furbearer species are examined, and "topographic" features of harvest density for each are interpreted in terms of ecology and/or buyer distribution. The trend surface technique removed some of the error inherent to harvest records, and produced an aesthetic graphical display of the information that was more easily interpreted and explained than other methods of analysis usually allow.

INTRODUCTION

Furbearer harvest records in Arkansas have received an appreciable amount of attention in recent years (Bailey and Heidt, 1978; Tumlison *et al.*, 1981; Tumlison *et al.*, 1982; Heidt *et al.*, 1984; Clark *et al.*, 1985; Heidt *et al.*, 1985; Peck and Heidt, 1985; Peck *et al.*, 1985; Tumlison and McDaniel, 1986). Analyses have examined questions of species distribution, effect of price on harvest level, and effect of furbuyer distribution on reported harvest. Heidt *et al.* (1985) and Peck *et al.* (1985) analyzed Arkansas fur harvests at a state and regional level, both using harvest records collected by the Arkansas Game and Fish Commission (AGFC) since 1942. The purposes of this paper are: 1) to analyze harvest records at a by-county level and 2) to demonstrate a new technique that may be applied to analysis of harvest records.

Fur harvest records have been compiled, by county, by the AGFC for each of the last nine harvest seasons (1977-78 through 1985-86). During the first few of these years, by-county results were displayed in tabular form, and in the latter years results were displayed on Arkansas maps. The use of maps rather than tables enhances interpretation, but yearly fluctuations obscure long-term trends, as they are affected by market trends, weather, furbearer population densities, and furbuyer distribution. Some of the annual variation may be decreased by averaging reported harvest levels for each ccounty over a period of several years. We used such averages as input data for computer-assisted cartographic analyses of harvest trends for twelve Arkansas furbearers.

METHODS AND MATERIALS

Several computer packages (e.g., SYMAP, SURFACE II, SASGRAPH, CALFORM) are available for generating maps. SYMAP fits a surface to data points located within a map outline, and one of the electives provides a plot of residuals which can be analyzed to show strengths and weaknesses in the fit of the generated surface to the data (in a manner similar to regression analysis of bivariate data). A more asesthetic map, albeit with less statistical information, is produced using the SURFACE II algorithm. This program generated the maps presented here.

The SURFACE II program requires two data sets: 1) an outline map obtained by identifying cartesian coordinates of landmark points around the map perimeter, and 2) a set of data to be plotted. Three values (identified as X, Y, and Z) are required in this data set. The X and Y values are cartesian coordinates of the data points, and the Z value is the datum to be placed at the coordinates. We approximated the centroid of each of the 75 counties on an Arkansas map and used the coordinates of these centroids as X and Y values, and used the nine-year means for each county as Z values. The SURFACE II program interpolated these points using nearest neighbor algorithms, and generated a contour surface similar to that seen in topographic maps. After the map was generated, it was drawn by a COMPLOT drum plotter to create a "publishable quality" map.

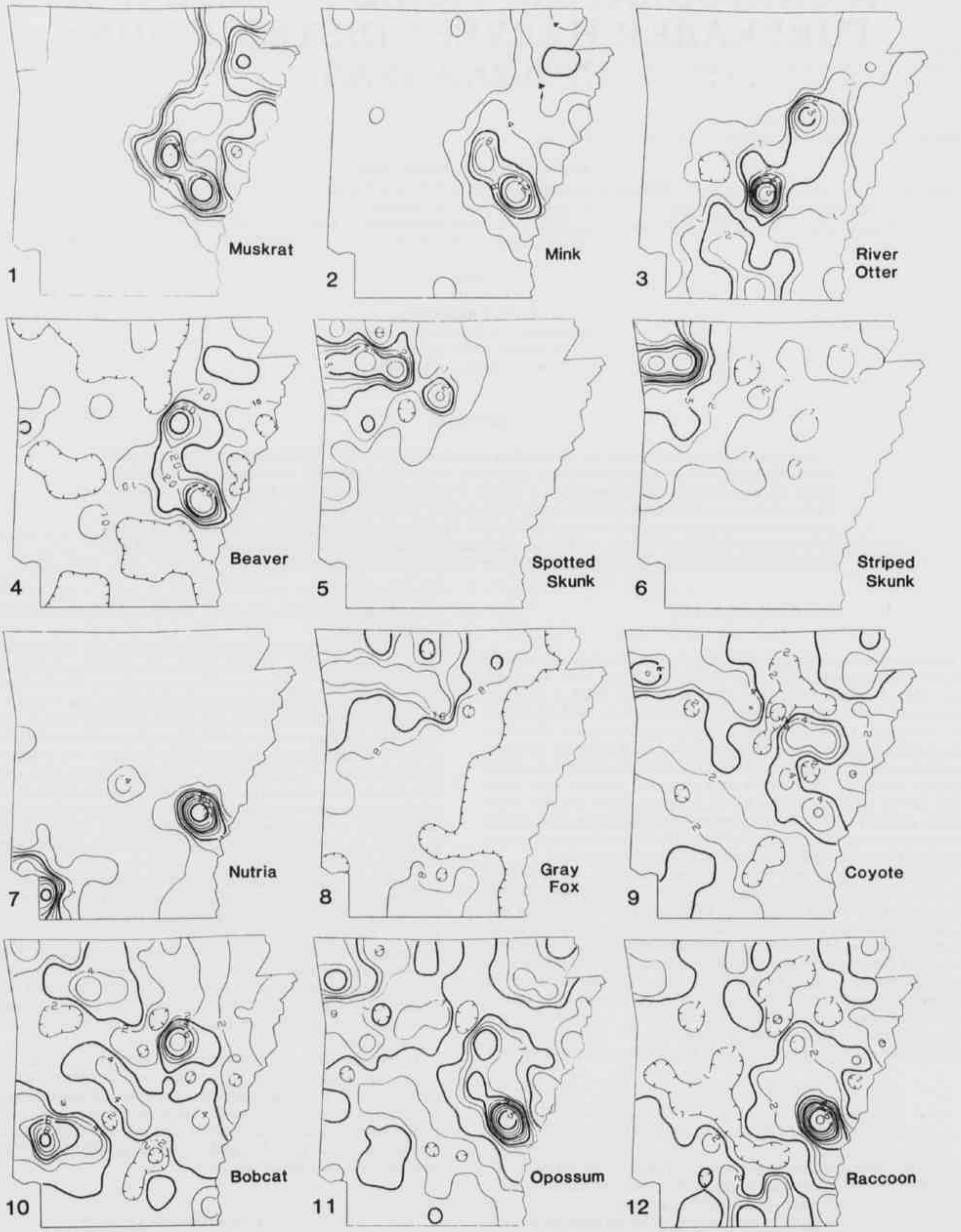
The user controls the number of contour intervals to be interpolated and drawn. Too many contours will isolate data points and are of little use, and too few may hide information. We found 8-12 intervals to be good for most cases.

The interpretation of contour lines is somewhat obscure. Technically, we would say that a contour of ten represents 10 individuals per area of the average size of a county. Rather than imposing this interpretation, it is more useful to envision contour lines as indicators of harvest density, paying more attention to the distribution of lines than to their numerical values.

The program has some idiosyncrasies. Hatchering always occurs in the lowest contour level of the map and is interpreted as base "topography". However, unclosed base contours (those that touch map boundaries) do not get hatchered. The map produced by the computer (rather than the COMPLOT) can be used to locate these contours, and we hatchered such areas by hand. As in topographic maps, hatchering also indicates depression contours.

RESULTS AND DISCUSSION

COMPLOT maps are provided for common furbearer species in Figs. 1-12. Below is a description and interpretation of each map, by species.



Figures 1-12. Contour maps for 1) muskrat, 2) mink, 3) river otter, 4) beaver, 5) spotted skunk, 7) nutria, 8) gray fox, 9) coyote, 10) bobcat, 11) opossum, and 12) raccoon, respectively.

Muskrat *(Ondatra zibethicus)*

The map (Fig. 1) has a contour interval of 0.25; each interval equaling 250 individuals. The muskrat is a wetland furbearer whose population level is determined largely by shoreline length (Glass, 1952); the map clearly depicts the large muskrat harvests in the Delta region. The area of greatest harvest density occurs in east central Arkansas, corresponding with the Grand Prairie region (Foti, 1974). Agricultural practices for rice have greatly increased shoreline habitat available to muskrats in this area, probably explaining the harvest distribution (Peck *et al.*, 1985).

Mink *(Mustela vison)*

The map (Fig. 2) has a contour interval of 2; each interval equaling 200 individuals. The mink is a wetland furbearer, and the map very closely resembles the map for muskrats, including a greatest density in the Grand Prairie area. Most individuals come from the Delta, but a few scattered locations also are suggested to produce several mink.

River Otter *(Lutra canadensis)*

The map (Fig. 3) has a contour interval of 0.5; each interval equaling 5 otters. Otters occur almost statewide (Tumlison *et al.*, 1981) but the map suggests that most individuals are trapped in the Delta and Gulf Coastal Plain, especially in the central portion of the southern two-thirds of the state. Comparison of the map with a map of river systems suggests most specimens are trapped from portions of the Ouachita, Saline, Arkansas, and White river systems. Tumlison *et al.* (1982) suggested increases in beaver populations in the Gulf Coastal Plain and Ouachita Mountains may account for otter expansion through habitat increases caused by beaver activity.

Beaver *(Castor canadensis)*

The map (Fig. 4) has a contour interval of 5; each interval equaling 50 beavers. Beavers were practically extirpated from Arkansas early in this century, but restocking efforts led to re-establishment (Holder, 1951). From 1942-1984, the Delta had yielded almost twice the harvest of each of the other three regions (Peck *et al.*, 1985), but the density suggested on the map reflects a trend even more highly favoring the Delta in the recent period of 1977-1985.

Spotted Skunk *(Spilogale putorius)*

The map (Fig. 5) has a contour interval of 0.5; each interval equaling 5 spotted skunks. Although spotted skunks are thought to occur almost statewide (Sealander, 1979), 92% of the harvest from 1942-1984 was from the mountainous regions of the state (Peck *et al.*, 1985). The map suggests the western Boston Mountains area to be the primary source of pelts in recent years.

Striped Skunk *(Mephitis mephitis)*

The map (Fig. 6) has a contour interval of 1; each interval equaling 10 individuals. The striped skunk occurs statewide (Sealander, 1979) but, like the spotted skunk, most of the harvest comes from the mountainous regions, especially the northwest corner of Arkansas. During the period 1942-1984, however, the Delta produced 54% of the total harvest and the Ozarks only 32% (Peck *et al.*, 1985). Peck *et al.*, (1985) suggested that a major decline in pelting was correlated with an epizootic of skunk rabies, which peaked in 1979 (Heidt, 1982; Heidt *et al.*, 1982). In recent years, only the trappers and buyers of the Ozark region appear to have continued a noticeable amount of pelting of striped skunks.

Nutria *(Myocastor coypus)*

The map (Fig. 7) has a contour interval of 2; each interval equaling 20 nutria. Bailey and Heidt (1978) noted that nutria were most solidly established in the southern portion of the West Gulf Coastal Plain, and in the southern and eastern Delta. The Arkansas River was also included in their proposed range. The map indicates that these observations remain true since 1978. The high harvest density in the vicinity of Arkansas County includes the Grand Prairie, used extensively for rice production. Further, the Arkansas and White rivers meet there, and form potential dispersal corridors. The two sets of contours near mid-state represent populations along the Arkansas River.

Gray Fox *(Urocyon cinereoargenteus)*

The map (Fig. 8) has a contour interval of 4; each interval equaling 40 foxes. Between 1942-1984, the Ozarks produced 55% of the harvest, followed by the Delta at 16% and the Gulf Coastal Plain at 15% (Peck *et al.*, 1985). Since 1977, the Delta produced the fewest gray foxes, but the Ozarks still contributed the most to the total harvest. The area of greatest harvest density corresponds with the Boston Mountains area.

Coyote *(Canis latrans)*

The map (Fig. 9) has a contour interval of 1; each interval equaling 10 coyotes. The primary harvest areas include much of the Ozarks and the west-central Delta. The coyote expanded into central Arkansas by the 1950's and became established throughout Arkansas in the early 1960's (Sealander, 1979), thus 37% of the harvest between 1942-1984 came from the Ozarks (Peck *et al.*, 1985). Poultry occurred often in coyote diets (Gipson and Sealander, 1976), thus coyotes may be more common in the Ozarks due to the poultry industry (Sealander, 1979) or because the Ozarks were the initial point of invasion by expanding populations of coyotes (Peck *et al.*, 1985). Coyotes are ubiquitous probably because they are opportunistic omnivores (King, 1981) and because agriculture and forest industries have provided suitable habitat to allow invasion.

Bobcat *(Felis rufus)*

The map (Fig. 10) has a contour interval of 1; each interval equaling 10 bobcats. The primary regions of harvest between 1942-1984 were the Ozarks (31%) and Delta (28%), with the Ouachitas and Gulf Coastal Plain even at about 20% of reported harvest (Peck *et al.*, 1985). However, in the period 1977-1985 the primary harvest has been in an area including portions of the Gulf Coastal Plain and Ouachitas in southwestern Arkansas, and an area including portions of the Ouachitas and Delta in central Arkansas.

Opossum *(Didelphis virginiana)*

The map (Fig. 11) has a contour interval of 0.25; each interval equaling 250 opossums. Peck *et al.* (1985) noted that 35% of the opossum harvest between 1942-1984 came from the Ozarks, and 32% from the Delta. Between 1977-1985, greatest opossum harvest has been reported from the central portion of the Delta.

Raccoon *(Procyon lotor)*

The map (Fig. 12) has a contour interval of 0.5; each interval equaling 500 raccoons. Raccoons have been harvested primarily from the Delta (42%) and Gulf Coastal Plain (23%) between 1942-1984 (Peck *et al.*, 1985), and the same trend appears to be true in the shorter, more recent, period. The greatest harvest density appears in the vicinity of Arkansas County, which includes the White River National Wildlife Refuge and part of the Grand Prairie sub-region.

Several questions can be addressed through a comparison of the maps. Perhaps the simplest question concerns ecological distribution. Harvest of wetland furbearers, such as muskrat and mink, are closely associated with the wet and agricultural Delta region. River otter, beaver, and nutria also are harvested most where their habitat preferences would suggest; however, maps for spotted and striped skunks do not fit well with their distributions. The latter case is probably effected by an epizootic of rabies (Peck *et al.*, 1985).

The effect of furbuyer distribution may be examined in some maps. Peaks in the vicinity of Arkansas County in the central Delta occur for muskrat, mink, beaver, nutria, coyote, opossum, and raccoon. This area could represent near optimal habitat for these species. The first four of these taxa are wetland species, and the rest are opportunistic omnivores. The area of interest has bottomland hardwoods along the Arkansas and White Rivers and their tributaries, and contains much of the Grand Prairie sub-region, which represents a unique habitat. Food supplies for these species are likely abundant. Thus, the greater number of buyers in this area may be a reflection of the availability of the fur resource due to habitat. Alternatively, there may be a greater harvest from this area because there are more markets therefore greater trapping pressure. Tumlison (1983) examined the distribution of furbuyers using the mean number licensed per county over four years (1977-1980). Several counties in the Delta (White, Lonoke, Prairie, Monroe, Arkansas, Lincoln, and Desha) were contiguous and had five or more buyers, whereas most other counties had two or less. This group of counties does much to explain the contours for beaver, coyote, opossum, and raccoon. From the data, however, it cannot be determined which factor drives the system.

Similarly, peaks in the Boston Mountains for spotted and striped skunks, gray fox, and coyote may be explained by buyer distribution. Washington, Madison, Searcy, and Van Buren counties, all in the Boston Mountains area, had 3-5 buyers each. Nine buyers in White County in the Delta may partially explain apparent harvest density peaks for river otter, beaver, coyote, and bobcat, but the peak for bobcat in southwestern Arkansas is not easily explained in this manner due to no correlates in other species maps.

If we predict that more pelts are reported from counties with many buyers, we must assume that fewer pelts were reported in areas with few buyers. Here, we examined ubiquitous species which occur in areas with many as well as few buyers. Coyote, bobcat, opossum, and raccoon occur statewide, but, in each case, there is a band with low harvest densities running through the southern half of the state in a northwest to southeast direction. Interestingly, six of the counties represented in these general bands had no buyers, five had one buyer, and one had two buyers. Apparently, a lack of buyers means low reported harvest and several buyers means high reported harvest. In some cases, more buyers may be able to operate in an area due to higher furbearer population densities, but more likely inaccurate reporting leads to incorrect placement of harvest densities.

CONCLUSIONS

The use of trend analysis maps allows questions to be asked and examined concerning harvest distributions. Trend maps can be used to establish trends through time or to compare across species in a particular time frame of interest. Trend maps can also suggest where emphasis in field studies should be made. This technique should prove quite useful in the continuing analysis of harvest data and population status of Arkansas furbearers.

In the present analysis, some harvest maps are consistent with species ecology. Maps for several species (i.e., coyote, bobcat, opossum, raccoon) suggest weaknesses may exist in the reporting of harvests on a county basis. It would be instructive to interview buyers and trappers in the low-harvest zone of southern Arkansas and in high-harvest zones of Arkansas and White counties and the Boston Mountains, to see whether harvest distributions are more biased through population density or reporting.

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TEXTURAL AND LITHOLOGIC DIFFERENCES OF CRETACEOUS, TERTIARY, AND QUATERNARY GRAVELS OF SOUTH ARKANSAS

LESLI WOOD
Department of Geology
University of Arkansas
Fayetteville, AR 72701

ABSTRACT

Stream gravels have been derived from the Ouachita Mountains since at least Cretaceous times. Past studies have assigned ages to gravel deposits in the basins of the Saline and Little Missouri Rivers on the basis of altitude above local floodplains. This study examines the lithologies and textures of seven gravel outcrops ranging in age from Cretaceous to Quaternary to determine whether any patterns of variation based on assigned ages, variable sources, or precise depositional setting can be discerned. No variation patterns could be found for size distributions of sand-sized and larger fractions. However, the amount of silt-clay matrix decreases through time from a high of 24% in Cretaceous samples to 6% in Holocene materials. The ratio chert:sandstone (C:S) varies irregularly. Roundness and sphericity are low in Cretaceous samples, and uniformly higher in later materials, though the highest mean roundness found was in a Cretaceous sample. Purple chert clasts occur only in Cretaceous samples, where the percentage of red chert is also higher. Most chert in Cenozoic deposits is brown. These differences are attributed to age and weathering. Those above depend on the source area and its distance from the depositional site.

INTRODUCTION

The Ouachita Mountains have been a source area for stream gravel at least since the Cretaceous. Gravels ranging in age from Cretaceous to Quaternary have been deposited along the margins of the province. Extensive gravel deposits of Cretaceous age occur on the Gulf Coastal Plain in south Arkansas. Isolated outcrops of gravel inferred to be Tertiary, occur on the primary divides of the Athens Plateau subprovince of the Ouachita Mountains, north of the Gulf Coastal Plain (Fig. 1). Quaternary gravel has been deposited as terrace and floodplain sediments in the present stream valleys. Previously the gravel deposits were assigned ages based on their elevation above local floodplain. Inconsistencies in dating these deposits have resulted. Commonly deposits mapped as one age by one individual may be mapped as another age by a second (Miser, 1929; Petroleum Information Corporation, 1984).

This pilot study was initiated to determine if there are any major lithologic or textural differences among gravel deposits of various ages in a small study area. In addition, the data on the gravel was used to determine if the source or environment of deposition has changed laterally or temporally.

STUDY AREA AND SAMPLE SITES

The study area is located within the Athens Plateau subprovince of the Ouachita Mountains Province and along the northern margins of the Gulf Coastal Plain Province (Fig. 1). Strata exposed within the study area are Mississippian-Pennsylvanian sandstones and shales and Cretaceous, Tertiary and Quaternary gravels.

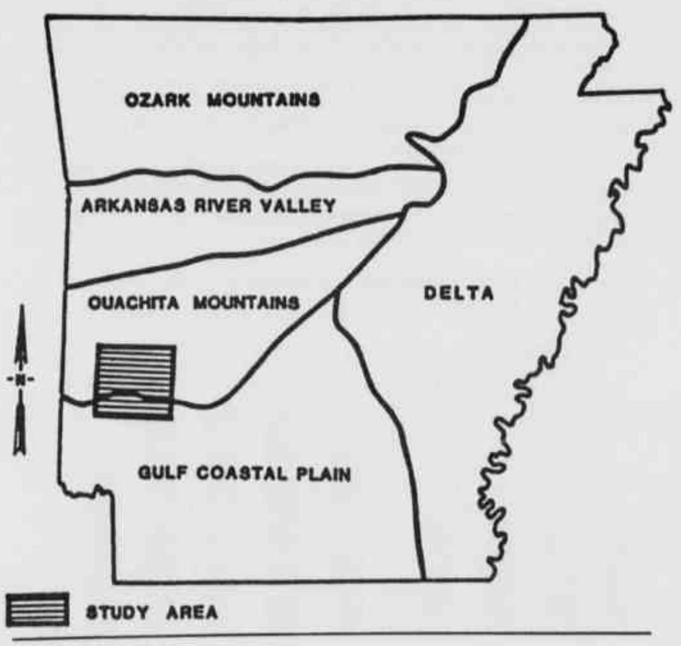

Figure 1. Index map showing study area and geologic provinces of Arkansas.

SITE Qal-1
LOCATION: NE1/4,NW1/4,SW1/4,Sec 3,T8S,R29W; approxmately 7km west of Dierks, Arkansas on the south side of Arkansas State Highway 70. This stream cut is along the eastern bank of the Saline River.
STRATIGRAPHY: This deposit consists of recent floodplain gravel of Quaternary age deposited on Paleozoic sandstones and shales of the Jackfork Formation.
SAMPLE: Sample Qal-1 was taken approximately 5 m up from the waters edge from the stream cut bank.

SITE Qal-2
LOCATION: SW1/4, SE1/4, SW1/4, Sec 8, T6S, R28W; located along the Saline River just off of Weyerhauser road 32790, and east of Umpire, Arkansas. This stream-cut is found approximately 50 m upstream from the bridge on the east side of the river.
STRATIGRAPHY: This recent floodplain gravel directly overlies the Paleozoic sandstones and shales of the Jackfork Formation.
SAMPLE: Sample Qal-2 was taken approximately 0.3 meters below the land surface.

SITE Qt-1
LOCATION: SE1/4, SW1/4, NE1/4, Sec 3, T8S, R29W; approximately 5 km west of Dierks, Arkansas on the left side of Arkansas State Highway 70. This outcrop is a roadcut in a terrace.
STRATIGRAPHY: This Quaternary age terrace directly overlies the Cretaceous deposits in the area, but the contact is not exposed at this site.
SAMPLE: Sample Qt-1T was taken 1 m below the land surface. Sample Qt-1B was taken approximately 2 m below the land surface.

SITE Qt-2
LOCATION: NW1/4,SE1/4,SW1/4,Sec 16,T5S, R27W; approximately 10 km east of Athens, Arkansas on Arkansas State Highway 84, then right 0.3 km on a small gravel road that parallels the Little Missouri River southward. This floodplain terrace is found on the east side of the Little Missouri River about 40 m from the river.
STRATIGRAPHY: This deposit is a terrace, deposited within the modern floodplain of the Little Missouri River. This Quaternary age deposit overlies the Paleozoic sandstones and shales of the Jackfork Formation.
SAMPLE: Sample Qt-2 was taken 1.1 m below the surface of the outcrop.

SITE T-1
LOCATION: NW1/4,NW1/4,SE1/4,Sec 26,T5S,R28W; roadcut located approximately 180 m above present day stream level on the eastern side of Weyerhauser road 35340.
STRATIGRAPHY: This deposit is speculated to be Tertiary in age (Miser,1929) and directly overlies the Paleozoic sandstones and shales of the Jackfork Formation.
SAMPLE: Sample T-1 was taken from the roadcut, 0.5 m down from the land surface.

SITE K-1
LOCATION: SE1/4,NW1/4,SW1/4,Sec 29,T7S,R28W; 0.5km east of State Highway 70 at a farm house in Dierks, Arkansas.
STRATIGRAPHY: This deposit is of the Pike Gravel Member of the Trinity Formation (Lower Cretaceous) and unconformably overlies the Jackfork Sandstone.
SAMPLE: K-1T was taken 8 m down the face of the outcrop from the top of the hill. K-1B was taken approximately 2 m below K-1T.

SITE K-2
LOCATION: NW1/4,NW1/4,NW1/4,Sec 18,T7S,R25W; a small gravel pit approximately 2 km south of the Narrows Dam on Lake Gresson on the eastern side of the Little Missouri River and the west side of State Highway 19.
STRATIGRAPHY: This outcrop of the Pike Gravel is Lower Cretaceous in age and overlies the Jackfork Formation (Pennsylvanian) in this area.
SAMPLE: Sample K-2 was taken 1.75 m to 2.5 m from the land surface.

METHODS

Three principal methods were utilized in this study: field observation, laboratory size analysis, and lithologic identification. Samples of gravels mapped as Cretaceous, Tertiary, and Quaternary gravels were taken at seven locations, shown in Fig. 2. The age of the samples were based on published maps of Miser and Purdue (1929), current Arkansas Geological Survey maps of the area, personal communication with Mr. William Willis of Weyerhauser Industries, and topographic position. At these same locations, observations were made regarding sedimentary structures, bedding contacts, and the character of any overlying and underlying deposits. Samples were returned to the lab and a sub-sample of between 30 and 40 g was used for textural analysis of the <2mm fraction. The sand fraction was dry sieved, and the silt and clay fractions were analyzed by standard pipette analysis (Day, 1965). The >2mm fraction was dry sieved into multiple gravel fractions. The percent by weight was calculated for the less than 2mm fraction and for the total sample. Cobbles were those particles >64mm, pebbles were 64 mm to 4mm, granules were 4mm to 2mm, sand was 2mm to 0.03125mm, silt particles were those 0.03125mm to 0.0039mm, and clay particles were 0.0039mm to 0.00048mm. Textural and lithologic analysis of 200 pebbles included sphericity, roundness, and lithology. The lithology and roundness of 50 cobbles was also noted. The degree of rounding and sphericity was analyzed semi-quantitatively. Two hundred pebbles and fifty cobbles from each sample locality were assigned to both roundness and sphericity classes (Lewis, 1984). The classes were assigned a number from 1 to 6 with the higher numbers representing increasing roundness and sphericity. The number of individuals in each class was then mutliplied by the number assigned to that class. The results were totaled and the mean calculated. The means are referred to as the weighted mean of sphericity and roundness.

Figure 2. Map of the study area with sample locations, gravel deposits and novaculite outcrop.

RESULTS

Cretaceous samples were taken in two localities (Fig. 2). Both outcrops are the Pike gravel Member of the Trinity Formation (Lower Cretaceous). The unit forms the basal member of the Trinity Formation within the study area and overlies a pronounced angular unconformity which truncates the upturned edges of the steeply dipping sandstone and shale of the Jackfork Formation. This unconformity represents a one-hundred-fifty million year hiatus in sedimentation (Miser, 1929). The Pike Gravel forms a dissected, southward-dipping surface along the northern edge of the Gulf Coastal Plain in southern Arkansas. It is composed dominantly of sandstone, quartz, and chert pebbles and cobbles derived from the Paleozoic strata which crop out in the Ouachita Mountains to the north. The unit is normally 6 to 15 m thick, but may be as much as 30 m near Pike, Arkansas (Miser, 1929). This gravel unit was deposited by streams and along the shoreline during the initial advance of the early Cretaceous sea into the south Arkansas area.

Tertiary

Tertiary gravel was sampled from a single outcrop approximately 106 m above the adjacent streams on a primary divide in the Athens Plateau subprovince (Miser, 1929) (Fig. 2). This gravel, as initially deposited on an unconformity in broad valleys, cut 30 to 90 m below a presumed Tertiary surface. Most of this gravel has been removed by erosion, but several outcrops of coarse gravel still cap the hills in the area. Remnants of the Tertiary surface without the overlying Tertiary gravel occur in some areas of the Ouachita Mountains (Miser, 1929) (Fig. 1).

Quaternary Terrace Gravels

Quaternary terrace gravel was sampled at two locations, in the Little Missouri River valley and the Saline River valley (Fig. 2). The width of the terraces increased markedly at the northern margin of the Gulf Coastal Plain Province compared to that of the terraces in the Athens Plateau Subprovince. The height of the terraces in the southern part of the study area is 10 to 45 m above stream level. The underlying deposits are mainly composed of chert and sandstone fragments, subangular to well rounded, and ranging in size from granules to cobbles. The gravels are derived from the Ouachita Mountains and reworking of Cretaceous gravels. These outcrops are differentiated from those mapped as Cretaceous by their lower elevation, association with the modern stream valleys, abundant sedimentary structures, and buried soil horizons.

Quaternary Channel Gravels

Holocene gravel was sampled at two locations along the Saline River (Fig. 2). The deposits have been derived from erosion of the adjacent terrace deposits, Paleozoic strata in the Ouachita Mountain Province, and Cretaceous gravel in the Gulf Coastal Plain Province. They are similar in composition and texture to older Quaternary Terraces which have been described, but have higher concentrations of the Pennsylvanian bedrock and lower concentrations of the reworked Cretaceous gravel than the terraces. The distribution of the gravel is confined to the flood plain of stream valleys.

Variables Affecting Gravel Character

Several variables have affected the lithology and texture of the various gravel deposits in the study area; including depositional environment, distance of transport from the Ouachita Mountains, drainage basin, and age.

Depositional Environments

Gravel character is affected by the environment in which it is deposited. Both the modern stream gravel and the Quaternary terrace gravel were deposited in stream channels. The Tertiary gravel on the Athens Plateau was deposited in a similar environment (Miser, 1929). This unit is a thin deposit of water-worn gravel with abundant circular impact scars. Unlike the Quaternary and Tertiary gravel, much of the Cretaceous gravel is reported to have been deposited in a beach environment during the northward advance of the early Cretaceous seas across the south Arkansas area (Miser, 1929). Variation in character of the Cretaceous deposit has been attributed to various facies along the shoreline (Miser, 1929). Fluvial facies are also present in the more northern portion of Cretaceous gravel (Clardy, Arkansas Geological Commission, personal communication, 1987). K-2 is interpreted to be a fluvial deposit because it has abundant crossbedding, pebble imbrication, stratification and a mean roundness of 4.33 (rounded to subrounded). The source of the pebble-sized fraction of the gravel may be reworked beach deposits because the pebble fraction has an anomalously high degree of rounding (Table 1). K-1 is also interpreted to be a fluvial deposit because of its lack of stratification and its angularity (3.38, subangular to subrounded).

Table 1. Textural and lithologic data on various aged gravel deposits of the study area.

SAMPLE	SIZE PERCENTAGES *					LITHOLOGY PERCENTAGES *					COLOR PERCENTAGES OF TOTAL CHERT PEBBLE FRACTION				ANGULARITY PERCENTAGES *						
	cobble	pebble	granule	sand	silt and clay	chert	sandstone	novaculite	shale	quartz	red	brown	black	purple	very angular	angular	subangular	subrounded	rounded	very rounded	MEAN
Qal-1	15	60	5	15	5	62	34	2	2	0	10	74	16	0	2	0	28	45	17	8	3.99
Qal-2	10	58	8	16	8	40	34	15	9	2	10	65	25	0	0	7	31	44	13	5	3.78
Qt-1T	0	50	11	26	13	83	17	3	0	0	14	71	15	0	0	7	34	45	13	1	3.67
Qt-1B	13	65	4	11	7	78	15	7	0	0	18	66	16	0	2	8	37	43	9	1	3.52
Qt-2	20	52	4	10	14	39	25	32	3	0	5	41	54	0	0	5	35	45	14	1	3.71
T-1	38	29	4	6	23	36	24	38	0	2	0	89	11	0	2	3	30	42	18	5	3.86
K-1T	1	67	2	7	23	77	5	17	0	1	43	31	15	11	1	3	52	39	4	1	3.45
K-1B	21	45	4	8	22	77	11	9	0	3	57	30	3	10	2	13	45	31	9	0	3.32
K-2	0	61	7	5	27	39	25	32	3	1	6	60	34	0	0	0	25	32	28	15	4.33

*(All percentages are those of the pebble fraction of the samples.)

Distance from Ouachita Mountains

There are lithologic differences between the gravel in the Ouachita Province and the gravel located immediately to the south in the Coastal Plain Province (Fig. 1). Gravel of all ages located in the Coastal Plain Province contains a higher percentage of chert, (75%) compared to that in the Ouachita Province (39%) (Fig. 3). The cherts in the older gravel deposits to the north were apparently reworked when they were transported downstream and were concentrated in the gravels within the southern parts of the study area. In contrast, recent stream gravel in the Ouachita Mountain Province contain an appreciable amount of

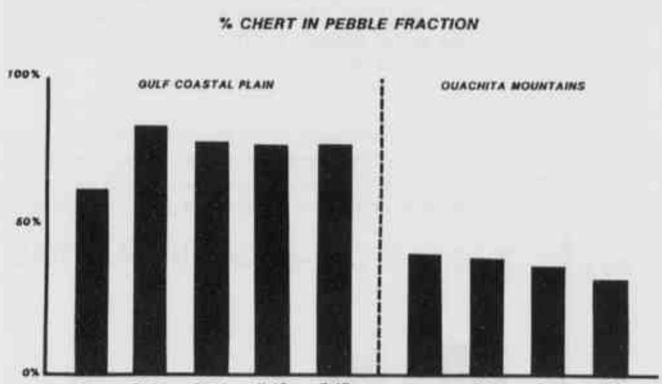

Figure 3. Bar graph of percent chert in the pebble fraction of gravel from the Gulf Coastal Plain Province and the Ouachita Mountain Province.

shale (10%) compared to recent stream gravel in the Coastal Plain Province. The shale in the stream deposits of the Ouachita Province was derived from the local shale outcrops of the Stanley Formation. This shale was apparently relatively unstable and was diminished in abundance downstream from the outcrop.

Drainage Basins

A third variable which affects the character of the gravel in the study area is the drainage basin in which the gravel was deposited. Gravel sampled from the Little Missouri River drainage basin in the eastern part of the study area differs lithologically from gravel sampled from the Saline River drainage basin in the western portion of the study area. The most noticeable difference in lithology is the relatively high amount

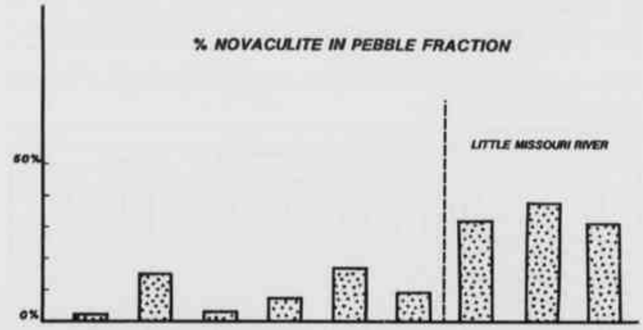

Figure 4. Bar graph of recent novaculite in gravels from the Little Missouri River and the Saline River drainage basin.

of novaculite (34%) in gravel from the Little Missouri River drainage basin (Fig. 4) compared to that in the Saline River drainage basin where novaculite composes only 9% of the gravel. Novaculite outcrops are present in the headwaters of the Little Missouri River drainage basin and are nearly absent from the area drained by the Saline River (Fig. 2). A less obvious lithologic difference between drainage basins is the greater abundance of black chert in the gravel from the Little Missouri River (33%) drainage basin compared to that in the gravel from the Saline River drainage basin (15%). The reason for this is unclear because chert color within the gravel deposits is affected both by weathering and by the original color of the chert.

Time

Many variables affect the character of the gravel deposits in the study area, as discussed above, but time appears to be dominant. The amount of clay increases in older gravel deposits compared to that of younger (Fig. 5) due to weathering and mechanical infiltration. The lithology

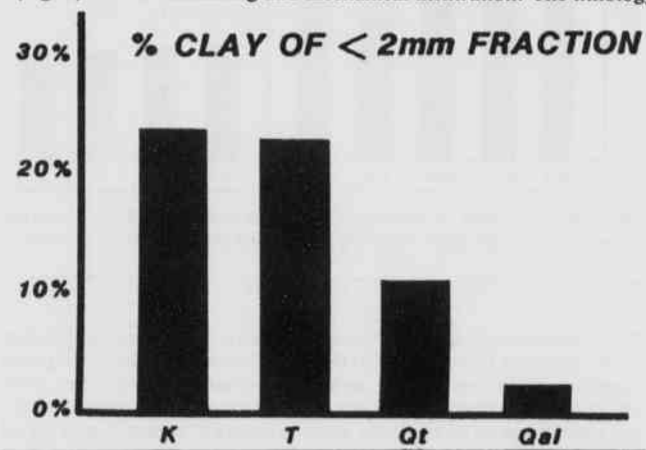

Figure 5. Bar graph of percent clay in gravel units of various ages.

of the gravel deposits also varies with age in the Saline River drainage basin. The percentage of red chert is 50% of the total chert in the Cretaceous gravel (Fig. 6). This red color is a weathering rind developed

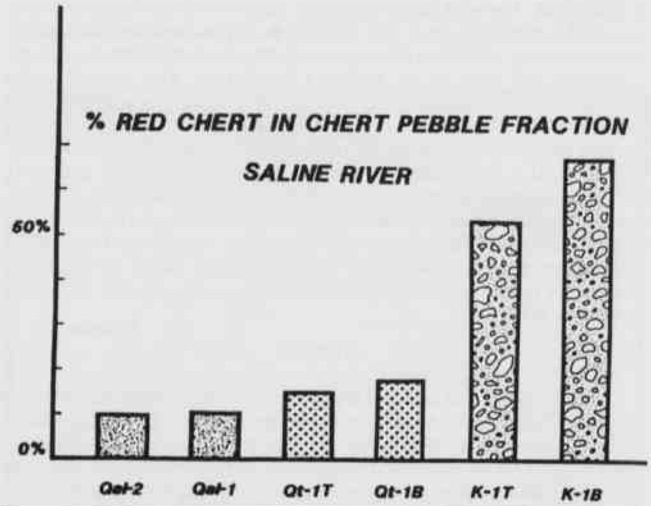

Figure 6. Bar graph of percent red chert in the chert pebble fraction of gravel units in the Saline River drainage area.

on the chert clasts. The percentage of sandstone also varies with age in a single drainage basin. The amount of sandstone is highest in the present channel gravel (34%). The Quaternary terrace gravel is intermediate in amount (19%), and the Cretaceous gravel has the least amount of sandstone (8%) (Fig. 7). Distribution of total chert and red

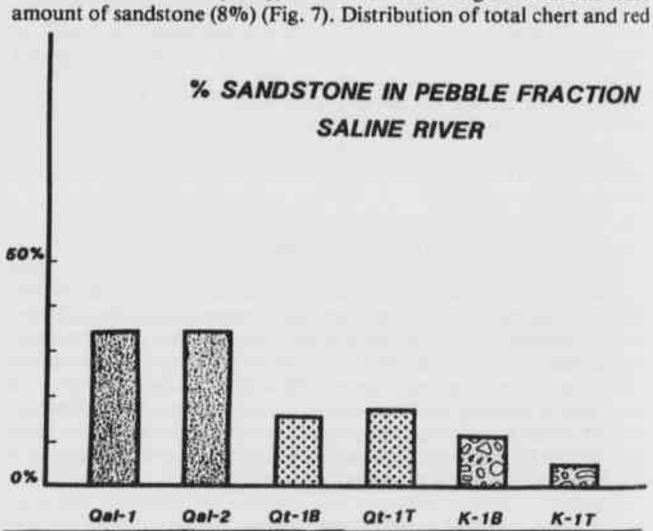

Figure 7. Bar graph of percent sandstone in pebble fraction of gravel units in the Saline River drainage area.

chert in Quaternary terrace deposits is probably controlled by the availability of older Cretaceous gravel deposits, which have a relatively high abundance of red chert and a low abundance of sandstone, for reworking and incorporation into younger deposits. In contrast, recent stream channels have eroded below the Cretaceous gravel and are eroding Pennsylvanian sandstone and shale. Therefore these recent gravels are composed of very little red chert, but have abundant sandstones.

DISCUSSION

Cretaceous gravel characteristically consists dominantly of subangular to subrounded chert, of pebble size or larger. In the field the gravel is distinguished by its red color caused by abundant red chert and the relatively high red clay content (24%) (Table 2), and by its presence on divides at the Ouachita Mountain-Gulf Coastal Plain Boundary. Cretaceous gravel unconformably overlies the Jackfork Formation in the study area. It occurs 90 to 260 m above the present floodplain and is generally below 200 m in elevation in the study area. This gravel has been mapped as Quaternary terrace deposits (Arkansas Geological Commission, 1976).

Tertiary gravel consists of subangular to subrounded chert, sandstone, and novaculite cobbles and pebbles. The chert present is dominantly brown in color. The coarse texture has allowed accumulation of a silt plus clay matrix (Table 1). In the field, Tertiary gravel can be recognized by its coarse texture (38% >16mm) and by its topographic position on primary divides within the Ouachita Mountain Province. It is generally 260 to 350+ m above sea level and 110+ m above present day stream level.

Quaternary terrace deposits are composed of subangular to subrounded chert with minor amounts of sandstone (Table 1). The clasts are mainly pebble-sized with a few cobbles. The dominant chert color is brown with a minor amount of red chert. Though often mistaken for Cretaceous deposits in the area, these terrace deposits contain a relatively low silt and clay percent (11%). The Quaternary terrace deposits are distinguished from older deposits by substantially less red chert, a finer texture, and abundant sedimentary structures.

Recent (Holocene) gravel are most easily recognized by their position on the present-day stream floodplains. They are composed of subangular to subrounded chert and sandstone. The lithology is strongly influenced by formations which outcrop in the immediate area (Table 1).

CONCLUSIONS

Though extensive gravel deposits do exist in south Arkansas, extensive research has not been done on their lithology and distribution. Most mapping has been accomplished by aerial photographs and field reconassance. The exception is the detailed map of the DeQueen and Caddo Gap Quadrangles done on horseback by Miser and Purdue (1929). The present study provides quantitative data and confirms most observations of Miser and Purdue. Differences do exist between the ages of gravel, both lithologically and texturally. These differences are relatively obvious in the field and allow recognition of these different gravels.

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GENERAL NOTES

RECENT COLLECTIONS OF FISHES FROM THE SPRING RIVER DRAINAGE IN NORTHEAST ARKANSAS

Several ichthyofaunal surveys have been conducted in the Spring River of Arkansas. Meek (1894) initially collected fish in some tributaries of the Upper Spring River. Buchanan (1973) sampled throughout the drainage in developing his *Key to the Fishes of Arkansas.* Several studies have been conducted in sub-basin tributary streams of the Spring River (Fowler and Harp, 1974; Bounds *et al.*, 1977; Johnson and Beadles, 1977; and Carter and Beadles, 1980). Winters (1985) conducted a survey of the Spring River ichthyofaunal for his master's thesis. Sampling throughout the Spring River basin has also been sporadically conducted by Arkansas Game and Fish Commission personnel.

An ichthyofaunal survey was conducted at eight locations within the main channel of the Spring River and South Fork of the Spring River in northeast Arkansas by the Arkansas Game and Fish Commission from September 1985 to September 1986. A total of 68 different fish species was collected. Sampling was performed by electrofishing, beach seining, and hoop netting.

Two species of fish were collected for the first time from the Spring River. *Moxostoma macrolepidotum,* the shorthead redhorse, was moderately common in samples collected from the Hardy area (NE ¼, S11, T19N, R5W) south to Williford (SE ¼, S36, T19N, R4W). *M. macrolepidotum* was collected by electrofishing in deeper pools below riffle areas, and was often found in conjunction with *M. erythrurum.* Although widely distributed throughout central and eastern United States (Jenkins, 1980), *M. macrolepidotum* has not previously been documented from the Spring River drainage.

Carassius auratus, the goldfish, was also collected from the Spring River at Hardy (NE ¼, S11, T19N, R4W). One specimen was collected by electrofishing in a deep pool and was likely a bait bucket release. This capture was the first collection of *C. auratus* from the Spring River.

Two fish species represent modern day catch records. *Cycleptus elongatus,* the blue sucker, was represented by one specimen collected at Hardy (NE ¼, S11, T19N, RW4). The most recent collection of *C. elongatus* from the Spring River was by Meek (1894). Robison (1974) noted that it was a rare inhabitant of the state. Pflieger (1975) discussed the typical habitat of the blue sucker as being large rivers. The site of collection in the Spring River drainage was at Hardy Beach, a stretch of the Spring River immediately south of water normally utilized by trout and characterized by clear water and moderately swift current. Thus, this occurrence also marked a collection of *C. elongatus* in an atypical habitat.

The American eel, *Anguilla rostrata,* was also collected in vegetated pools in the Hardy area. Winters (1985) noted that *A. rostrata* was observed in a fisherman's creel near Spring River Oakes Camp in Fulton County. Two specimens were collected by electrofishing in this survey.

Two species of fish were collected at locations which extended their distributions within the drainage. The gizzard shad, *Dorosoma cepedianum,* was documented by Winters (1985) as an inhabitant of the South Fork and lower reaches of the Spring River. In this survey *D. cepedianum* was frequently collected by electrofishing in pools at Hardy and Williford.

The sauger *(Stizostedion canadense)* was noted by Winters (1985) as part of a fisherman's creel near Ravenden. Buchanan (1973) records *S. canadense* only from the lower reaches of the Spring River. The sauger was collected in this survey from both Hardy and Williford and was an inhabitant of deep pools below riffle areas.

This survey, coupled with several others throughout the Spring River drainage, reemphasizes that the Spring River is a valuable river system with a highly diverse ichthyofaunal which demands careful monitoring and conservation. Future studies may document still more previously undiscovered species of fish from the system.

We gratefully thank J. K. Beadles, Thomas Buchanan, and George Harp with their assistance in identifying some of the specimens.

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STEVE C. BAKER[1] *and MICHAEL L. ARMSTRONG, Arkansas Game and Fish Commission, No. 2 Natural Resources Drive, Little Rock, AR 72205.*

[1]Present address: Southern Illinois Fish Laboratory, Southern Illinois University, Carbondale, Illinois 62901-6511.

STRIPED BASS *(MORONE SAXATILIS)* SCALE ANALYSIS BY SCANNING ELECTRON MICROSCOPY FOR DELINEATION OF ANNULI

Ever since Scofield (1931) demonstrated the utility of striped bass *(Morone saxatilis)* scales for age determination, striped bass have been aged mainly by the scales. Recently, Heidinger and Clodfelter (1987) and Kilambi and Prabhakaran (1987) showed that the scale method underestimated striped bass age in comparison to otolith and dorsal spine methods, respectively. Detection of scale annuli is difficult, especially of older fish, due to their compacted nature at the scale margin. Conventional methods (light [optical] microscopy and scale projection techniques) may not yield desired resolving power to depict the annuli. Due to greater resolving power and depth of focus, the scanning electron microscopy (SEM) was used to study the ultrastructure of the sculptural design, growth pattern, and annual formation of external ridges on scales and otoliths (DeLamater and Courtenany, 1974; Liew, 1974; Radtke and Hurley, 1983; Wilson and Dean, 1983; Morales-Nin, 1987). Body scales that underestimated the ages of Beaver Reservoir striped bass (T. L. 658 and 979 mm) in comparison to dorsal spine sections were examined by the SEM for the sculptural pattern of circuli and delineation of annuli.

The striped bass scales from below the lateral line at the tip of the left pectoral fin were obtained in August 1986 (Kilambi and Prabhakaran, 1987). The scales were cleaned of adhesive tissue by soaking them in water, dipping them for about a minute in a 5% HCl solution and then rinsing them in water. A pie-shaped section of the scale passing through the focus was made and dehydrated through a series of alcohol to 100%. After blotting free of solvent, the specimen was mounted on a metal stud using double stick tape. The scales were examined by the SEM and photographed.

The SEM examination of the scale from the 979 mm striped bass revealed that the circuli were semicircular in shape extending between the radii becoming flat close to the annulus and resumed semicircularity with increasing concavity away from the annulus (Fig. 1). The annulus was further delineated as an opaque zone extending dorso-ventrally (Fig. 1). Nine scale annuli were counted from the SEM photographs and the same number of annuli were observed on the microfiche photograph. Ten annuli were recorded from the dorsal spine section of this fish examined under the phase-contrast microscope (Kilambi and Prabhakaran, 1987). Examination of the SEM photographs of the scale from the 658 mm striped bass showed the configuration of the circuli and annuli similar to that of the 979 mm fish and the focus area of the scale was translucent (Fig. 2). Using the criteria described above, three scale annuli were observed, same as the number of annuli denumerable from the microfiche photograph. However, the dorsal spine section of this fish revealed six annuli (Fig. 3).

The SEM provided greater resolution of the circuli and annuli compared to the conventional scale projection technique. However, the number of scale annuli observed on the scales of the two striped bass used in this study by the SEM and the microfiche photographs were identical. The ages of the striped bass estimated from the body scales were lower than the spine ages. The results of this study are in agreement with the findings of Kilambi and Prabhakaran (1987), that the scales underestimated the ages of the Beaver Reservoir striped bass compared to the dorsal spine ages.

We thank Ms. Betty Martin of the Plant Pathology Department, University of Arkansas, for her valuable help in operating the scanning electron microscope.

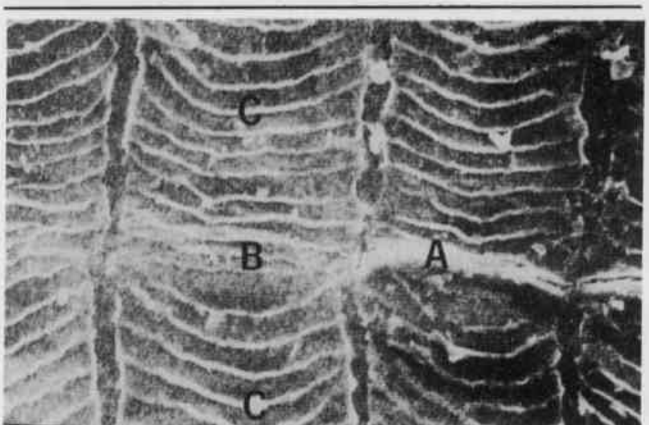
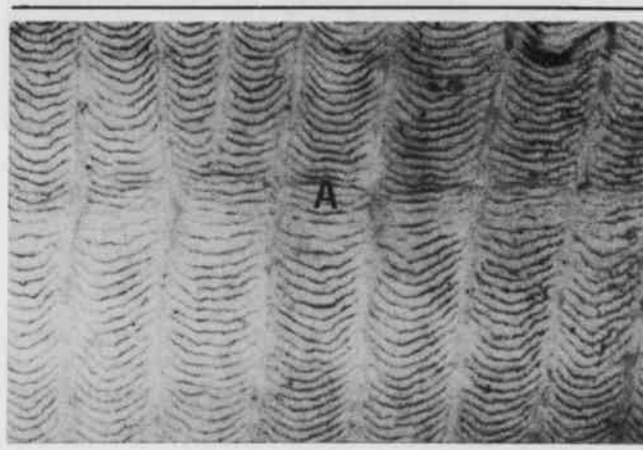


Figure 1. SEM photograph of body scale from 979 mm striped bass (x450). (Above)
- A. Annulus
- B. Flat circuli in annulus
- C. Concave circuli away from annulus



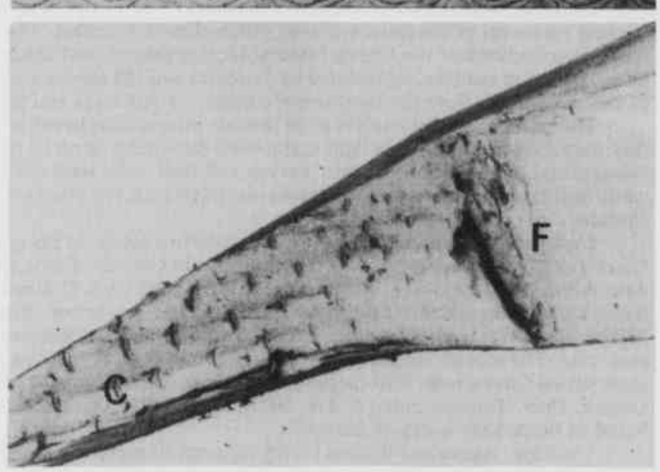


Figure 2. SEM photographs of body scale from 656 mm striped bass (x150). (Upper and Lower Right)
- A. Annulus
- C. Ctenii
- F. Focus

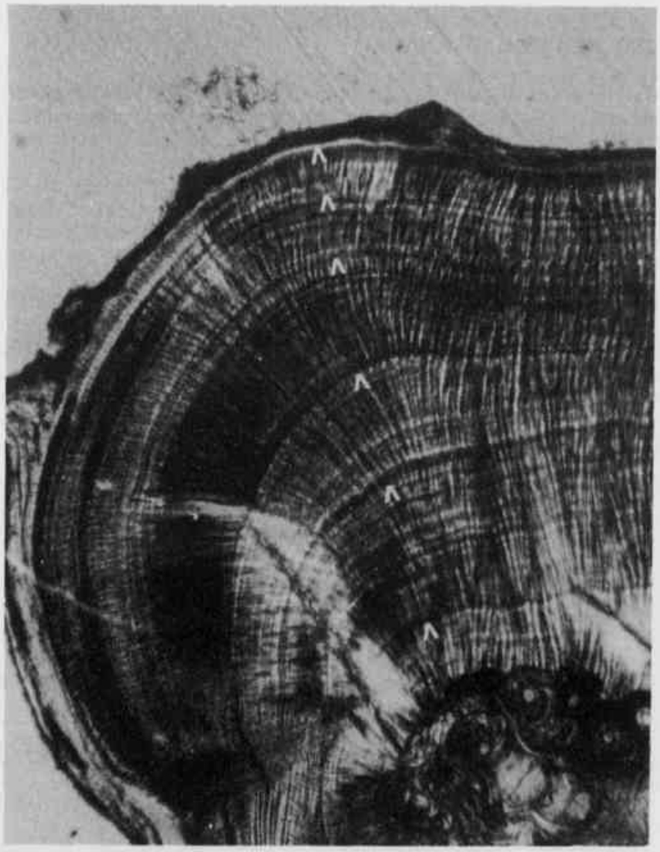


Figure 3. Phase-contrast micrograph of dorsal spine section from 658 mm striped bass showing six annuli (x40).

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BARRY L. BARNOSKI and RAJ V. KILAMBI, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

SELECTED FAMILIES OF TRICHOPTERA IN ARKANSAS

Unzicker, Aggus and Warren (A Preliminary List of the Arkansas Trichoptera, J. Georgia Entomolog. Soc. 5(3):167-174, 1970) provides the best statement of the distribution of caddis flies in Arkansas. The records listed in this report came from three sources, literature search, the synoptic collections of the Illinois Natural History Survey, and the pre-impoundment study of the aquatic insect fauna of the Beaver Reservoir Basin. Fourteen families, represented by 39 genera and 102 species were reported. However, as a consequence of the pre-impoundment study, most of the records are from the northwestern corner of Arkansas and give a very limited seasonal and geographical distribution.

The purpose of this study was to provide information based on observations from a wider geographical and seasonal range. Adult caddis flies were collected by a black light maintained three miles north of Batesville in a residential area, another portable black light used near aquatic habitats and the use of sweep nets. Larvae and their cases were collected by hand or through the use of dip and drift nets. Identifcations were confirmed by comparison with specimens borrowed from the Illinois Natural History Survey. Specimens were housed in the collections at Arkansas College.

Unzicker, Aggus and Warren (1970) reported two species of Phryganeidae from a single site on Cove Creek south of Prairie Grove in Washington County. *Agrypnia vestita* (Walker) was collected in October. Farris and Harp (Aquatic Macroinvertebrates of Wapanoca Wildlife Refuge, Proc. Ark. Acad. Sci. 34:115-117, 1982) reported the species from Crittenden County, but did not provide a date. The species was collected north of Batesville in Independence County in June, July and September. Ross (The Caddis Flies or Trichoptera of Illinois, Bull. Ill. Nat. Hist. Survey 23[1]:1-326, 1944) reported that the adults of this species were collected from May to August and that more than one generation might be produced each year. The second species reported by Unzicker et al. (1970) was *Ptilostomis ocellifera* (Walker) with records during June and July from the same site on Cove Creek. This species has also been collected north of Batesville in June of 1986. Wiggins (Larvae of the North American Caddisfly Genera, Univ. Toronto Press, p. 336, 1977) reported that this species is univoltine in Canada. A third species, *Phryanea sayi* Milne has been collected at black light north of Batesville.

Unzicker, Aggus and Warren (1970) reported *Rhyacophila kiamichi* Ross from Crawford, Washington and Hot Springs counties with collections made from April through June. A second species, *R. fenestra* Ross was collected twice north of Batesville during May of 1986. Ross (1944) described this species from Ozarkian region of southern Illinois and stated that it was only known in Illinois.

I appreciate the loan of specimens from the Illinois Natural History Survey by John Unzicker and the correspondence with George Harp, Arkansas State University. This study was made possible by a faculty research grant from Arkansas College.

VERYL BOARD, Health and Sciences Program. Arkansas College, Batesville, Arkansas 72501.

STATUS REVIEW OF THE THREATENED OZARK CAVEFISH *(Amblyopsis rosae)*

The Ozark cavefish, *Amblyopsis rosae* (Eigenmann), is a small, white, blind fish that is specially adapted for living in Ozark Highlands cave ecosystems. It is one of the most cave-adapted vertebrates known (Poulson, Amer. Midl. Natur., 70[2]:257-290, 1963). This degree of specialization, which includes limited reproductive effort, severely restricts its ability to recover from even moderate population declines.

The range of *A. rosae* is limited to limestone solution caverns in the Springfield Plateau of Arkansas, Oklahoma, and Missouri. After searching 180 potential habitat sites during the period 1980-1983, Willis and Brown (Amer. Midl. Natur., 114:311-317, 1985) reported having seen cavefish in five caves in Missouri, four in Arkansas, and three in Oklahoma. Sightings by others during this period added locations in Missouri (Fantastic Caverns) and Oklahoma (Cave Springs Ranch Cave).

Historically the Ozark cavefish occurred in at least 24 caves in nine counties. Unconfirmed reports would extend its previous occurrence to 52 caves in 14 counties. The report by Willis and Brown (Amer. Midl. Natur., 114:311-317, 1985) of demes in 14 caves in six counties indicated substantial losses of former range, particularly in southwestern Missouri.

Destruction of cave habitat is the primary cause of the decline of cavefish populations, although collecting, disturbance by spelunkers, and limited reproduction are also responsible. Several caves which formerly contained Ozark cavefish have been sealed shut by landowners, flooded by reservoirs, or dried up by lowered water tables (Willis, M.S. Thesis, University of Arkansas, Fayetteville, AR, 1984). Optimum cavefish habitat consists of caves occupied by large colonies of gray bats *(Myotis grisescens)*. Of the 14 cave habitats reported by Willis and Brown (Amer. Midl. Natur., 114:311-317, 1985) to contain fish, five still contain bat colonies, while six others contain guano from past use by bats. Therefore *A. rosae* appears to be dependent on a species which is itself endangered.

This study was initiated to review the status of the Ozark cavefish by checking the previously-known populations and searching for additional ones. Caves were searched using bright lights by two people (three in Caves Springs Cave, Benton County, Arkansas) moving slowly upstream counting cavefish as they were encountered. In larger pools, the surveys were continued using facemasks and snorkels. Efforts were taken to minimize

Location and Cave Name	1980-1983 survey no. of visits	1980-1983 survey max. no. of cavefish	1985-1987 survey no. of visits	1985-1987 survey max. no. of cavefish
Arkansas, Benton Co.				
Cave Springs Cave	5	100	1	122
Logan Cave	10	12	2	32
Mule Hole Sink	3	4	2	0
Civil War Cave	5	4	1	5
Rootville Cave	4	0	1	1
Nursery Pond	0	0	6	5
James Ditto Cave	0	0	3	2
Bear Hollow	4	0	6	0
Dickerson Cave	1	0	3	0
Leslie Cave	1	0	1	0
Hickory Creek	1	0	2	0
Arkansas, Washington Co.				
Mineral Springs	1	0	1	0
Zero Mountain	0	0	1	0
Oklahoma, Delaware Co.				
Twin Cave	6	5	4	3
Jail Cave	7	3	3	3
Engelbrecht Cave	2	1	1	0
Engelbrecht Spring	0	0	1	0
Mitchell #1,2,3	2	0	1	0
Mitchell New Sink	0	0	1	0
January-Stansbury	2	0	2	0
Missouri, Green Co.				
Fantastic Caverns	7	2	3	0
New Sink	0	0	1	0
Missouri, Jasper Co.				
Sarcoxie Cave	2	3	0	0
Kellhaufer's Cave	1	4	1	4
Wilson's Cave	6	4	1	0
Missouri, Lawrence Co.				
Turnback Creek Cave	5	1	3	1
Missouri, Newton Co.				
Ben Lassiter Cave	6	4	3	2
Elm Spring	1	0	3	0
Missouri, McDonald Co.				
Henson Cave	1	0	3	0

Table 1. Status of Ozark cavefish in the Springfield Plateau during 1980-1983 and during 1986

disturbance to the cave system. Searches were discontinued from March 15 through September 15 in caves known to contain gray bats, and at other times when endangered bats were seen.

Of the 14 caves reported by Willis and Brown (Amer. Midl. Natur., 114:311-317, 1985) to contain cavefish, fish were sighted in eight (Table 1). These were Logan Cave, Cave Springs Cave, and Civil War Cave in Arkansas; Ben Lassiter Cave, Turnback Creek Cave, and Kellhaufer's Cave in Missouri; and Twin Cave and Jail Cave in Oklahoma. However, two of the caves could not be adequately surveyed. Sarcoxie Cave and Kellhaufer's Cave, Jasper County, Missouri, were flooded by heavy rains. The owners of Kellhaufer's Cave reported seeing four fish in the cave June 30, 1986. Failure to sight fish in Fantastic Caverns in three visits is significant because a large area can be searched during each visit.

Three new Ozark cavefish populations were found in Benton County, Arkansas. A single fish was observed in Rootville Cave January 17, 1986. Henry James and Scott Ditto, amateur cavers, excavated a narrow passageway into a small cave near Gentry, Arkansas. Our visits to the cave on January 29, 1987 confirmed their reports of an *A. rosae* population. An unintentional excavation of a water-filled cave on the east bank of Beaver Reservoir by Arkansas Game and Fish Commission personnel revealed the third additional location for Ozark cavefish in Arkansas.

During the 1983 survey (Willis and Brown, Amer. Midl. Natur., 114:311-317, 1985), Mule Hole Sink, Benton Co., Arkansas, contained a small pool at the bottom which contained cavefish. During the present study the pool did not exist. Mule Hole Sink is probably connected to Cave Springs Cave which is 2 kilometers to the south, and has easier access. Wilson's Cave in Jasper County, Missouri, consists of only a small pool in the twilight zone that is accessible to humans. During this study the pool contained several bluegill *(Lepomis macrochirus)* and a large snapping turtle *(Chelydra serpentina)*. Presence of these predators probably is related to lack of sightings of cavefish at this location.

The larger number of fish seen in Logan Cave in 1986 (Table 1) was probably due to use of facemasks and snorkels in the larger pools. Many of the fish could not have been seen from the surface because of their position beneath undercut areas of the cave walls. Apparently, greater numbers of fish can be seen in the caves between December and March compared with other times of the year.

Many of the caves continue to be abused by frequent visits by cavers, as evidenced by debris left in the caves, writing on the walls, etc. Strict limitation of this traffic must be achieved to ensure continued survival of this interesting species.

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ARTHUR V. BROWN, and C. STAN TODD, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

THE EFFECT OF CITY EFFLUENT ON THE DIVERSITY OF AQUATIC MACROINVERTEBRATES OF SUGAR CREEK, CLAY COUNTY, ARKANSAS

Sugar Creek is a small stream that originates on Crowley's Ridge in Clay County, Arkansas. It flows through Piggott and receives surface runoff from the community. South of Piggott, it has been channelized and drains into Big Slough Ditch, within the St. Francis River watershed. The purpose of the study was to determine what effect, if any, the surface runoff from Piggott had on the aquatic macroinvertebrate community of Sugar Creek.

Only three previous studies have been published with respect to biota of streams on Crowley's Ridge. Cather and Harp (1975) compared the aquatic macroinvertebrates of an Ozark stream to those of a deltaic stream that originates on Crowley's Ridge in Greene County, approximately 60 km southeast of this study area. Beadles (1970) noted effluent effects on fishes of Lost Creek, and Fulmer and Harp (1977) surveyed the fishes of streams occurring on the Ridge, three of which are in Clay County.

Sugar Creek is a second order stream within the study area. The main channel has a mean width of approximately 12 m and a maximum depth of 3 m at flood stage. The stream has a substrate of sand, gravel, silt and organic mud and the banks are steep and often eroded. Vegetation along the banks includes oak, willow, elm, hickory, sycamore, sweet gum, hackberry and tulip poplar. The soil type in the northern part of the study area is Collins silt loam. This loam is moderately well drained and found on upland drainageways and level areas next to Crowley's Ridge. Falaya silt loam was found south of Piggott along the creek. This loam is poorly drained and found on the flood plains of upland drainageways and level areas near the Ridge. Both soil types are primarily a mixture of brown silt loam and mottled brown silt loam. Both are low in organic matter and strongly acid. They are often geographically associated (Soil Conservation Service, 1978).

For collection purposes, two stations were established on Sugar Creek. Station I was located at the northern edge of the city limits in the SE¼ S3, T20N, R8E. Station II was located downstream, at the southern city limits, in the SW¼ S11, T20N, R8E. Collections were made for a timed period of 45 minutes from each station every two weeks from 31 August-9 November 1985. Collections were made with a fine mesh aquatic "D" net. An attempt was made to sample all microhabitats. Specimens were preserved in 70% ethanol. After identification, all specimens were catalogued and housed in the Aquatic Macroinvertebrate Collection of the Arkansas State University Museum of Zoology (ASUMZ).

Simpson Diversity, Simpson Dominance, Shannon-Wiener Diversity, H'max and Evenness values were calculated using the AQUATIC ECOLOGY-PC disc of Oakleaf Systems, Decorah, IA. Simpson's Index of Diversity corresponds to the number of randomly selected pairs of individuals that must be drawn from a community in order to have an even chance of obtaining a pair with both individuals of the same species. It therefore expresses the dominance of or concentration of abundance into the one or two commonest species of the community (Poole, 1974). Conversely, the Shannon-Wiener Diversity Index expresses the relative eveness of the abundances of all the species. Further, it is relatively independent of sample size (Poole, 1974). H'max is a calculated theoretical maximum diversity (Wilhm and Dorris, 1968). The base 2 logarithm was selected for calculating diversity indices, as it is the most commonly utilized log (Cox, 1985).

A total of 927 specimens of aquatic macroinvertebrates was collected (Table 1). Station I showed the greatest species richness with 44 taxa, 24 of which were found only at Station I. Station II had 24 taxa, with four taxa found only at that station. Stations I and II had 20 taxa in common. Of the 44 taxa collected, 42 were generalists, or species found in many different habitats. Two exceptions to this were *Hydrometra hungerfordi*, a rarely collected species that prefers clean water streams (Harp, 1985), and *Calopteryx maculata*, which is characteristically found in small shaded streams in forested areas (Walker, 1953). These two species were collected at Station I.

Table 1. Total Number of Aquatic Macroinvertebrates Collected at Sugar Creek, 31 Aug - 9 Nov 1985.

Taxa	Station I	Station II
Branchiobdellidae	5	
Physa	141	188
Musculium		1
Simocephalus	13	
Caecidotea	96	60
Synurella bifurca (Hay)	3	
Palaemonetes kadiakensis Rathbun		7
Cambarinae	28	26
Isotomurus palustris (Muller)	2	
Bourletiella spinata (MacG.)	1	
Callibaetis	10	6
Caenis	1	6
Hesperocorixa nitida (Fieber)	1	
Sigara alternata (Say)	1	
Trichocorixa kanza	7	
Gelastocoris oculatus oculatus (Fabricius)	1	9
Gerris remigis Say	10	1
Limnoporus canaliculatus (Say)	16	16
Neogerris hesione (Kirkaldy)	3	1
Rheumatobates	3	1
Trepobates	1	
Hydrometra hungerfordi Torre-Bueno	1	
H. martini Kirkaldy	6	
Mesovelia mulsanti White	1	
Notonecta undulata Say	8	20
Microvelia americana (Uhler)	31	19
M. hinei Drake	16	
Calopteryx maculata (Beauvois)	3	
Ischnura	6	24
Nasiaeschna pentacantha Rambur	1	1
Libellula	3	11
Acilius fraternus fraternus (Harris)	1	
Coptotomus venustus (Say)	2	1
Hydroporus	2	
Laccophilus fasciatus rufus Melsheimer	14	4
Thermonectus ornaticollis Aube	1	
Gyrinus	1	
Cyphon	3	
Peltodytes dunavani Young	1	
P. sexmaculatus Roberts		1
Enochrus sayi Gundersen	1	
E. pygmaeus nebulosus (Say)		1
Tropisternus lateralis nimbatus (Say)	20	15
Chironomus	10	4
Anopheles punctipennis (Say)	6	4
Culex restuans Theobald	8	
Cyrysops	1	
Eristalis	10	
Total Organisms	500	427
Total Taxa	44	24

Table 2. Shannon - Wiener Diversity values for Sugar Creek, 1985.

Date	Station I	Station II
31 Aug	2.309	2.966
14 Sep	3.299	2.166
28 Sep	3.375	2.777
12 Oct	3.737	2.342
26 Oct	2.903	2.903
9 Nov	2.824	2.797

Table 3. Nested (Combined) Values for Sugar Creek, 1985.

Parameter	Station I	Station II
Simpson Diversity Index	.870	.772
Simpson Dominance	.130	.228
Shannon - Wiener Diversity Index	3.893	3.026
H'max	5.458	4.584
Evenness	.713	.660

Diversity index values fluctuated, with respect to a given station in time, and also between stations. For example, Shannon-Wiener Diversity values at Station I gradually increased from 31 Aug-12 Oct, then declined. At Station II, these values alternately rose and fell. Further, these values were greater at Station I on three occasions, similar at both stations twice, but greater at Station II once (Table 2). Nevertheless, when the data for all six sampling dates are combined, or nested, all measures of diversity show the community diversity to be greater at Station I (Table 3).

Greater community diversity (stability) at Station I appears to be the result of two basic conditions — a greater number of microhabitats and less pollution. Station I had isolated shallow pools lined with vegetation and often covered with filamentous algae. In areas, creek banks were gently sloping and grass-covered. Grass clippings had been dumped into the creek. Upstream from the study area, tin cans and other solid waste had been dumped along the bank of the creek, and a small amount of asphalt had been dumped into a spring that flowed into the creek. At Station II the creek banks were steeper, more heavily eroded, and had less vegetation. The stream had a small volume flow, except when heavy rains increased runoff. Pools of water up to 0.5 m in depth alternated with riffle areas between rains. Observed sources of pollution included erosion and residue from the burning of creek-bank vegetation, oils and gases from surface runoff from roadways, chemicals from a cleaning establishment, aluminum cans, concrete slabs and other solid waste dumped along the banks and some rotten apples dumped into the creek.

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KAY CARGILL and GEORGE L. HARP, Dept. of Biological Sciences, Arkansas State University, State University, AR 72467. (Current address for KC is Dept. of Botany and Microbiology, Univ. of Arkansas-Fayetteville, Fayetteville, AR 72701.)

NEW COUNTY RECORDS OF ARKANSAS VASCULAR FLORA FROM THE UNIVERSITY OF CENTRAL ARKANSAS HERBARIUM

A search of specimens in the Vascular Plant Herbarium of the University of Central Arkansas was conducted from 1983 to the present to compile records not documented by Smith (1978) in his *Atlas and Annotated List of the Vascular Plants of Arkansas* nor in his five supplements (Smith, 1986). As a result, 916 new county records were located. They represent 650 species in 112 families located in 46 counties throughout Arkansas. Most records, however, are from Faulkner County or the central part of the state. Of special note is one specimen, *Lathyrus aphaca* L. from Pulaski County. This is an Asian species which Smith (pers. communication) says may represent a waif and may not persist. This yellow flowered legume was collected from a field near a house in Little Rock where it was growing profusely on May 16, 1971.

These species/county occurrence records add to the plant distribution of a geographical area and are important steps toward the publication of a manual of vascular plants, a work that is yet to be completed for Arkansas. This listing of records can be found in the Arkansas Native Plant Society Occasional Papers No. 7.

A University of Central Arkansas Faculty Research Grant (#212-158-1601) provided partial financial assistance for this project. I appreciate the able assistance of Gwen Barber and student workers, including Alice Long, who spent many hours in the herbarium.

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SMITH, E. B. 1986. Additions, Deletions and Corrections for the Atlas and Annotated List of the Vascular Plants of Arkansas. Ark. Native Plant Soc. Occasional Papers (1 - 5). (Supplement #1 [reprinted from 1979] 22 pp; Supplement #2 [reprinted from 1980] 12 pp; Supplement #3 [reprinted from 1981] 10 pp; Supplement #4 [reprinted from 1982] 18 pp; Supplement #5, 22 pp.)

DONALD E. CULWELL, Biology Department, University of Central Arkansas, Conway, AR 72032.

WOODY PLANTS OF SOUTH ARKANSAS: COMPUTER AIDED INSTRUCTION IN DENDROLOGY

The objective of this paper is to introduce a program for Apple II computers designed to supplement existing instruction in the identification of woody plants and their corresponding common and scientific names. At many universities dendrology is a sophomore level course introducing majors to the identification, classification, and nomenclature of woody plants of the forest. Laboratory field exercises reinforce concepts presented during lecture and introduce advanced concepts from upper level courses. In this manner, dendrology establishes a foundation through formal and informal instruction leading to the successful completion of the dendrology course and subsequent upper level courses. For example, at the University of Arkansas at Monticello, each weekly trip introduces students to one of Arkansas' many varied habitats and approximately 15 forest species of woody plants. These species are described botanically, related to the unique characteristics of the site, and presented as a member of a dynamic and complex forest community valued for its products and intangible amenities. After a few weeks of study, students have (1) acquired an appreciation of forest species as members of the broader plant community, (2) participated in the consumptive and nonconsumptive uses of the forest, and (3) observed patterns in phenotypic variation explained by concepts from synecology, autecology, and genetics which are applied to forest management during courses in silviculture, tree improvement, and forest recreation. For these reasons dendrology initiates the foundation for advanced study in forest resources management and is the base on which professional careers are built. The ability to recognize and identify the forest resource is fundamental to appreciation, advanced study, and professional development in forestry.

Laboratory exercises in dendrology are designed to encompass as many different habitats, forest communities, and species as possible. Sometimes sites selected for field study require traveling 40 or more miles from campus. Students needing additional out-of-class review with limited available time for study or lacking personal transportation may encounter difficulty returning to a laboratory site. Consequently, an inexpensive and effective means of collectively presenting species from diverse habitats for review and study by students is needed. Computer graphics offer a partial solution to this problem.

Woody Plants of South Arkansas presents graphic images of leaf silhouettes from 120 species of woody plants native to southern Arkansas. All leaf images and botanical characteristics needed for identification were created with Computer Colorworks' Digital Paintbrush System (Figure 1). These images were incorporated into a BASIC program which presents questions requiring students to enter both a common and a scientific name.

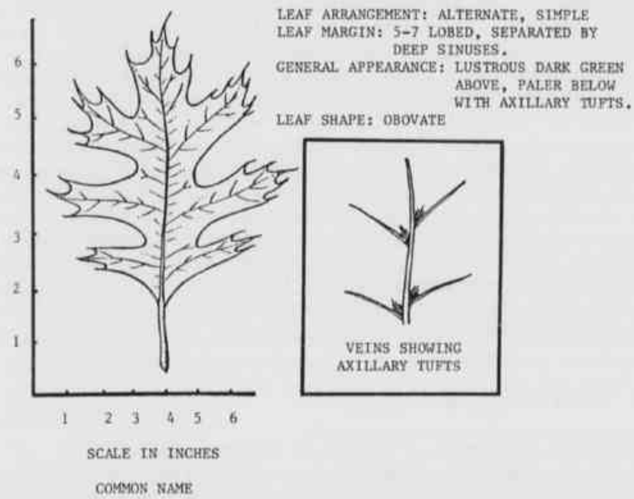

Figure 1. Monitor screen showing common name inquiry prior to user input.

Table 1. Editorial symbols employed by *Woody Plants of South Arkansas* to aid students in correcting their response.

Symbol	Error explanation
×	Extra character
=	Wrong character
∽	Transposed letters
⌞	Missing character before here
⌟	Missing character after here
X	Wrong word
▲	Word missing here

The program begins when the diskette is placed in the disk drive and the computer is turned on. The instructions for operation are then displayed. Once the student has read the instructions he is prompted to press the RETURN key to begin. As with many other programs designed for use on Apple computers, the RETURN key signifies the end of a user input. A randomly selected leaf slide is displayed and the student is asked to input the common name of the species. The student's response is evaluated for accuracy and, if the response is correct, adds a point to his score. If the answer is incorrect the computer will allow a second or third attempt. However, if the first response is incorrect the student cannot change the score by a correct second or third response. If the answer is spelled incorrectly, editorial symbols (Table 1) appear on the screen to aid the student in correcting the answer. The same series of questions and responses are then repeated substituting Latin names for common names. After three attempts the computer provides the correct answer and advances to the next species. The same sequence is repeated for all species on the diskette. After all of the species have been attempted, the student's score is displayed along with instructions for more study of the same diskette or another of the 13 diskettes.

The program has many strengths as well as weaknesses. This program is user friendly and encourages computer literacy early in the students collegiate career. The program is not only applicable to forestry students taking dendrology, but also botany students, plant taxonomy students, vo-tech students, and even Boy Scouts and Girl Scouts. A major strength is that the program will check the student's spelling for mistakes, and uses editorial symbols to mark the mistakes. The student is then given the opportunity to enter the correct answer. Another strength of the program is that it scores the student's first response, as it would be graded on a laboratory quiz. The student is allowed three chances at correct identification of the species before he is given the correct spelling of the common or scientific name. The program is written such that an infinite number of questions may be substituted for the current questions, however, the space on the video screen limits the length of questions. Another advantage is that the program was developed for the Apple II series computers, which are reasonably inexpensive, come with graphics capabilities standard, and are found in many high schools and universities.

One of the major weaknesses of the program is the resolution deficiency of the Apple II series of personal computers. This lack of resolution limits the amount of detail that may be shown in the leaf silhouettes. This is a particular problem for finely serrate leaf margins or elliptical leaf shapes. Since the program is written for a 5¼ inch disk drive system, space on a given disk is limited to approximately 10 individual "slides", which is an inconvenience if the student wishes to review all of the species at one time. Since all of the species cannot be contained on one disk, a cumulative score is not possible. More information than just leaf characteristics is needed to identify many species such as ashes and hickories; however, the lack of resolution makes the inclusion of twig or bark characteristics on the slide very difficult.

In conclusion, *Woody Plants of South Arkansas* is a user friendly computer program written for the Apple II series of personal computers. This program is intended to supplement formal instruction in woody plant identification. Programmed instruction enables infrequent users of the computer to easily access over 120 species for study. Leaf shapes and botanical descriptions are computer generated and the user queried for the appropriate name. The program may be adapted to present a variety of questions pertaining to the species.

This program is available to the public. Interested individuals may acquire this program by sending 13, 5¼ inch diskettes to Yeiser at the address which follows.

J. F. DICKSON, and J. L. YEISER, Department of Forest Resources, University of Arkansas at Monticello, P.O. Box 3468, Monticello, AR 71655.

CAN CREATIVITY BE TAUGHT IN THE PHYSICS LABORATORY?

Student ability to think creatively or in a divergent mode is important in engineering and physics to generate ideas which might lead to new designs, ways to solve problems, or in new products. Several tests and methods to evaluate creative thinking have been developed, such as the Torrance Tests of Creative Thinking (Verbal and Figural), Harris' A.C. tests of engineering creativity and the Judgment Criteria Instrument, which I validated in an earlier study to be used in an educational environment (Eichenberger, 1978). Torrance, Guilford and others identified the factors of fluency, flexibility, and originality as being associated with creativity (Torrance, 1979). Some researchers reported that creativity can not be learned (Carlsson and Smith, 1987) while others report that creativity can be improved through education techniques (Parnes, 1984).

I decided to investigate whether a student's creative ability could be improved through practice of doing divergent thinking in the physics laboratory of an introductory physics course. The sample size was small, consisting of 10 students in each of two laboratory sections. No selection process or matching was done. Students were in the Monday or Tuesday laboratory sections by natural schedule selection. One section, the experimental group, was given creativity stimulation, divergent thinking and questions at the end of the laboratory. The other section, the control group, was given convergent questions from the end of the laboratory book. After a six week period (six laboratory sessions), both groups were tested on one creativity question with motivation provided by bonus points on the midterm practical laboratory exam. The practice question types for the two sections were switched for the second half of the semester. The original control group was given the creativity practice questions and became the experimental group. The original experimental group became the control group getting the regular, convergent type physics questions. Both groups again were given a creativity question at the end of these six practice (laboratory) sessions. Motivation was again provided by bonus points toward grades. The midterm and final creativity test questions were scored by two scorers using the Judging Criteria Instrument. The averages of individuals for the groups were compared using coefficients of correlation between the pretest and post test scores of the participants in the experiment. The correlation coefficient was computed and the suggested t-test applied. The significance level was preset; alpha = 0.1. The t-test equation is:

$$t = (M1 - M2)/(S1\uparrow 2/N1 + S2\uparrow 2/N2 - 2R[S1/N1\uparrow .5][S2/N2\uparrow .5])\uparrow .5$$

Where M's are group means, S↑2 are variances, S are standard deviations and N's are number of students in the groups (Best, 1981).

There were no significant differences between the group which had practice on creativity questions and the group which had not. The practice of creativity with stimulation questions did not significantly increase the student's creativity (Table 1). The experimental section which practiced creative thinking between pretesting and post testing showed the most gain. This method may have possibilities for future research, particularly when used with larger sections with specific instruction in ways of divergent thinking.

Table 1. Correlation of creativity scores

Comparison	Mean X Value	Mean Y Value	Correlation Coefficient	T-Test	N	Critical Value
Pretest (X) - practice - Post test (Y) Experimental Group	49.1	57.5	0.158	1.212	9	1.39
Experimental (X) vs Control (Y); Post Test*	56.5	49.1	0.120	0.810	9	1.39

*Indicates that the sections were matched on the basis of achievement test averages in the lecture theory part of the course.

Two examples of the creativity of divergent questions which were used are: 1) find as many applications as possible for Newton's first law, 2) find as many applications of physics as possible to medicine. The investigator observed that these types of creativity practice questions appeared to reduce the number of usual student questions of "how is physics used in his/her area of study?" which also suggests an area for further research.

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RUDOLPH J. EICHENBERGER, Department of Physics, Southern Arkansas University, Magnolia, AR 71753.

INFECTION RATE OF TALL FESCUE WITH ACREMONIUM COENOPHIALUM

There are approximately 0.8 million hectares of tall fescue (*Festuca arundinacea* Schreb.) in Arkansas. Plants of this cool season perennial grass growing in established pastures harbor an endophyte fungus (*Acremonium coenophialum* Morgan, Jones, and Gams) at an infection level of 83 percent (Daniels, Piper, Nelson, Gee, and Hankins, Proc. Amer. Forage Grasslands Coun. Conf., Pp. 254-257, 1987). The fungus is associated with poor animal health (Reed and Camp, Agronomy J. 79:848, 1986).

The purpose of this study was to determine whether uninfected plants remained uninfected while growing adjacent to infected ones.

Seed of Forager tall fescue, labeled as having less than five percent of its seed infected (the seed trade refers to this as endophyte free or reduced endophyte seed), was planted during the fall of 1984 in rows at distances of either 60 cm (treatment one), 40 cm (treatment two), 20 cm (treatment three), or 0 cm (treatment four) from rows of heavily infected Kentucky 31 tall fescue. Twenty percent of the culms produced by plants that grew from the forager seed and 60 percent of the culms produced by plants that grew from the Kentucky 31 seed were initially infected with the endophyte.

The experiment was planted on October 3, 1984 at the University of Arkansas Livestock and Forestry Research Station near Batesville. Four treatments were assigned to four replications in a randomized complete block design. Each treatment in the experiment consisted of 16 rows 15.4 meters long. Treatment four was planted to a mixture of 60 percent Forager and 40 percent Kentucky 31 tall fescue seed. The seed hopper of a 16 row grain drill with 20 cm row spacing was then partitioned to facilitate placing the seed into proper row spacing for each of the remaining three treatments. A small amount of volunteer ryegrass (*Lolium multiflorum* Lam.), but no volunteer fescue was observed during the fall of 1984. Mowing was used to inhibit seedhead formation and thereby reduce to a minimum contamination of the plots with volunteer seed. A low soil fertility level was maintained to impede plant spreading. As a result, original rows were distinguishable throughout the duration of the experiment.

Endophyte infection analysis was performed microscopically on plant tissue from each plot in the experiment twice annually — at the end of the spring and fall growth periods. The lowermost portion of 15 culms were collected from both Forager and Kentucky 31 plants growing within each of the four treatments in each of the two replications in July, 1985 and within each of four replications in the experiment thereafter. From each sample of 15 culms, six were chosen at random for leaf sheath analysis to determine the endophyte infection levels. Results of the analysis are presented in Table 1.

Table 1. The influence of distance and time on *Acremonium coenophialum* fungal infection of low endophyte forager

Treatment	Distance separating Rows of Forager and Kentucky 31 Tall Fescue (cm)	Tall Fescue Variety	Endophyte Infection Level (%) July 85	Nov. 85	May 86	Oct. 86
1	60	Forager	0	0	0	0
		Kentucky 31	60	25	37	41
2	40	Forager	20	9	0	13
		Kentucky 31	40	0	54	63
3	20	Forager	40	0	12	29
		Kentucky 31	80	44	65	41
4	0	Mix	0	42	33	38

The endophyte fungal infection level observed in Forager plants that had grown for 28 months in rows located only 20 cm from rows of heavily infected Kentucky 31 fescue plants was 29 percent while the infection level in Forager plants that grew 60 cm from the source of infection for the same length of time, was only eight percent. However, the differences among all treatments means were not significant at $P = 0.05$. Therefore, the infection level of Forager tall fescue grown under Arkansas conditions did not increase for a period of 28 months after planting regardless of how close it grew to heavily infected Kentucky 31 plants.

We thank the Arkansas Beef Council for supplying the funds to conduct this experiment. We also thank Dr. Ken Harrison for his assistance in caring for the experiment at the University of Arkansas Livestock and Forestry Research Station near Batesville, and Dr. Bernard Daniels for assistance in analysis of samples.

B. J. HANKINS, University of Arkansas Cooperative Extension Service, P.O. Box 391, Little Rock, AR 72203, and TERRY KIRKPATRICK, Southwest Research and Extension Center, Route 3, Box 258, Hope, AR 71801.

REPORTED BAT RABIES IN ARKANSAS

Data on bat rabies were not reported in the United States until 1953 (Baer, 1975). Since then, bats have become recognized as one of the major wildlife vectors, and bat rabies is the most widespread geographically (*e.g.*, 47, 46, and 45 states in 1982, 1983, and 1984 respectively) in the United States (CDC, 1983, 1984, 1986). These figures may reflect that, for reporting purposes, data on all species of bats are lumped together and that over 30 species have been reported to carry rabies (Constantine, 1979).

In Arkansas, bat rabies was not reported until 1961. Heidt (1982) summarized reported bat rabies from 1961 through 1981. McChesney *et al.* (1983) reviewed reported bat rabies for 1982. Heidt (1982) pointed out that between 1961 and 1981, reported rabid bats averaged a little over nine cases per year and accounted for 6.7% of the total reported cases in Arkansas. He further pointed out that reported cases were increasing and that bat rabies epidemiology was hampered in that the Arkansas Department of Health did not identify those bats submitted for testing.

Beginning in July, 1982 one of the authors (DAS) has routinely identified bats submitted for testing to the Arkansas Department of Health. This paper reviews reported bat rabies in Arkansas since identification procedures have been practiced (1982-1986).

Table 1 summarizes reported bat rabies and compares it to the total reported rabies in Arkansas between 1982 and 1986. Reported cases have risen from an average of nine (Heidt, 1982) to 15.6 cases per year, and the percent of total reported rabies has risen from 6.9 to 10.3. Reasons for these increases are not clear. As the epidemiology of rabies is complex, it would not be safe to simply assume that there are more rabid bats in the state.

Between 1982-1986, a total of 641 bats have been identified (83% of the bats submitted) and 61 tested positive (78% of the total positive bats). There are 16 species of bats in Arkansas (Sealander, 1979); all of which have been reported in the literature to have carried rabies (Constantine, 1979). Of the 16 species, 11 have been submitted for testing since identification procedures were initiated (Table 2). Individuals from six of the 11 species have tested positive.

Table 1. Summary of reported bat rabies in Arkansas: 1982 - 1986

Year	Number of Bats Tested/Positive	% Positive	% Total Animals Tested	% Reported Rabies
1982	149/19	12.8	7.6	12.1
1983	137/16	11.7	7.0	10.0
1984	249/16	6.4	14.7	15.8
1985	142/13	9.1	9.2	8.6
1986	100/14	14.0	15.5	8.3
Total	777/78	10.0	8.9	10.3

Table 2. Summary of identified bats tested for rabies in Arkansas: 1982-86

Species	Number Submitted/ Positive	(%)
Family Vespertilionidae		
Red Bat (Lasiurus borealis)	258/44	(17.1)
Big Brown Bat (Eptesicus fuscus)	134/7	(5.2)
Evening Bat (Nycticeius humeralis)	83/1	(1.2)
Eastern Pipistrelle (Pipistrellus subflavus)	25/5	(25.1)
Hoary Bat (Lasiurus cinereus)	15/3	(20.1)
Gray Bat (Myotis grisescens)	11/0	(0.0)
Little Brown Bat (Myotis lucifugus)	9/0	(0.0)
Keen's Bat (Myotis keeni)	1/0	(0.0)
Silver-haired Bat (Lasionycteris noctivagans)	7/0	(0.0)
East. Big-eared Bat (Plecotus rafinesquii)	4/0	(0.0)
Family Molossidae		
Free-tailed Bat (Tadarida brasiliensis)	94/1	(1.1)
Total	641/61	(9.5)

The red bat *(Lasiurus borealis)* accounted for roughly 40% of the total bats submitted and 72% of the bats testing positive. The red bat is found throughout the state and is one of the most common species (Sealander, 1979). Positive red bats have been reported from 24 counties: Arkansas (2), Benton (2), Cleveland, Conway (2), Dallas, Faulkner (5), Franklin, Garland, Hot Spring, Jefferson (3), Logan, Lonoke, Mississippi (3), Ouachita, Perry, Pulaski (6), Saline (2), Scott, Sebastian, Sevier, Van Buren, Yell, Washington, and White. Although scattered across the state, all of the counties (except Desha) encompassing the Arkansas River Valley are represented. Furthermore, the majority of cases involve the counties with major population centers (i.e., Pulaski, Saline, Faulkner and Jefferson counties).

The second most commonly submitted bat was the big brown bat *(Eptesicus fuscus)* with 134 (21%) animals. The big brown bat is also found statewide and is quite common, especially around human habitations (Sealander, 1979). This probably accounts for the high number of submissions and low incidence of positive cases (5.2%). Positive big brown bats have been reported from the following counties: Cleburne, Craighead, Faulkner, Garland, Pulaski, and Scott (2).

The evening bat *(Nycticeius humeralis)* occurs statewide, but is not particularly common (Sealander, 1979). While primarily a tree-dwelling species, it may use human habitations. Only one (from Pulaski County) of 83 submissions was positive.

The eastern pipistrelle *(Pipistrellus subflavus)* is a small, but common bat found statewide (Sealander, 1979). Five of 25 (20%) eastern pipistrelles have tested positive. Because relatively few bats were submitted, the significance of the high positive percentage is not known. Positive bats were from Benton (2), Garland, Saline, and Searcy counties.

The hoary bat *(Lasiurus cinereus)* is the largest bat in Arkansas. It is found statewide, but is not particularly common (Sealander, 1979). Three of 15 bats tested were positive. Again, the total number of bats tested was too small to draw any conclusions from the high positive percent. Positive bats were from Logan, Jefferson, and Pulaski counties.

The freetail bat *(Tadarida brasiliensis)* is the only member of the Family Molossidae in Arkansas. Its exact range and status in the state is not known; however, large colonies have been found in human habitations in Pulaski, Faulkner, Garland, and Little River counties (Saugey *et al.*, 1983; authors' unpubl. data).

Only one of 94 freetail bats submitted for testing was positive. The positive animal was one of 74 from a housing project in Hot Springs, Garland County. The role of the freetail bat in the epidemiology of rabies in Arkansas is not known, although western populations have been highly implicated in the transmission of the disease (Baer, 1975).

As reported in Table 2, there were no positive submissions of the gray bat *(Myotis griscescens)*, little brown bat *(Myotis lucifugus)*, silver-haired bat *(Lasionycterus noctivagans)*, eastern big-eared bat *(Plecotus rafinesquii)*, or Keen's bat *(Myotis keenii)*. This does not mean, however, that these species are rabies-free. It should be noted that the gray bat is included on the Federal Endangered Species List.

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GARY A. HEIDT, DAVID A. SAUGEY, and SUSAN R. BRADFORD-LUCK, Department of Biology, University of Arkansas at Little Rock, Little Rock, Arkansas 72204 (GAH, SRB-L) and U.S. Forest Service, Mt. Ida, Arkansas 71957 (DAS).

A YELLOW RAIL *(COTURNICOPS NOVABORACENSIS)* WITH DARK PLUMAGE FROM ARKANSAS

A Yellow Rail *(Coturnicops novaboracensis)* that is much darker than others of its species was collected by Buford Smith in January 1963 near Beebe in White County, Arkansas. The specimen was mounted by Truston H. Holder in a lifelike position (Fig. 1 and 2) before presentation to the University of Arkansas at Fayetteville, where it now is part of the university museum collection (Cat. No. 784). Roberts (The birds of Minnesota, 2 vols., Univ. of Minn. Press, 1932) thought that dark Yellow Rails were young birds and Ripley (Rails of the world, D. R. Godine Publ., Boston, 1977) supported this view. However, Friedmann (Ridgeway and Friedmann, The birds of north and middle America, Part IX, U.S. National Museum Bull. no. 50, 1941) recognized a pale and rufescent plumage phase in both adult and juvenile birds. My study of museum skins of Yellow Rails did not clarify this matter due to a lack of specimens with specific age data. Dickerman (1971, Wilson Bull. 83:49-56) also stressed this problem. Therefore, not having better information, I am treating the Arkansas specimen simply as one that exhibits an unusually dark plumage. However, a specimen taken in September in Ontario, Canada, and identified as a juvenile (ROM 37443, Royal Ontario Museum) also showed a dark scaling pattern on the sides of the head and on the breast, which most Yellow Rails lack, but the criterion for calling the bird a juvenile was not given. The presence of dark Yellow Rails presents some difficulty in field identification with respect to the other small North American rail, the Black Rail *(Laterallus jamaicensis).*

In searching for dark Yellow Rails, I have inspected over 100 specimens in several collections (American Museum of Natural History, Bell Museum of Natural History at the University of Minnesota, U.S. National Museum of Natural History, and Royal Ontario Museum). Specimens range from light birds to dark birds especially ventrally (Fig. 3), not so pronounced dorsally (Fig. 4). The graded series shown in Fig. 3 and 4 are from the U.S. National Museum, but is similar in variation to specimens found in other collections. None of the specimens are as dark ventrally as the Arkansas specimen.

The Arkansas bird is not as dark as it appears in Fig. 1 and 2. The light longitudinal edges of the black feathers on the dorsum and wing coverts are actually buffy or yellowish in color. The thin white cross bars turning to spotting on the head and upper breast are very white. The back and wing coverts are in fact similar to other Yellow Rails. It is in the underparts that the Arkansas bird is much darker than other specimens. Most of its breast and belly is a dark buffy brown with thin white barring. The underparts behind the legs are blackish with white barring as in other Yellow Rails. The extensive light venter found in most Yellow Rails is reduced in the Arkansas specimen to a small whitish triangle on the chin and upper throat, and a whitish area (25 x 25 mm in size) just anterior to the legs. The several white secondaries are present in the wing that produces the posterior white wing patch on the inner part of each wing in flight.

Using the specimens from the U.S. National Museum (USNM) for a detailed comparative synopsis, the amount of buff edging on the back feathers varies somewhat (Fig. 4) and is minimal in the Arkansas bird, but not less than in some other specimens. So, although the Arkansas bird is on the dark end of the dorsal gradient, other specimens are just as dark. The black of the back feathers with the thin white barring is the same in all birds (Fig. 4), and the varying lightness in overall shade is due to differing amounts of buffy edging to the feathers. There is more buff on the margins of the upper tail coverts in some specimens than in the Arkansas bird, but most other specimens are equally as dark there as the Arkansas bird.

The dark brown of the lower flank feathers and under tail coverts appear darker in the Arkansas specimen than in all others, and the dark area is more extensive too. Also, the white area on the lower mid-breast and abdomen is smaller in the Arkansas bird than in the others. The Arkansas bird (Fig. 1 and 2) differs most markedly from the other specimens (Fig. 3) in the nature of the sides of the face, sides and front of the neck, and breast and upper flanks. In most Yellow Rails the breast is a light buffy color, but varies from pale buff to a darker buffy brown shade (Fig. 3). The light color on the breast extends on to the sides of the head and neck and includes the superciliary line that borders above a darker area extending from the beak back below the eye. In the Arkansas specimen the breast, upper flanks, neck and sides of the face are a darkish buffy brown, giving these areas a very dark appearance. The feathers have numerous thin white bars on the breast and flanks shortening to white spots on the neck and head. Even the dark crown has white flecks. The superciliary line is barely visible. Only the bird on the far right in Fig. 3 (USNM 189862) has this type of plumage on the head and breast, but even in this bird the light whitish of the belly extends medially on the breast to join the light throat and chin (not visible in Fig. 3 because of the way the head was turned in preparing the specimen). Thus, only the sides of the breast has the dark speckled appearance. In the Arkansas bird the dark plumage extends across the breast and upper abdomen (Fig. 2) giving it its very dark appearance.

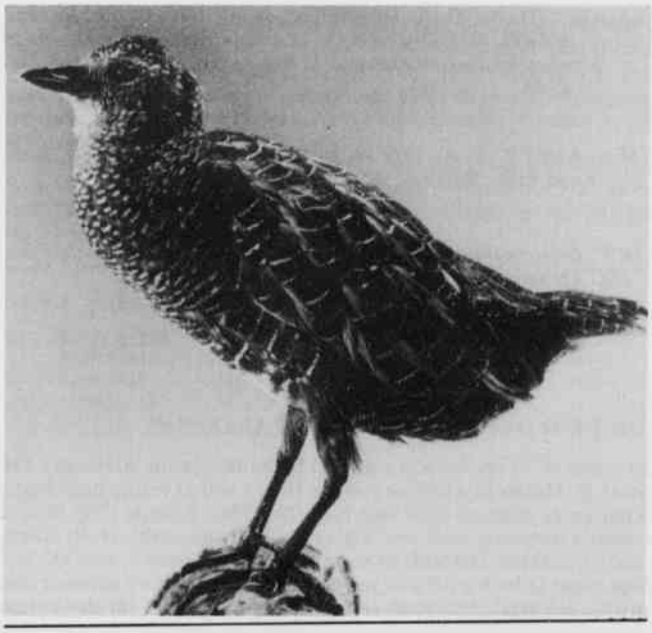

Figure 1. Side view of the dark Yellow Rail from Arkansas.

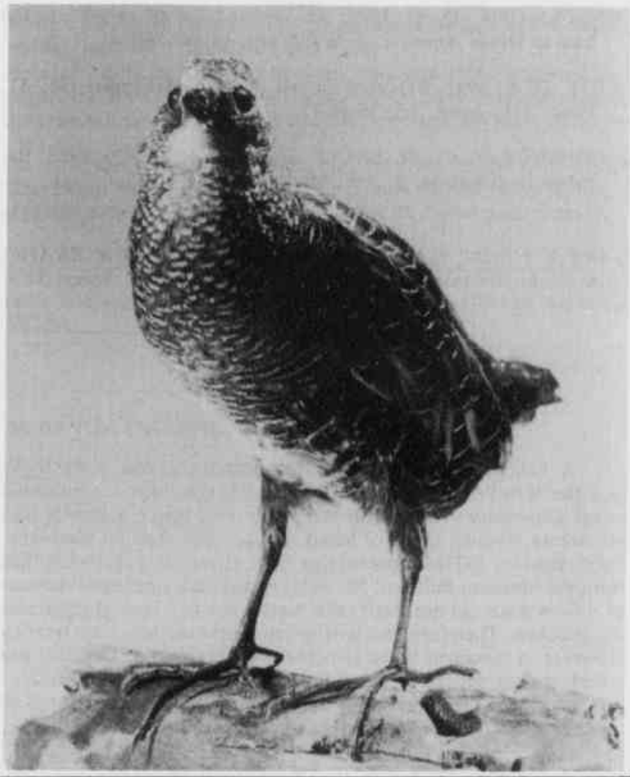

Figure 2. Front view of the dark Arkansas specimen.

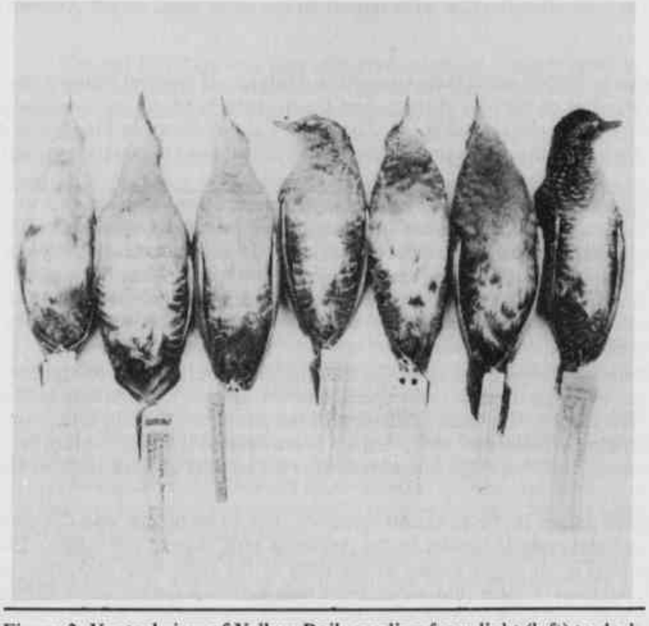

Figure 3. Ventral view of Yellow Rails grading from light (left) to dark (right).

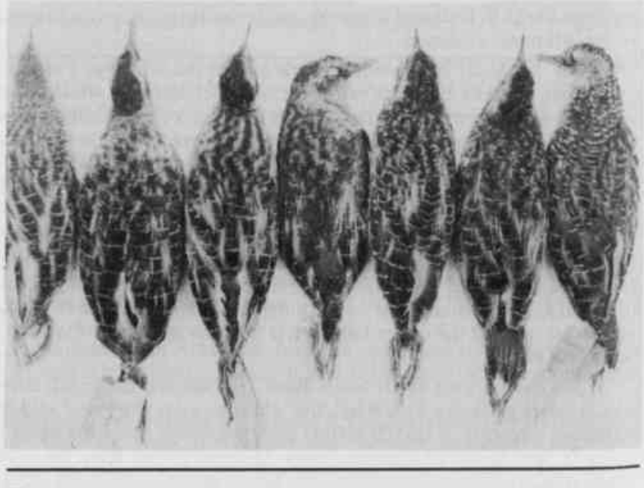

Figure 4. Dorsal view of Yellow Rails shown in Figure 3 in the same left to right arrangement.

The photographs and plumage color notations were made soon after the Arkansas rail was collected in the 1960s. Since then it has been kept in a closed, light-proof specimen cabinet at room temperature. In analyzing plumage color, two color guides were consulted: Smithe (Naturalist's color guide, American Museum Natural History, 1975); and the color plate in Palmer (Handbook of North American birds, Vol. 1, Yale Univ. Press, 1962).

DOUGLAS A. JAMES, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

EFFICIENCY OF DIFFERENT STORAGE METHODS FOR PRESERVING LAKE TROUT *(Salvelinus namacush)* EYE TISSUE

Sea lamprey predation and over-fishing during the past 40 years have caused lake trout *(Salvelinus namaycush)* populations in the Great Lakes to be greatly reduced. The U.S. Fish and Wildlife Service in cooperation with State Fishery Agencies and the Canadian Government is working on a program to restore lake trout populations to the Great Lakes region. The National Fishery Research Development Laboratory, Wellsboro, Pennsylvania, is studying inheritance of cataracts in lake trout, as a recurring problem in hatchery fish populations. Brandt *et al.* (1986) studied the incidence of corneal cloudiness in transported large mouth bass and found that 80% of the eyes cleared within 20 to 36 hours after transport. It also was demonstrated that nutritional problems, pollution and other physical parameters may increase the incidence of cataracts in hatchery reared fish (Steucke *et al.*, 1986; Bodammer 1985; Ketola, 1979). As a part of the inheritance project, we conducted a study to determine how cataracts collected in field locations can best be stored for shipment to the laboratory for analysis without significant distortion or deterioration. An extended storage period would allow adequate time for collections at remote field stations to reach the lab for analysis.

Four methods of fish eye tissue storage were used: 1) dry storage at 40°F.; 2) storage in iced water; 3) frozen (without additional water); and 4) fixed in 10% buffered formalin solution. All samples were evaluated daily over 10 days to determine stage of tissue deterioration. A total of 20 fish (five fish per treatment) with cataracts were tested with the four methods. The cataracts were evaluated under low magnification (7 X power). Deterioration in eye tissue due to preservation method was defined in two stages. Stage 1 was indicated with a distinct ring around the deteriorating cataract; this was designated as a rim cataract (Orme and Lemm, 1974). Stage 2 was indicated by the disappearance of the rim and a progressive breakdown of lens tissue leading to an opague then solid white lens. This indicated destruction of the cataract.

The number of days to stages one and two for each treatment are shown in Table 1. The normal lake trout eye is lucid and shining and does not contain light colored spots or lines in the lens. Our initial findings revealed that for the nuclear cataract to remain visible in any of the storage methods, the cornea of the eye had to remain moist or refrigerated. Lake trout eye tissues were preserved longest without deterioration in both the refrigeration and water treatments.

Table 1. The average number of days to stages 1 and 2 for each storage treatment of Lake trout eye tissue.

TREATMENT	REFRIGERATED	WATER	FROZEN	FORMALIN
Number of days to stage 1	2	3	1	1
Number of days to stage 2	3	3	1	1

During the first three days of observations, 10% of the samples in the refrigeration method changed from normal to stage 1. From days 4-7, an additional 40% of the samples changed from stage 1 to stage 2. With each method what appears to be a halo or rim cataract developed in the outer layer of the lens. The halo appeared as a ghostly circle with or without feathered edges, and the posterior lens surface may have a mirror-like appearance. In the iced method, 20% of the fish developed the halo, and during days 3-5, 60% of the fish lenses deteriorated to stage 1. Fish eyes preserved by methods 3 and 4 reached stage 2 within one day of treatment. The freezer method caused widespread lesions in the lens tissue, which totally obliterated visual evidence of the cataract. In the formalin method, lesions in the lens tissue were filled with formalin solution which completely obscured the cataract after the second day of treatment. These results suggest that laboratory storage of corneal eye tissues may best be accomplished with refrigeration or water storage in ice for short term preservation of fresh tissues. Under field conditions without refrigeration, eye tissues may be adequately stored in iced water and remain relatively fresh for up to three days. This should provide ample time for transport to laboratories.

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BASIL L. JOINER, Department of Agriculture, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601; JOSEPH R. SYLVESTER, Arkansas Cooperative Fishery Project, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601; and HAROLD L. KINCAID, National Fishery Research Development Laboratory, Wellsboro, PA.

REDISCOVERY OF THE SUCKERMOUTH MINNOW, *PHENACOBIUS MIRABILIS* (GIRARD), IN ARKANSAS

The suckermouth minnow, *Phenacobius mirabilis* (Girard), is primarily a northern and western prairie stream species and is quite common in sand and gravel-bottomed riffles of permanent streams throughout much of Indiana, Illinois, Iowa, Missouri, Kansas, and Oklahoma. It is known to occur today in every state bordering Arkansas. Although *P. mirabilis* was originaly described from the Arkansas River at Fort Smith (Girad, Proc. Acad. Nat. Sci. Phila., 8:165-213, 1856) is has always been rare in this state, and the lack of any recent records, despite numerous collecting attempts, suggested the possibility of its extirpation from Arkansas waters.

Until now, the only verified records of *P. mirabilis* from Arkansas were five pre-1940 collections, all from western Arkansas (Black, Ph.D. Dissertation, Univ. Michigan, Ann Arbor, 500 pp., 1940). However, on 16 July 1986, a single adult specimen of *P. mirabilis* was collected from Little Bay Ditch (St. Francis River drainage), 3 miles southeast of Jonesboro, Craighead County, Arkansas (R5E, T13N, Sec 18) by William E. Keith, Roland McDaniel, Bob Singleton, Mark Brady, and Bo Smith of the ADPC&E. The specimen, 73 mm in standard length, which will be deposited in the Arkansas State University Museum of Zoology in Jonesboro, possessed the following meristics: 46 lateral line scales, 8 dorsal rays, 7 anal rays, and 14 pectoral rays.

Little Bay Ditch is a channelized stream with a drainage area of approximately 45 square miles. Land use within this watershed is about 60% agricultural and 40% suburban. Habitat at the collecting site consisted of 70% shallow, slow-flowing pools and 30% shallow, fast-flowing riffles. The substrate consisted of 78.3% sand and 21.7% mud and silt. Brush, logs, and debris comprised the instream cover (17.5% of mean stream width). Other physical habitat features were: a stream gradient of 0.9 ft/mi, a mean stream width of 41.4 ft, a mean stream velocity of 1.01 ft/sec, an observed flow of 27.4 cfs, a mean depth of 0.9 ft, and a maximum depth of 2.5 ft. The following water quality data were recorded: water temperature 27°C, dissolved oxygen 5.1 mg/1, pH 7.99, turbidity 90 NTU, Total suspended solids 142 mg/1, Total dissolved solids 302 mg/1, BOD_5 3.8 mg/1, BOD_{20} 12.4 mg/1, Total phosphate 0.3 mg/1, NO_3 + NO_2-nitrogen 0.29 mg/1, NH_3-nitrogen 0.38 mg/1, chloride 9.0 mg/1, sulfate 18.0 mg/1, conductivity 426 μmho, Total hardness 166 mg/1, alkalinity 174 mg/1, chlorophyll-a 13.4 μg/1, fecal coliform 700 counts/100ml. A substantial summer rain had occurred 2-3 days previously resulting in above normal stream flow.

The single *P. mirabilis* specimen was collected in a shallow sandy-bottomed riffle in swift current with a 110 volt AC backpack electric shocker. The most abundant fishes by number at the collecting site were: *Gambusia affinis* (83), *Ictalurus punctatus* (76), *Lepomis cyanellus* (70), *Lepomis megalotis* (22), and *Notropis venustus* (22). Other fishes collected at this site were: *Amia calva* (1), *Lepisosteus oculatus* (6), *Dorosoma cepedianum* (11), *Cyprinus carpio* (10), *Notropis atherinoides* (2), *Fundulus notatus* (1), *Ictalurus natalis* (5), *Lepomis macrochirus* (1), and *Aplodinotus grunniens* (10).

WILLIAM E. KEITH, Department of Pollution Control and Ecology, P.O. Box 9583, Little Rock, AR 72219; THOMAS M. BUCHANAN, Department of Biology, Westark College, Fort Smith, AR 72901; and HENRY W. ROBISON, Department of Biological Sciences, Southern Arkansas University, Magnolia, AR 71753.

EVALUATION OF STRIPED BASS *(MORONE SAXATILIS)* AGE FROM BODY SCALES, OPERCULAR SCALES, OPERCLES AND DORSAL SPINES

Scales have been used in aging fish for almost a century (Carlander, 1987). Age estimates from scales often lead to systematic errors if the fish are very slow growing, or are old (Casselman, 1983). It is further complicated by resorption of scales to provide calcium to fish during periods of deficiency associated with ovary development and cessation of feeding during spawning migrations (Simkiss, 1974). Ever since Scofield (1931) demonstrated the validity of using striped bass *(Morone saxatilis)* scales to determine age, aging of striped bass was done mainly by the scales (Horn, *et al.*, 1984). Collins (1982) stated that incidence of age disagreements between readers increased over 50% in older striped bass due to compacted nature of annuli at the scale margin. Heidinger and Clodfelter (1987), using known age fish, found that otoliths correctly aged striped bass while scales mis-aged 20% of fish. It is apparent that there is a need to search for a suitable hard part other than the body scale for easy and accurate assessment of fish age. The objective of our study was to compare and evaluate four calcified structures — dorsal spine, opercle, opercular, and body scales — in assessing the age of Beaver Reservoir striped bass.

A total of 28 striped bass (total length 635-979 mm) was obtained in August 1986 from the Beaver Lake National Striped Bass Tournament at Rocky Branch. Body scales from below the lateral line at the tip of the left pectoral fin, the left opercle, and the second spine from the dorsal fin were collected from each fish. The opercular scales were of two types — oval and circular. The ovoid scales were located at the antero-dorsal region of the opercles. The ovoid opercular scales were used in this study due to the clarity of annular rings compared to the circular scales. Opercular and body scales were cleaned, mounted on glass slides, and photographed by microfiche reader-printer. Opercles were cleaned of tissue by boiling them in water. Spine sections of 0.45-0.50 mm thickness were mounted on glass slides in Permount and examined under phase-contrast microscope and photographed. Fish were aged by counting the number of annuli on the scales and the translucent zones on the opercles and spine sections.

The spine annuli (translucent zones), even of the older striped bass, were very distinct and denumerable under the phase-contrast microscope. Hence, the spine ages were used as the basis of comparison with ages estimated from the other three calcified structures. Graphical comparison (Fig. 1) showed that the opercular scale and body scale ages were lower than the spine ages. The percentage agreements of opercle, body scale, and opercular scale ages with spine ages were 82.1, 17.9, and 7.1, respectively. The opercle, opercular, and body scale ages were regressed respectively on the spine ages (Fig. 1), and the deviations of the predicted ages from the spine ages were calculated. The opercular and body scales underestimated the striped bass age by an average of 1.81 (range, 1.3-2.4) and 1.89 (range, 1.2-2.6) years respectively. This trend increased with spine age. The average underestimation of age by the opercle was 0.27 (range, 0.1-0.4).

Several investigators evaluated the reliability of scale method in age assessment and found the method wanting. Beamish and Chilton (1977) reported that the scales of older lingcod *(Ophiodon elongatus)* underestimate the fish age compared to fin-ray ages. Harrison and Hadley (1979) suggested the cleithral technique to be superior to the scale method for the older muskellunge *(Esox masquinongy)* due to resolution of cleithral annuli. Mills and Beamish (1980) found the scale ages to be consistently lower than the fin-ray ages in a mark-recapture age analysis of lake whitefish *(Coregonus clupeaformis)*. Based on percent errors in aging and coefficient of variation, Boxrucker (1986) reported on greater precision in aging white crappie *(Pomoxis annularis)* by otoliths than by scales. Heidinger and Clodfelter (1987) correctly aged the known-age (0-4 yr.) walleye *(Stizostedion vitreum)*, striped bass, and smallmouth bass *(Micropterus dolomieui)* by otoliths, while many of these fish were underaged by the scale method. Without validation through mark-recapture or by known-age fish study, it was not possible to confirm which of the four hard parts examined in our study truly depicted the correct ages of striped bass. However, it is reasonable to assume that the spines provide a better source for aging striped bass, in view of the fact that the marginal annuli are more distinct and countable in spine sections than in other hard parts used in this study.

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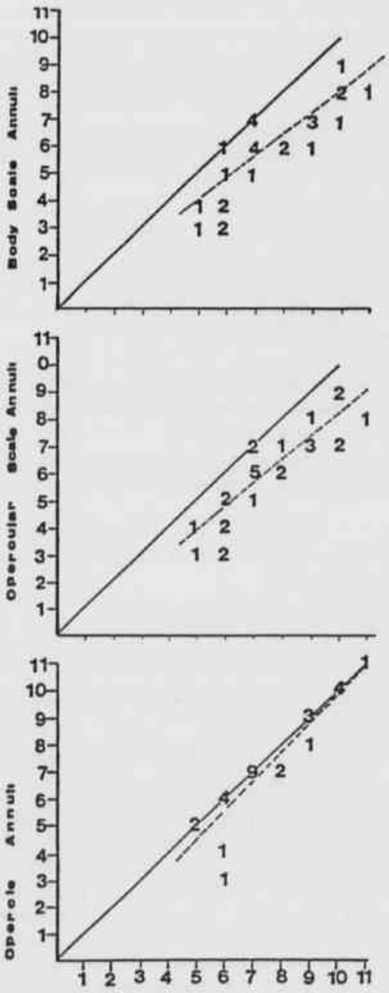

Figure 1. Comparison of body scale, opercular scale, and opercle ages with dorsal spine ages of striped bass. 45° diagonal line (—). Fitted regression line (---)

RAJ V. KILAMBI and THONIOT T. PRABHAKARAN, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

General Notes

STATUS REPORT ON THE FERN *WOODSIA SCOPULINA* IN ARKANSAS

Woodsia scopulina D. C. Eat. var. *appalachiana* (Taylor) Morton (Polypodiophyta: Woodsiaceae) is one of the rarest ferns in the state's flora, occurring in Arkansas only on Mt. Magazine, Logan Co. (Taylor, 1984; Taylor and Demaree, 1979). The Arkansas population is disjunct over 740 km from the nearest populations to the east in eastern Kentucky and Tennessee (Cranfill, 1980) and to the west in the Rocky Mountains of Colorado (Lellinger, 1985). The Arkansas plants have a pronounced morphological affinity with plants in the Southern Appalachian Mountains, which Taylor (1948) recognized at the varietal rank. In 1985, a field study, supported by the Arkansas Nongame Preservation Committee, was conducted at Mt. Magazine to determine the field status of this fern in Arkansas.

The occurrence of *W. scopulina* was highly restricted, being present in a single location near the summit. The Arkansas population consists of approximately 700 sporophytes, only 2% of which were juvenile plants; no gametophyte plants were observed. This contrasts markedly with the situation for the species in Montana, wherein recruitment was quite conspicuous (Watson and Vazquez, 1981). Although little evidence of successful sporophyte recruitment from sexual reproduction was observed, the sporophyte plants demonstrated strong vegetative vigor (# fronds per plant) and strong reproductive vitality (# spores per plant).

Approximately 80% of the population occurs on the cliff-face, with the remainder within 10 m on the talus below. In both habitats, over 90% of the sporophytes were reproductively fertile (producing spores). Sporophytes on the cliff-face averaged 18 fronds per plant, while plants on the talus averaged 11 fronds per plant. Sporophytes on the cliff-face averaged 11 fertile fronds, while plants of the talus averaged 7 fertile fronds per plant. Cliff-face plants averaged 674 sori per frond, while talus plants averaged 439 sori per frond.

These and other reproductive and ecologic differences between plants on the cliff-face and those on the talus result in a disproportionate contribution by cliff-face plants to the total annual spore production of this population. The entire population produces an estimated 22 billion spores each year, of which 20 billion are produced by cliff-face plants. Their 10:1 advantage in spore production is greater than their 4:1 advantage in number of plants. For this reason, maintenance of plants on the cliff-face may be an extremely important factor to consider in the development of any management plan or recovery plan that is dedicated to the protection of this population.

In that the present population seems to have minimal recruitment from sexual reproduction, even though it is most certainly saturating the local environment with spores, the population should be considered extremely fragile. Based on the line of inquiry presented here, we suggest that any future forest management or recreational development plans of the summit of Mt. Magazine should preclude alterations in the vicinity of this population.

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PECK, JAMES H. and CAROL J. PECK, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204, and Department of Natural Sciences, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601.

DISCOVERY OF *LYCOPODIUM* COMMUNITIES IN THE GULF COASTAL PLAIN REGION OF ARKANSAS

Until recently,the pteridophytes in the genus *Lycopodium* were represented in Arkansas by two species (Taylor, 1984; Taylor and Demaree, 1979). A few, small populations of the Shinin Clubmoss (*L. lucidulum* Michx.) occur in the Ozark Region, representing extreme southwestern disjuncts of this species. Widely dispersed populations of the Appressed Clubmoss (*L. appressum* [Chapm.] Lloyd & Underw.) occur in the Gulf Coastal Plain Region, representing extreme northwestern populations of this species. Over the last three collecting seasons (1985-1987), the authors have added appreciably to the floristic knowledge about *Lycopodium* in Arkansas. Amason noted the widespread occurrence and large local abundance of *Lycopodium* in Calhoun Co., AR. Orzell and Bridges detected that the populations were mixed, and included taxa not previously reported from Arkansas. Peck and Peck expanded the field survey, added additional populations with unreported taxa, and compared Arkansas material with that of plants from across Southeastern United States held at Missouri Botanical Garden (MO).

These efforts resulted in the discovery of additional populations of *L. appressum* in Calhoun and Garland counties, previously thought to be quite restricted in its Arkansas occurrence. We report as new to Arkansas three clubmoss species: *L. carolinianum* L., *L. alopecuroides* L., and *L. prostratum* Harper. We also report as new to Arkansas three clubmoss hybrids: *L.* X *bruceii* Lellinger (*L. appressum* X *L. prostratum*), L. X *copelandii (L. alopecuroides* X *L. appresum),* and *L. alopecuroides* X *L. prostratum.*

These *Lycopodium* taxa range along the Atlantic Coastal Plain from Florida to Massachusetts and along the Gulf Coastal Plain from Florida westward to Texas (Bruce, 1965; Synder and Bruce, 1986). They have the ability to survive, at least for a while, in interior continental areas far northward from the Gulf of Mexico, in that they were located in southern Kentucky (Johnson and McCoy, 1975; Cranfill, 1980; 1981).

These taxa are part of the *Lycopodium inundatum*-complex, a group of species plus their hybrids which are cryptic, difficult to tell apart morphologically (Bruce, 1975; Beitel, 1979; Lellinger, 1985). They maintain their distinctness across their range, in spite of their co-occurrence as a genus community and their propensity to hybridize. The use of pteridophyte genus communities (communities of many species of one genus) to expand the recognition of taxonomically useful characteristics (such as comparisons of vegetative and reproductive phenology) for cryptic species of pteridophytes was summarized by Wagner and Wagner (1983), who noted that much comparative data which validates the distinctness of species can only be ascertained when the taxa co-occur.

All of these newly reported *Lycopodium* taxa were found occurring in genus communities across Calhoun Co., at locations where disturbance was pronounced, including barrow pits, gravel/sand quarries, roadside ditches, cleared pine plantations, and in the midst of refuse of a landfill operation. The permanence of these populations is open to study; Amason showed us one location where a large stand once flurished, but where only a few stems were presently evident, apparently having been invaded and replaced by various grasses and sedges. Although presently known in Arkansas from one county, we fully expect that additional search will establish that they occur throughout the Gulf Coastal Plain in Arkansas.

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PECK, JAMES H., CAROL J. PECK, STEVE L. ORZELL, EDWIN BRIDGES, and CARL AMASON, Biology Department, University of Arkansas at Little Rock, Little Rock, AR 72204; Department of Natural Sciences, University of Arkansas at Pine Bluff, Pine Bluff, AR 71601; Texas Natural Heritage Program, Austin, TX 78701; Institute Botanical Research, Austin, TX 78746; Calion, AR 71724.

ARKANSAS PTERIDOPHYTE FLORA UPDATE: A NEW CHECKLIST AND ADDITIONAL COUNTY-LEVEL OCCURRENCE RECORDS

This note announces the publication of a new state checklist of pteridophytes (Peck, Peck, and Taylor, 1987) and of a compilation of county occurrence record from specimens deposited at the UALR Herbarium (Peck and Peck, 1986). Over the last 152 years, 14 checklists or floras of the Arkansas pteridophytes (ferns plus fern allies) were published (Taylor, 1984). Our new checklist of 85 taxa (species plus hybrids) provides a timely update, summarizing the numerous changes in Arkansas pteridophyte floristic information that have developed through the efforts of several workers over the last 10 years. As part of his doctoral studies on the Arkansas pteridophyte flora, Taylor (1976) inspected herbarium material and conducted numerous field trips with D. Demaree to relocate populations of taxa rare in Arkansas (Taylor and Demaree, 1979). Various staff members of the Arkansas Natural Heritage Commission and Arkansas Nature Conservancy have continued to relocate rare pteridophyte populations and have located taxa previously unknown to Arkansas (Peck, Orzell, Sundell, and Peck, 1985; Peck, Peacock, and Shepherd, 1985; Peck, Peck, Orzell, Bridges, and Amason, 1987). Over the last six years, two of us (JHP and CJP) have conducted research on the reproductive biology of disjunct fern populations (Peck, 1985; Peck, 1986; Peck and Peck, 1987) and have encouraged our students to collect ferns, resulting in additions of county records from under-collected areas of the state. The summary (Peck and Peck, 1986) of county-occurrence records was compiled from a 1986 inventory of pteridophyte collections deposited at the UALR Herbarium (LRU). A total of 287 new county records belonging to 48 taxa were added to the distributional data presented in the atlas of the Arkansas flora (Smith, 1978). The authors welcome notification of other additions to the pteridophyte flora of Arkansas.

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PECK, JAMES H., CAROL J. PECK, and W. CARL TAYLOR, Department of Biology, University of Arkansas at Little Rock, Little Rock, AR 72204; Department of Natural Sciences, University of Arkansas at Pine Bluff, Pine Bluff, AR 61901; and Botany Division, Milwaukee Public Museum, Milwaukee, WI 53233.

NEW LOCATIONS FOR PONDBERRY *(LINDERA MELISSIFOLIA)* IN ARKANSAS

Pondberry *(Lindera melissifolia)* belongs to the Laurel Family *(Lauraceae)* and is closely related to Spicebush *(Lindera benzoin)*. These two shrubs occupy low-wooded moist habitats with Pondberry occurring in water and forming dense vegetative colonies. Pondberry reaches two meters in heighth with little branching whereas Spicebush can attain heights of five meters and branches frequently.

Before 1985, Pondberry *(Lindera melissifolia)* was known in Arkansas from a few locations in northern Clay County. One of the original sites in Arkansas is the Hartwig site in Clay County discovered by Tucker in 1972 (Tucker, 1974a). Pondberry is known from adjacent Ripley County in Missouri (Steyermark, 1949).

Pondberry is cited by Steyermark (1963) as one of the rare shrubs in the United States. This plant is verified as occurring in four to six states outside of Arkansas. The U.S. Fish and Wildlife Service classifies Pondberry as a Category 2 species, classified as endangered or threatened, pending further information. Ayensu and DeFilipps (1978) recommended Pondberry for national endangered status, Tucker (1974b) classified Pondberry as endangered in Arkansas, Berger and Neuner (1979) listed Pondberry as threatened in Louisiana.

Pondberry occurs in Arkansas in the Mississippi Embayment Region which has a varied topography of depressions and sandy knolls. Saucier (1978) discusses sand dunes and related eolian features of the lower Mississippi River Valley, including such areas in the St. Francis River Basin of Arkansas and Missouri. The Arkansas Natural Heritage Commission contracted an aerial survey over this area in March, 1984 to look for potential Pondberry sites. The Commission analyzed the results of this survey and determined the depressions with standing water and forest cover as the best areas to conduct a ground survey.

Seventeen such sites were selected as potential Pondberry locations with an additional 12 subdivisions from the original areas in a nine county area of Arkansas. The counties include: Clay, Greene, Jackson, Lawrence, Lee, Monroe, Phillips, Randolph and Woodruff. A ground survey was initiated in the spring of 1985 to search for this plant. All of the above areas were checked by walking through the sites to determine the presence or absence of Pondberry. This small shrub was found in seven of the 17 main areas and four of the 12 subdivisions in the above counties. The results were positive for one area each for Lawrence and Woodruff Counties and four areas were found with Pondberry in Jackson County. An additional site was also found in Clay County. This increases the county distribution from one to four for *Lindera melissifolia* in Arkansas.

Pondberry habitats in Arkansas are threatened by land clearing and many small populations have been damaged or destroyed since 1970 (personal communication from the Arkansas Natural Heritage Commission). One site of historical occurrence in Clay County for this shrub could not be verified in this study. Klomps (1980) mentions the destruction of an additional Arkansas site where land was converted to row crops. Clearing, levelling and destruction of mounds and depressions is currently taking place. It is hoped with the finding of additional sites during this study that some areas can be permanently preserved. Thanks are due the Arkansas Natural Heritage Commission for financial support for this research.

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EDWARD L. RICHARDS, Dept. of Biological Sciences, Arkansas State University, State University, Arkansas 72467, and STEVE L. ORZELL, Texas Natural Heritage Program, 1700 N. Congress Ave., Austin, Texas 78701.

APPLICATION OF GELIGAM SOFTWARE TO THE ANALYSIS OF X-RAY SPECTRA

In 1986 a feasibility study (H. B. Eldridge, "Testing Treated Posts Using X-Ray Fluorescence-A Feasibility Study." Paper presented at the Forty-Second Arkansas Transportation Research Committee Meeting April 1986.) was conducted to determine if X-ray fluorescence energy dispersive techniques could be used as a timely and nondestructive means of testing the quality of treatment of wood products. This project was of interest to and was funded by The Arkansas Highway and Transportation Department (AHTD), which uses the preservative Copper-Chrominum Arsenate (CCA).

The X-ray fluorescence energy dispersive techniques currently being investigated uses an ^{241}Am isotopic X-ray source with an ADCAM system consisting of a model 918 Multichannel Buffer, and Lithium-Drifted Silicon X-ray Detector. The software used for analysis of the spectrum collected with this system was the Geligam Gamma-ray Analysis (Geligam is a Software program developed by EG&G ORTEC 100 Midland Road, Oak Ridge, TN 37831-0895) package. Geligam is a modular software package designed for analysis of Gamma-ray spectra collected with a germanium gamma radiation detector. The modules of Geligam which were used for the X-ray analysis project were A18-BI Application Manager and A30-BI Gamma-Ray Analysis. A18-BI Application Manager program allows the user to collect data with the ADACAM, transfer spectral data, create, modify, delete or transfer bookkeeping data, print spectral or bookkeeping data, or convert emulator output files to the form needed for the analysis program to be able to use them. The emulator program is the software part of the ADCAM system which allows the PC to be used to collect spectra.

The A30-BI Gamma-ray analysis module is designed to analyze Gamma-ray spectra collected with a germanium solid state detector. The gamma analysis software is designed to work with files produced by the A18-BI application manager, in order to produce a report containing the intensities of Gamma-rays found and the concentrations of the radioactive nuclide present.

The first program to be run from the Geligam software package is the Gerpar file. This file allows the user to set initial parameters. The most important of these parameters are the MCA number, which makes sure the same set-up is used during the entire analysis, and the analysis version number, which tells the type of analysis to be performed. The only other parameters changed from the program defaults were the start and stop channels (200 and 500 respectively) and the intermediate print-out.

The next program run should be the library program which creates, modifies, or prints a library of the nuclide that the user would like the analysis program to find. In our case, the elements were Copper, Chromium and Arsenic. Only Copper and Chromium were entered into the library, due to the effect of the Compton edge of ^{241}Am on the counting statistics of Arsenic. There are three possible types of libraries which may be used. These are GAMMA, NAAA, and NAAC. The type of library used was the GAMMA simply because it fit the needs of the analysis performed.

The GAMMA library needs the following information; the half life, which was chosen to be large enough so as not to interfere with the calculations, the branching ratios, determined to be the fractional area under each of the peaks as compared to the total area of the peaks in the library. The Gammas/100D were chosen to be 100 times the branching ratio. All data entered into the library was taken from experimental data.

The Convert file must then be run in order to change the CHN file into a spectrum file and combine the outputs of the library and analysis parameter files with the spectrum. Next to calibration file must be run. This file serves three purposes. One, to calibrate the file, secondly, to adjust for the detector's efficiency knee, and third, to find the efficiency of the spectrum. The calibration file produced is then combined with the spectrum file with the use of the Convert file. The first analysis file (AN1) is then run. This file produces a UFO file which is needed in the final analysis. It also allows the user to modify any parameters set in Gerpar. The second analysis file (AN2) analyzes the UFO file formed by the first analysis program and makes a report which is placed in this file. The final program to be run is the report file, which will print a report of the file to the monitor, printer, or save it as a disk file. The report this file creates shows the energy of the peak found, the corresponding channel, the corresponding nuclide, and the peaks found that are not in the library.

As stated, the Geligam analysis software package is for the analysis of Gamma-ray spectra collected with a germanium solid state detector. The X-ray spectra which is analyzed with this study is collected with a Silicon lithium solid state detector using a ^{241}Am isotopic X-ray source. The spectra which has been collected thus far is from liquid CCA. There were 10 samples made. The samples ranged from 10% CCA to pure CCA at 10% increments. The samples were then placed in standard liquid sample containers that provided a 0.15 mil thick Mylar entrance window to the incident X-ray beam.

The background continuum and Compton edge of ^{241}Am interfered with the counting statistics of the Cr and As peaks at low concentrations of CCA. The Compton edge of ^{241}Am is approximately 9 Kev. Another X-ray (^{109}Cd) source, which is being purchased, has no appreciable Compton edge, and should not interfere with any of the peaks. However, since the As peak has good counting statistics through the range of CCA concentrations, a graph was constructed of the concentration of As versus its activity. The resulting curve was linear, as was expected.

Geligam Gamma-ray analysis program found the peaks in the X-ray spectra of the elements in the library and reported their activity. Although this is not a true activity, as in Gamma-ray analysis it may be used to find the amounts of elements in a sample. In the study underway, Geligam will be used to find the amount of CCA in a sample and the concentrations of the elements involved.

R. S. SAUNDERS, H. L. PRAY, and H. B. ELDRIDGE, University of Central Arkansas, Conway, Arkansas 72032.

FAUNA AND DISTRIBUTION OF FREE LIVING CHIGGERS (ACARINA:TROMBICULIDAE) IN ARKANSAS

In the southern United States, the pest chigger *Eutrombicula alfreddugesi* (Oudemans), is widely distributed and medically important (Jenkins, 1949; Crossley and Proctor, 1971). Infestive larvae of this mite cause dermatitis in man and some animals, resulting in economic losses (Wharton and Fuller, 1952). Dense populations of this chigger may have an adverse effect on forestry operations, recreation, and military training (Martinko, 1974; Anonymous, 1976). In the Pacific, other Trombiculid mites have long been known to transmit scrub typhus or Tsutsugamushi disease. *E. alfreddugesi* is the most common and abundant chigger on the Georgia piedmont (Ludwig, *et al.*, 1984). No previous extensive survey in the state of Arkansas has been undertaken.

A three year study of the fauna and distribution of the free living Trombiculidae of Arkansas was initiated in the fall of 1984. At this date, the authors feel that the survey has been fairly complete, but some additional work needs to be done.

Free living chiggers were collected throughout the state using "chigger samplers" as described by Wicht and Crossley (in manuscript). This method consists of placing 7 x 14 centimeter (about 100 cm^2) black vinyl baseboard rectangles on objects and placed where chiggers might occur. From previous experience in the field, the authors have learned that chiggers are most likely to be found on logs, stumps, and rocks, where lizards might sun themselves, where birds might land, or where some mammal might walk.

Localities were sampled in all hours of daylight, in temperatures ranging from 22 to 40 degrees Celsius, and in a wide variety of weather conditions including overcast, partly cloudy, and sunny. The earliest successful sampling date was May 4 and the latest successful sampling date was September 28. Even though sampling was conducted under various weather conditions, previous experience has also taught the authors that chiggers are most apt to respond to the chigger sampler if it is placed on an object, partially shaded, on a bright sunny day (Wicht and Crossley; field notes, summer of 1982) with the incident sunlight being on the order of 1000 foot candles.

Others have used small black objects to collect unengorged chiggers. Wharton and Fuller (1952) used black bakelite caps removed from reagent bottles. Loomis (1956) used rigid black plexiglass-acrylic rectangles to locate chiggers. Using his type of "chigger sampler," Loomis recoverd a total of eight different species of chigger in the state of Kansas (*Eutrombicula alfreddugesi, Trombicula sylvilagi,* and *Trombicula gurneyi* being common; *Eutrombicula lipovskyana, Trombicula lipovskyi,* and *Neoschongastia americana* in small numbers; *Euschongastia diversa* and *Euschongastia jonesi,* a single specimen each). Crossley and Proctor (1970) reported the use of small rectangles of prepainted masonite material.

Mounted specimens were identified using taxonomic keys provided by Brennan and Jones (1959). Further identifications were confirmed by D. A. Crossley (personal communication).

To date, 124 localities in 55 of Arkansas' counties have been identified in which chiggers occur. Over 2500 specimens have been collected from these localities and over 1500 of these specimens have been mounted and identified to species. Three species thus far have been identified. They are *Eutrombicula alfreddugesi, Eutrombicula splendens,* and what appears to be a new species heretofore not described.

Eutrombicula alfreddugesi is by far the most pominent species in the state. It is the most prevalent and occurs in greatest numbers in habitats where a mixture of oak-hickory pre-climax forest exists mixed with conifers. This species appears throughout all parts of the state but occurs in much less numbers and is much harder to find in areas of poor drainage and little forest such as in the delta and eastern counties. There appears to be a definite association between pine and the occurrence of this species. Boone County, for example, has a significant amount of oak, hickory, and other hardwoods, but much less than a county such as Cleburne. *E. alfreddugesi* also occurs in much greater numbers in Cleburne and like counties than in Boone County; however, there was also a great deal of variation in numbers of chiggers found in the individual sampling sites. A woods environment is not the only habitat in which chiggers were found, however. Numerous specimens were collected from such examples as stumps in state parks, logs and boards near pasture fence lines, large stones in the middle of fields or on road banks, and in one instance, from a slab of concrete in a grassy area in the middle of town.

Eutrombicula splendens is the second most prevalent free living chigger in the state. Numerous specimens of this species were recovered, but it is much less prevalent than *alfreddugesi.* It is concentrated, like *alfreddugesi,* mostly in the central and western counties. The authors believe that succinct populations of *splendens* occur; however, numbers of this species were never collected without *alfreddugesi* being found within a few meters. Both these chiggers, in fact, have been collected from the same spot on the same log at the same time. This is not to suggest that they are the same species or that they are two different species occupying the same ecological niche.

According to Jenkins (1949), *E. alfreddugesi* and *E. splendens* have sympatric ranges but tend to be concentrated in different habitats. *E. alfreddugesi* is more abundant in drier, upland habitats, while *E. splendens* is more abundant in mesic to moist situations. Our observations support those of Jenkins'.

Numerous specimens which we are calling "variants" were collected from Perry, Marion, Searcy, Pulaski, and White Counties. These chiggers keyed out to be either *alfreddugesi* or *splendens* but had either unusual or uneven setation. Both arrangement and numbers of setae in particular are important taxonomic characteristics in this family. The cause of the variation in these specimens needs to be investigated further.

A single specimen of an unknown species was taken from Scott County. Personal communication with D. A. Crossley indicates that this is probably a new species. Regrettably, efforts to obtain additional specimens from this site have proven unsuccessful.

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M. C. WICHT, JR. and A. C. ROWLAND, Department of Medical Technology, Arkansas College, Batesville, AR 72501.

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FLEMING, T. H. 1969. Population ecology of three species of Neotropical rodents. Unpublished Ph.D. dissertation. Univ. Michigcan, Ann Arbor, 231 pp.

JONES, I. C. 1957. The adrenal cortex. Cambridge Univ. Press, London, 316 pp.

WRIGHT, P. L. 1966. Observations on the reproductive cycle of the American badger *(Taxidea taxus)*. Pp. 27-45, *in* Comparative biology of reproduction in mammals (I. W. Rowlands, ed.) Academic Press, London, xxi + 559 pp.

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