Proceedings of the

ARKANSAS ACADEMY
OF SCIENCE

VOLUME XXXVII
1983

MAY 3 1984

ARKANSAS ACADEMY OF SCIENCE
BOX 837
STATE UNIVERSITY, ARKANSAS 72467
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

INSTITUTIONAL MEMBERS

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

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

EDITORIAL STAFF

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

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

ASSOCIATE EDITORS:

John K. Beadles
Aquatic Environment

Robert Steinmeier
Chemistry

Kenneth Steele
Geology

Cover: Drawing of Southern Flying Squirrel (Glaucomys volans) on white oak (Quercus alba) by Renn Tumlison.
MINUTES OF THE SIXTY-SEVENTH ANNUAL MEETING — 1-2 APRIL 1983

FIRST BUSINESS MEETING

Dr. Robbin Anderson, President, opened the meeting and recognized Dr. David Chittenden, who presented the minutes of the 66th annual meeting as printed in the Proceedings.

President Anderson recognized Dr. Robert Wright, chairman of the Department of Biology at the University of Central Arkansas and local arrangements chairman, who welcomed the Academy and made announcements.

Dr. Anderson recognized Dr. Arthur Johnson, Treasurer, who presented the following Treasurer’s Report.

FINANCIAL STATEMENT

March 10, 1983

Statement Approved by Audit April 3, 1982

Heritage Savings and Loan, Passbook Account
1,119.18

Heritage Savings and Loan, Certificates of Deposit
1,222.20

Total Funds, March 24, 1982
$4,447.47

INCOME: March 24, 1982 to March 28, 1982

1. Meeting Income
$1,871.00

2. Individual Memberships
   a. Sustaining (30) $360.00
   b. Regular (86) $860.00
   c. Associate (1) 3.00

   Total Dues (excl. Inv. above) $1,225.00

3. Institutional Dues (excl. Inv. above)
450.00

4. PROCEEDINGS, Subscriptions
1,215.00

5. Page Charges
80.00

6. RIOB Reprints
41.80

7. Interest
   a. Checking Account $28.16
   b. Certificates of Deposit 178.76
   c. Savings Account 58.87

   Total Interest $266.39

8. Collegiate Academy of Science
53.86

Total Income $4,359.99

EXPENSES: March 24, 1982 to March 10, 1983

1. PROCEEDINGS, Publication and Distribution
   a. C. Reid, Travel (585) 80.00
   b. Phillips Litho Co., Power (102) 2,000.00
   c. Jones Truck Line, Mailing (104) 28.91
   d. ARS, Editor Litho (505) 40.00
   e. Phillips Litho Co, Print (504) 900.00
   f. Phillips Litho Co, Print (710) 794.68
   g. Mary Ann McDaniel, Mink. Amt. (112) 248.36
   h. V. Nick McDaniel, Ed. Travel (314) 117.53
   i. Mary Ann McDaniel, Ed. Amt. (422) 100.43
   j. V. Nick McDaniel, Ed. Travel (323) 117.53
   k. IRS(102) 71.28
   l. IRS(119) 114.49
   m. Ark. Dept. Fish. & Admin. (111) 8.15

   Total for PROCEEDINGS $4,920.99

2. Meeting Expenses
   a. Diversified Data (583) 7.34
   b. Kinko Copier (584) 22.88
   c. Henderson State University (589) 283.48

   Total for Meeting Expenses $313.60

3. Awards
   a. Wendy Koppel, Ed. T. (186) 35.00
   b. Brian Espenschild, Ed. T. (587) 39.00
   c. Ark. Sci. Fair Assn. (118) 100.00

   Total for Awards $365.00

4. Operating Costs
   a. UAPB Bookstore, Rep. Ms. (591) 13.70
   b. Mcllroy Bank, Cashiers Ca. (592) 2.00
   c. First State Bank and Trust Co. (69) 4.94
   d. David Chittenden, St. Exp. (106) 111.05
   e. Inv. Deposit, Tenn. (107) 36.60
   f. Print, St. Bk. & Trst. Co., Chkst. (59) 13.70
   g. Hendrix College Bookstore, Stamps (311) 20.00
   h. David Chittenden, St. Exp. (112) 55.54
   i. Copy Cat, Newsletter (115) 104.87
   j. Copy Cat, Newsletter (116) 63.60
   k. UAPB Bookstore, Rep. MS. (590) 130.31
   l. UAPB Bookstore, Rep. MS. (591) 23.68
   m. Hendrix College Bookstore, Stamps (126) 20.00
   n. Pauley, BOBM(106) 51.35

   Total Operating Costs $710.71

Total Expenses
$6,648.28

BUDGET

Balance Approved by Audit April 3, 1982
$4,447.97

Total Income (See Page 11) $4,359.99

Total Expenses (see Page 23) $6,648.28

Balance for the Year — 268.29

Funds on Hand March 10, 1983
$4,359.99

Arkansas Academy of Science Proceedings, Vol. XXXVII, 1983

Published by Arkansas Academy of Science, 1983
Secretary's Report

Distribution of Accounts
(March 10, 1983)

TOTAL: $1,240.07
- First State Bank and Trust
- Arkansas-Safeway Bank and Trust

SAVINGS: $1,027.45
- First State Bank and Trust
- Arkansas-Safeway Bank and Trust

Calculations: $1,597.16
- First State Bank and Trust
- Arkansas-Safeway Bank and Trust

Total Funds, March 10, 1983: $4,359.68

Respectfully Submitted,

Arthur A. Johnson, Treasurer

Meeting: April 1-2, 1983
University of Central Arkansas
Conway, Arkansas 72032

Dr. Anderson appointed the following committees:

Audit Committee: Paul Sharrah, chair; Daniel R. England; Walter Godwin

Resolutions Committee: P. M. Johnston, chair

Meeting place Committee: not necessary since it had been previously approved that the University of Arkansas-Fayetteville will host the 1984 Academy meeting on 6-7 April. Dr. William Evans will chair the committee to choose the site for the 1985 meeting.

Dr. Tom Goodwin, chairman of the Nominating Committee presented the following candidates for office:

For Vice-President: Dr. Gary Heidt, UALR

For Historian: Dr. Henry Robison, SAU

It was moved and seconded that nominations cease. The motion passed.

Dr. Heidt presented the report of the Committee on the Collegiate Academy as follows:

The Ad Hoc Committee recommends that the Arkansas Academy of Science adopt the following procedure and awards for outstanding undergraduate research:

1. We recommend that the undergraduate papers continue to be mixed with the senior papers and carry an indication that they are presented by undergraduates and in competition for the student awards.

2. That the abstracts be submitted to and scheduled by the local committee at each meeting. However, the chairman of the local committee needs to check with the chairman of the committee to make sure that the papers are scheduled in such a way that they can be easily judged.

3. That the abstract form for submitted papers include a clearly indicated space as to whether the research was conducted and will be presented by an undergraduate student.

4. That two awards be presented. One award each for the outstanding paper in Life Science and the outstanding paper for Math & Physical Science.

5. That the awards should consist of a one year membership and subscription to Science (the Academy already has two such memberships to be given to students each year) and an appropriate certificate of merit. In addition, the President of the Academy should send a letter of commendation to the student's professor with a carbon to the professor's department chairman.

6. That a permanent standing committee on student awards be established by the Academy. This committee's charge will be to coordinate student awards. Tasks will include cooperation with the chairman of the meeting's local committee concerning scheduling of competing papers, provision of at least two judges (ideally three) for each category, formulation of judging criteria, tabulation of the judges' opinions and the presentation of awards and certificates.

After discussion the following motion was made and passed.

Furthermore, since the entire Academy membership will be unable to vote on the proposal before the 1983 annual meeting at UCA, the committee would like to submit the following motion to the Executive Committee:

"The Ad Hoc Committee on Undergraduate Student Awards moves that its recommendations concerning the procedures and award for outstanding undergraduate research efforts be approved by the Executive Committee of the Arkansas Academy of Science. The Executive Committee furthermore authorizes the Ad Hoc Committee to implement these procedures for the 1983 annual meeting of the AAS to be held at UCA. The Executive Committee authorizes the expenditure of funds necessary for the certificates of merit. And that the Executive Committee present a motion for the acceptance of these recommendations at the AAS's 1983 Business Meeting in Conway, Arkansas."

In accordance with that motion the above two committees would like to offer the following motion to the general membership:

It is moved that the general membership of the Arkansas Academy of Science accept the Ad Hoc Committee on Undergraduate Research Awards' recommendations and also accept the motion passed by the Executive Committee on 3 September 1982 concerning those recommendations. The President is thus instructed to implement the proposed recommendations.

The motion was seconded and passed.

Dr. William Evans, Vice-President, presented the report of the Committee on Dues Structure.

The ad hoc committee on dues structure appointed by President Robbin Anderson met at UALR on March 14, 1983, to consider the charge "to give our general dues structure some study and to report to the Executive Committee at the April meeting this year recommendations for change if any seem appropriate."

Dr. Arthur Johnson reported that the total funds in the Academy accounts are only slightly less than at this time last year. He also noted that, in general, the funding in the Academy has not changed significantly in the past few years. This excludes meeting costs.

The unanimous consensus of the committee members was that there is a critical need to increase the income for the Academy, particularly in view of rising costs during the past few years. After considerable discussion, the following proposals were agreed upon and are hereby submitted:

1. Expand the number of types of individual memberships with the dues as indicated:
Regular member $ 10.00 (no change)
Sustaining member 15.00 (up from $12.00)
Sponsoring member 25.00 (new)
Life member 200.00 (new)
Undergraduate member 5.00 (no change)

Note: A life membership of $200 may be made in four payments of $50.00 each over a four-year period. On this plan, the individual shall be considered as a sponsoring member until the total is paid.

2. Publish a list of members each year in the PROCEEDINGS. Different categories of members should be indicated. It was suggested that such a list could be reduced from standard-size print to the size currently used for the Treasurer’s report to save space.

3. In addition, it is suggested to the Executive Committee of the Academy that a continuing effort should be made to obtain financial support from industrial, business, federal and state government sources. A standing committee for this purpose might be in order. One member suggested that the vice president might chair such a committee.

If Item I of the report is approved by the Executive Committee and no changes in the recommendations are made, the following changes in the constitution and By-Laws will be necessary:

**ARTICLE III. MEMBERSHIP**

Section 2. There shall be two general classes of membership in the Academy: Members (consisting of Regular, Sustaining, Sponsoring, Life, and Undergraduate Members) and Institutional Members.

**BY-LAWS**

10. Dues for members (Regular, Sustaining, Sponsoring, Life, and Undergraduate) shall be set by the officers of the Academy and submitted to the membership for approval. Approval by the membership shall be by majority vote of those present. Any change of dues approved by the membership shall be effective January 1 of the year following in which the change has been approved.

**SECOND BUSINESS MEETING**

President Anderson recognized David Chittenden, Secretary, who made the following motion.

I move that the Minutes of the 66th Annual Meeting, published in the 36th Proceedings of the Arkansas Academy of Science be approved as written.

The motion was seconded and passed.

The Audit Committee presented the following report.

The members of the Audit Committee report that the books balanced and were in order.

It was moved and seconded to accept the Audit Committee’s report. The motion passed.

It was moved and seconded to accept the Treasurer’s report as presented in the First Business Meeting. The motion passed.

Dr. Evans moved the acceptance of the dues schedule as presented at the First Business Meeting and the acceptance of the changes in the Constitution and By-laws made necessary by the change in dues schedule. The motion was seconded and passed.

Mrs. Marie Arthur presented the following report on the Junior Academy of Science.

The Arkansas Junior Academy of Science is composed of high school students with the basic objective of stimulating interest in science and research among these students.

Students prepare and present papers on this research at regional meetings with the better presentations being presented at the state meeting which this year will be held at the University of Central Arkansas on April 13. One or two students will be chosen by the Academy to represent Arkansas at the American Junior Academy of Science which will be held in Detroit in May as one section of the American Association for the Advancement of Science meeting.

In addition to individual research, the Academy has involved some forty schools and four hundred students in a cooperative research project to determine if Arkansas has a significant nitrate pollution problem in drinking water from rural wells. The data from this project will be analyzed this summer.

We believe the encouragement to students and teachers, the experience, activities and association with fellow students and adult scientists that result from the activities of the Junior Academy are worthy of continued support by the Arkansas Academy of Science and I move that the Arkansas Academy of Science continue the $200 support.

The motion was seconded and passed.

Dr. Robert Kirkwood, co-chairman of the State Science Fair, reported that a site is needed for next year’s Science Fair. Any volunteers should contact Dr. Kirkwood. Dr. Kirkwood also reported that he was withdrawing as co-chairman and would need a replacement. It was moved and seconded that the Academy continue its $100 support of the Science Fair. The motion passed.

Dr. Leo Paulissen reported that the quality of papers at this year’s Westinghouse Science Talent Search was quite good. The award winners this year were

1st place: Rebecca Sue Sample
2nd place: Timothy J. Groseclose

There was one honorable mention for the Arkansas delegation at the national meeting.

Tom Palko reported that there was great involvement of students and faculty at this year’s Junior Science and Humanities Symposium. Fifteen students from ten high schools were involved in the state meeting. Mr. Palko recommended that the Academy encourage participation of students with scientific talent in JSHS activities.

It was moved and seconded that the recommendations of the Committee on the Collegiate Academy be implemented. The motion passed. The winners of the undergraduate awards were

in Life Sciences: Cheryl Tabor, UALR
in Physical Science & Math: David Coussens, Hendrix

P. M. Johnston, chairman of the Resolutions Committee, moved the adoption of the following resolution.

Be it resolved:
The members of the Arkansas Academy of Science express their gratitude to Robert Wright, Chairman of the Biology Department, and to the members of the local arrangements committee, Neal Buffaloe, Don Culwell, Fred Dalske, Arthur Hoyt and Denver Prince, for the careful planning of the meeting and for the sumptuous repast. Also, the Academy thanks the other members of the faculty of the Biology Department for their hospitality. Appreciation is expressed to the administration of the University of Central Arkansas for the use of the facilities of the university.

The Academy appreciates the efforts of the section chairmen and recognizes that they play an important role in the conduction of the meeting. To be noted are John Bealies (Aquatic Environment), James Daly (Biomedical Sciences), Robert Steinmayer (Chemistry), Ken Steele (Geology), Joe Gunter (Physics/Mathematics), Henry Robison (Vertebrate Zoology), Carl Jameson (Geography), Peggy Dorris (Invertebrate Zoology), Neal Buffaloe (Science Education), and Gary Tucker (Botany). The members of the Arkansas Academy of Science rely heavily upon the officers of the Academy to implement the programs of the Academy. We extend our thanks to Robin Anderson, President; Paul Sharrah, President-Elect; David Chittenden, Secretary; William Evans, Vice President; Arthur Johnson, Treasurer; V. Rick McDaniel, Proceedings editor; John Rickett, Newsletter editor; and in particular to Robert Kirkwood who is retiring as Historian.

The Academy expresses gratitude to the various directors of science youth activities which are supported by the Academy; Pat Howerton, Mike Rapp and Robert Kirkwood, Co-Directors of the Arkansas State Science Fair; Tom Palko, Director of the Junior Science and Humanities Symposium; Leo Paulissen, Science Talent Search; Marle Arthur, Director of the Arkansas Junior Academy of Science; and to Wayne Everett, who is Liaison Officer for all supported activities.

The Academy also wishes to recognize, along with President Farris and the biology faculty of the University of Central Arkansas, the renaming of the UCA Nature Reserve to the Jewel E. Moore Nature Reserve.

It was moved and seconded to elect the nominees for the offices of Vice President and Historian by acclaimation. The motion passed.

It was moved and seconded to appropriate $500 for editorial assistance and travel for the publication of the Proceedings. The motion passed.

It was moved and seconded that the Academy continue support for the publications of two editions of the Newsletter for 1983-1984. The motion passed.

President Anderson reported that a tentative invitation for the 1985 meeting had been made by representatives of the University of Arkansas at Monticello.

Dr. Neal Buffaloe presented the following statement and motion.

Mr. President, it is my opinion that science education at all levels in both the state and the nation is at a critical low point. On the whole, we seem to be doing little to educate the public on scientific issues that are crucial to our present and future welfare.

Therefore, I wish to move that the President of the Academy be authorized to appoint a special committee to explore ways and means whereby the Academy might communicate and cooperate with existing organizations, such as the Arkansas Science Teachers Association, whose aim is to inform the public of scientific issues.

The motion was seconded and passed.

It was announced that the outstanding science teacher for Arkansas is Bill Ingram, Dardanelle High School. This is the last year for the award of a microscope from Bausch & Lomb.

President Anderson turned the gavel over to Paul Sharrah. President Sharrah adjourned the Second Business Meeting.

Respectfully submitted,

David M. Chittenden
Secretary

Arkansas Academy of Science Proceedings, Vol. XXXVII, 1983
PROGRAM
Arkansas Academy of Science

Sixty-seventh Annual Meeting
UNIVERSITY OF CENTRAL ARKANSAS
Conway, Arkansas
Meeting concurrently with sessions of:
The Collegiate Academy of Science

Friday, 1 April
SENIOR AND COLLEGIATE ACADEMIES -- Registration
SENIOR ACADEMY -- Executive Board Meeting
SENIOR ACADEMY -- First General Business Meeting
Lunch
SENIOR AND COLLEGIATE ACADEMIES -- Registration
SENIOR AND COLLEGIATE ACADEMIES -- Papers [Concurrent Sessions]:
Chemistry I
Aquatic Environment I
Geology
Biomedical Sciences
Vertebrate Zoology
Geography
Physics-Math
SENIOR AND COLLEGIATE ACADEMIES -- Banquet
POST BANQUET SPEAKER -- Mr. Randall Sabine, EPA, Dallas

Saturday, 2 April
SENIOR AND COLLEGIATE ACADEMIES -- Registration
SENIOR AND COLLEGIATE ACADEMIES -- Papers [Concurrent Sessions]:
Botany
Chemistry II
Aquatic Environment II
Invertebrate Zoology
Science Education
ARKANSAS SCIENCE TALENT SEARCH
SENIOR ACADEMY -- Second General Business Meeting
SECTION PROGRAMS

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

CHEMISTRY I
Section Chairman: Robert Steinmeyer

EFFECT OF pH, SALT AND COUPLING STATE ON THE INTERACTION OF FERREDOXIN WITH THE CHLOROPLAST MEMBRANE.
Kim Colvert and Danny J. Davis, Department of Chemistry, University of Arkansas, Fayetteville, AR 72701.

CHEMICAL MODIFICATION OF SPINACH FERREDOXIN WITH DIETHYLPYRROCARBONATE (DEPC).
Barbara J. Vieira and Danny J. Davis, Department of Chemistry, University of Arkansas, Fayetteville, AR 72701.

FRIEDEL-CRAFTS REACTIONS OF OXALYL CHLORIDE WITH SEVERAL POLYCYCLIC AROMATIC HYDROCARBONS.
Dominic T. C. Yang and W. M. Trie, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR 72204.

ELECTROCHEMICAL STUDIES OF SOME COPPER COMPLEXES HAVING SUPEROXIDE DISMUTATIVE ACTIVITY IN BIOLOGICAL SYSTEMS.
Lonnie E. Harrison and Ali U. Shaikh, Department of Chemistry, University of Arkansas at Little Rock, AR 72204.

A THROMBIN-LIKE ENZYME FROM TIMBER RATTLESNAKE VENOM.
Collis R. Geren and Yu-Yan Shu, Department of Chemistry, University of Arkansas, Fayetteville, AR 72701.

THE HEMORRHAGIC COMPONENT FROM THE VENOM OF THE SOUTHERN COPPERHEAD.
Randal T. Tucker and Collis R. Geren, Department of Chemistry, University of Arkansas, Fayetteville, AR 72701.

THE SYSTEMIC E TOXIN OF TIMBER RATTLESNAKE VENOM.
H. Raymond Allen and Collis R. Geren, Department of Chemistry, University of Arkansas, Fayetteville, AR 72701.

SYNTHESIS AND PURIFICATION OF ALLYL-ENKEPHALINS AS MORPHINE ANTAGONISTS.
A. N. Voldeng and S. A. Essawy, College of Pharmacy, University of Arkansas for Medical Sciences, Little Rock, AR 72204.

ANALYSIS OF PESTICIDES BY LOW TEMPERATURE PHOSPHORIMETRY.
Norman L. Trautwein, Department of Chemistry, Arkansas State University, State University, AR 72467, and John C. Guyon, Department of Chemistry, Southern Illinois University, Carbondale, IL 62901.

NOBLE SYNTHESIS OF 6-HYDROXYBENZO(a)PYRENE AND 7-HYDROXYBENZ(a)ANTHRACENE.
Dominic T. C. Yang, Department of Chemistry, University of Arkansas at Little Rock, Little Rock, AR, and Leo Huang, Natural Science Department, Truman College, Chicago, IL.

NEUTRAL SUGARS FROM VARIOUS VENOMS.
Ahmed El-Sherif, Paul Gwinup, Bob Johnson, and Dewey H. Siford, Departments of Biology and Chemistry, Arkansas State University, State University, AR 72467.

SYNTHESIS OF TETRATHIAFULVALENE (TTF); CONDUCTIVITY STUDIES OF SELECTED CHARGE-TRANSFER COMPLEXES.

SYNTHESIS AND RESISTIVITY EVALUATIONS OF CHARGE TRANSFER COMPLEXES OF 7,7,8,8-TETRACYANOQUINODIMETHAN.
M. W. Teague, W. S. Taylor, C. M. Means, Department of Chemistry, Hendrix College, Conway, AR 72032.

A SYNTHETIC ROUTE TO 3,7-DIDEAZAGUANINE.
Michael W. Rapp and Michael D. Wood, University of Central Arkansas, Conway, AR.

CLONING OF ADENOVIRUS TYPED DNA FRAGMENTS.
R. K. Padmanabhan, Department of Biochemistry, University of Kansas Medical Center, Kansas City, KS, and D. M. Coussens, Department of Chemistry, Hendrix College, Conway, AR 72032.

METHEMOGLOBIN AND METMYOGLOBIN REDUCTION BY POTASSIUM FERROCYANIDE IN THE PRESENCE OF CARBON MONOXIDE.
A. Mansourl, VA Medical Center and University of Arkansas for Medical Sciences, Little Rock, AR 72206.

AQUATIC ENVIRONMENT I
Section Chairman: John K. Beadles

A PRELIMINARY REPORT ON THE ZYGOPTERA OF ARKANSAS.
George L. Harp, Dept. of Biological Sciences, Arkansas State University, State University, AR 72467.

John D. Rickett and Robert L. Watson, Biology Dept., University of Arkansas at Little Rock, Little Rock, AR 72204.

John D. Rickett and Robert L. Watson, Biology Dept., University of Arkansas at Little Rock, Little Rock, AR 72204.

EFFECTS OF TREATED WASTEWATER FROM THE CITY OF FAYETTEVILLE, ARKANSAS ON WATER QUALITY OF THE WHITE RIVER.
Arthur V. Brown, Larry D. Willis, and Peter P. Brussick, Department of Zoology, University of Arkansas, Fayetteville, AR 72701.

AEROBIC DIGESTION OF SWINE WASTELAGE WITH RECOVERY OF SOLIDS FOR CATTLE FEED.
B. D. Lowe and G. H. Emerit, Biomass Research Center, University of Arkansas, Fayetteville, AR 72701.

THE STUDY OF D-XYLOSE FERMENTATION BY Pachysolen tannophilus.
H. Punnapayak and G. H. Emerit, Biomass Research Center, University of Arkansas, Fayetteville, AR 72701.

PRODUCTION OF PROTOPLASTS FROM Triehotomopsis STRAINS.
S. J. Gracheck and G. H. Emerit, Biomass Research Center, University of Arkansas, Fayetteville, AR 72701.

AQUATIC MACROINVERTEBRATES OF THE HIATT PRAIRIE REGION: FRANKLIN COUNTY, ARKANSAS.
Julie A. Huggins and George L. Harp, Arkansas State University, State University, AR 72467.
Zooplankton Population Structure in Three Reservoirs Near the Ouachita Mountain-Gulf Coastal Plain Interface. 
Stephen B. Smith and Thomas E. Moen, U. S. Fish and Wildlife Service, Multi-Outlet Reservoir Studies, Box 705 OBU, Arkadelphia, AR 71923.

New and Uncommon Anisoptera Records for Arkansas. 
George L. Harp, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

An Ecological Assessment of Faulkner Lake, Pulaski County, Arkansas. 
Loretta Gates and Robert Wright, Dept. of Biology, University of Central Arkansas, Conway, AR 72032.

GEOLOGY 
Section Chairman: Ken Steele

Origin of the Earth's Magnetic Field. 
Laymont V. Woodruff, Hendrix College, Conway, AR 72032-3080.

Lime Mud Mounds in the St. Joe Limestone. 
L. A. Gandl, #3 Broadview Dr., Little Rock, AR 72207.

Short Creek Oolite Deposition, War Eagle Quarry, Madison County, Arkansas. 
Barbara A. Lisle, Fayetteville, AR 72701.

Early Pennsylvanian Conodont-Ammonoid Biostatigraphy and the Witts Springs Problem. 
Mary Ann Eocher, Daniel J. Murthaugh, and Wildon D. Hawkins, Department of Geology, University of Arkansas, Fayetteville, AR 72701.

Lignites of the Arkansas Gulf Coastal Plain. 
William L. Prior, Arkansas Geological Commission, 3815 West Roosevelt Road, Little Rock, AR 72204.

Depositional Environment of the Caney Point Member, White Bluff Formation (Eocene) of Southeast Arkansas. 
James E. Edson, Department of Natural Sciences, University of Arkansas, Monticello, AR 71655.

Petrology of Lower Atoka Sandstone Units at the Northern Margin of the Arkoma Basin of Northeastern Arkansas. 
Doy L. Zachry, Dean A. Ramsey, and Gary D. Harris, Department of Geology, University of Arkansas, Fayetteville, AR 72701.

Possible Causes of Channel Pattern Changes of the Red River, Arkansas. 
Margaret J. Guecione, Geology Department, University of Arkansas, Fayetteville, AR 72701.

Vitor Vere, Department of Physical Science - Geology, Arkansas Tech University, Russellville, AR 72801.

Textures of Chert and Novaculite: A Preliminary Report. 
Walter D. Keller, University of Missouri-Columbia, Columbia, MO 65211; Charles G. Stone, Arkansas Geological Commission, Little Rock, AR 72204; and Alice L. Hoerch, LaSalle College, Philadelphia, PA 19141.

A Comparison of Carbonatites at Magnet Cove and Potash Sulfur Springs, Arkansas. 
John R. Bales, Department of Geology, University of Arkansas, Fayetteville, AR 72701.

Creationism, the Arkansas Story. 
P. L. Keeler, Department of Earth Science, UALR, Little Rock, AR 72204.

Arkansas' Contribution to the DNA Field-Guide Project. 

A Paleocurrent and Petrological Analysis of the Middle Blythe Sandstone (Pennsylvanian, Morrowan). 
Richard S. Luker, P.O. Box 337, Dardanelle, AR 72834.

BIOMEDICAL SCIENCES 
Chairman: James Daly

Alterations in Immune Function in Mice Dosed with DMSO. 
Dale Ferguson, Don Deems, and James Hughes, University of Arkansas at Little Rock, Little Rock, AR 72204; D. Roberts, National Center for Toxicological Research, Jefferson, AR 72079.

Effect of Phenotype on Immunocompetence in Avy/a Mice. 
W. Campbell and D. Roberts, National Center for Toxicological Research, Jefferson, AR 72079.

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James M. Guldin, Asst. Professor, Department of Forest Resources, University of Arkansas at Monticello, Monticello, AR 71655, and N. Minx Olsen, Director, Instructional Media Center, Univ. of Arkansas at Monticello, Monticello, AR 71655.

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Michael W. Rapp, Department of Chemistry, University of Central Arkansas, Conway, AR 72032.

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Jerome C. Rose, Department of Anthropology, University of Arkansas, Fayetteville, AR 72701.

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Arthur Hoyt, Jr., Chemistry Department, University of Central Arkansas, Conway, AR 72032.

SOME NEW DIRECTIONS FOR SCIENCE EDUCATION IN ARKANSAS IN 1983.
Robbin C. Anderson, Dept. of Chemistry, University of Arkansas, Fayetteville, AR 72701.
EFFECTS OF SEWAGE POLLUTION IN THE WHITE RIVER, ARKANSAS

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ABSTRACT

Recently there has been much emphasis placed on the importance of leaf detritus processing to the energetics of stream invertebrates. This study was designed primarily to assess the effects of municipal effluent on the ability of a stream community to utilize leaf detritus, and secondarily to evaluate the extent of the pollution of the White River by the Fayetteville, Arkansas, effluent discharge. Physical and chemical water quality and benthos were sampled periodically at one station upstream and two stations downstream from the discharge, and in the Richland Creek tributary. Processing of leaf detritus was also studied at each site using 5 g of red oak (Quercus shumardii) leaves. The physicochemistry and benthic community structure indicated moderate to heavy pollution by the effluent. Despite this, leaf detritus processing rates were extremely rapid which indicated that leaf decomposition is virtually unaffected by macroinvertebrates.

INTRODUCTION

Discharge of treated municipal wastewater into a stream always alters the stream's physical, chemical and biological characteristics. The extent of the alteration is governed by the quality and quantity of the effluent and the ability of the receiving stream to assimilate and metabolize the wastes. Reduction of the biological community is recognized to be the most important result of stream pollution. Several physicochemical studies have been performed in the upper White River (Evel, 1969; Bayliss, 1971; Stone, 1971; Carahan, 1973; Gearhart, 1973; Reed, 1973; Rows, 1973) but we know of no studies which directly assessed the impact of the sewage on this stream's biota.

A general theory concerning the community organization and functional dynamics of lotic ecosystems has recently been developed (see Cummins, 1977; McIntire and Colby, 1978; Vannote et al., 1980; Minshall et al., 1983). The model is primarily based on the sequential utilization of decomposing organic detritus that enters streams from their watersheds primarily in the form of autumn shed leaves (Minshall, 1967; Coffman et al., 1971; Cummins, 1974). The rates and mechanisms involved in processing of leaves by stream invertebrates and decomposers have been rather extensively studied in unperturbed streams (e.g., see Petersen and Cummins, 1974; Suberkropp and Klug, 1976; Anderson and Sedell, 1979; Brown and Ricke, 1982), but no studies previous to this one have addressed leaf decomposition in a stream receiving municipal waste. In order to successfully manage receiving streams we must first understand how they function ecologically.

The primary objective of this study was to assess the effects of polluting a stream with treated municipal wastewater on its capacity to process natural allochthonous detritus inputs. This included an assessment of the mechanisms and rates of leaf processing, determination of the benthic macroinvertebrate community structure and analysis of the physicochemical water quality. Additional benthic community samples were taken in the Illinois River, Arkansas (an adjacent drainage basin) for comparison.

STUDY SITE DESCRIPTION

The headwaters of the White River flow northward through the Ozark Mountains in northwest Arkansas into Beaver Reservoir (Figure 1). There are three major tributaries, two of which are impounded to form Lake Sequoyah, which is owned and managed by the City of Fayetteville. After the confluence with West Fork the river is a fifth order stream and remains so downstream to Beaver Reservoir. The river meanders for approximately 15 km below Lake Sequoyah before reaching Beaver Reservoir. The headwaters streams flow through the sandstones and shales of the Boston Mountains. Downstream from the lake the river flows through cherty limestone of the Springfield Plateau. The different substrata have little influence on the physicochemistry of the river (Horn and Garner, 1965). Numerous springs contribute to the river flow along its course.

The White River is used for many purposes in addition to receiving treated wastewaters. These uses include irrigation of farmland, watering livestock and wild game, and as recreation by fishermen, canoeists and swimmers. The most significant aspect of its fishery is the annual white bass (Morone chrysops) spawning migration from Beaver Lake each spring. However, there is year around fishing for other species including crappie, various catfish, sunfish, black bass, and walleye. The intake for the municipal water supply for Fayetteville and several other communities is located in Beaver Reservoir approximately 42 km downstream from the effluent discharge.

The headwaters downstream to Beaver Reservoir have been placed in use-class A by the Arkansas Department of Pollution Control and Ecology (1975, 1981). These streams, then, are classified as suitable for primary contact recreation, propagation of desirable species of fish, wildlife and other aquatic life, raw water source for public water supplies, and other compatible uses. In addition the stream is classified as a smallmouth bass fishery. The section of the river downstream from the sewar plant has actually experienced rather extensive fish kills during the summers of 1978, 1979, 1980, and 1982.

Locations of the sampling stations are indicated on Figure 1. The first station (WR 1) was chosen to represent the environmental quality of the river before receiving secondary treated effluent from the Fayetteville sewage treatment plant. The Richland Creek site (RC) similarly provided comparative data from a relatively unpolluted tributary. Station WR 2 was about 250 m below the effluent discharge and station WR 3 was about 8 km farther downstream.

METHODS

For each station leaf packs were prepared, deployed, retrieved and analyzed similar to the methods of Petersen and Cummins (1974). Small (5.0 g) packs of air dry Shumard's Red Oak (Quercus shumardii) leaves were sandwiched between small plastic tabs and stapled together. This species does not shed its leaves until spring. The leaves were all collected from one tree during late January 1982 to ensure comparable leaf packs among sites. Instead of lashing the packs to bricks as recommended by Petersen and Cummins (1974) we secured them to the surface of the substrate using a 60d common nail through the center.

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Published by Arkansas Academy of Science, 1983
of each. This avoided the nuisance of having our experiments ruined by removal of the packs by curious passers-by. On March 24 the leaf packs were placed in areas of similar depth, current and substrate type at each station. Three packs were carefully removed after three, eight, 20, and 37 days exposure at each station. Invertebrates were removed and preserved, after which the remaining leaf material was dried at moderate temperature (50°C), allowed to air dry in the laboratory for several days, and then weighed. Processing rate coefficients (k) for the leaf packs were calculated by the method developed by Petersen and Cummins (1974) using the equation: 

\[ k = \log \left( \frac{\% R}{100} \right) / t \]

where %R is the percent leaf material remaining after the time in days (t) of exposure.

Four quantitative substrate samples of benthic macroinvertebrates were collected using a Surber square foot sampler (250 μm mesh) at each station each month from April 1982 through October 1982. Sites for these samples were chosen to best represent the variety of habitats available at each station. These invertebrate samples were preserved in 75% ethanol and returned to the laboratory where they were hand picked, sorted, identified and counted. Additional invertebrate samples were collected from a comparable study site in the fifth order reach of the Illinois River (IR), Arkansas, during April, July and October, 1982. Three samples were taken each date using a 0.05 m² vacuum sampler with a mesh size of 250 μm. Species diversity was calculated by the Shannon-Weaver index: 

\[ S.D. = \sum \frac{n_i}{N} \log \frac{n_i}{N} \]

where \( n_i \) is the ratio of the number of individuals in the \( i \)th species to the total number of organisms in the sample.

Selected physicochemical analyses were performed at each station periodically from April 1982 through March 1983. These tests included flow, dissolved oxygen, turbidity, conductivity, chloride, nitrate nitrogen, ammonia nitrogen, orthophosphate, and fine particulate organic matter (FPOM). The FPOM was collected by filtration of 500 ml of water on Whatman GFF filters. The other tests were performed according to standard methods (American Public Health Association, 1975).

RESULTS AND DISCUSSION

Leaf processing rates observed in this study were extremely rapid. The slowest decay rate was at the site immediately below the plant (k = 0.0108) but was not very different from those observed upstream (k = 0.0129) (Fig. 2). The fastest decomposition rate was observed at the second station (WR 3) downstream from the sewage outfall (k = 0.0346). Even the slower leaf processing rates would be classified as fast by Petersen and Cummins (1974) even though oak leaves are generally slow (i.e., k ≈ 0.005) to decay. The processing rate at station WR 3 was faster than that recorded for the same species in a similar study in the nearby Illinois River (k = 0.025, Brown and Ricker, 1982).

The faster processing rates must be due to a greater density and/or activity of the microbial organisms responsible for decomposition (bacteria and fungi) and perhaps higher stream temperatures experienced during the studies in Arkansas. The highest processing rate reported by Petersen and Cummins (1974) (k = 0.0305) was obtained from a study performed during the summer in Michigan. Summer stream temperatures in Michigan may be equivalent to Arkansas spring time temperatures during this study 9-14°C). In any case the leaf processing rates were definitely faster than any previously reported.

The observed differences in leaf processing rates can not be explained by the numbers of macroinvertebrates which colonized the leaf packs (Figure 3), or by the functional groups (sensu Cummins, 1974; Merritt and Cummins, 1978) associated with them. Shredders were conspicuously absent from the leaf packs at all sites; only collectors and predators were on them. The paucity of invertebrates associated with the leaf packs (< 8 spp) and the absence of shredders indicates that invertebrates may have little effect on leaf processing rates. This agrees with the conclusion from a leaf processing study in an Ozark cave stream (Brown and Schram, 1982). A shredder species (Tipula sp) was collected by Surber sampler at stations 1, 3 and 4 (see Table 1) but was never collected with a leaf pack.

Figure 1. Map of the headwaters region of the White River, Arkansas,with study sites indicated.

Figure 2. Leaf pack weight loss at four sites in the White River, Arkansas. WR1 = ○, WR2 = □, WR3 = △, RC = ▼. See Figure 1 for location of study sites.
The benthic macroinvertebrate community, as indicated by collections with Surber samplers, was most diverse above the effluent discharge with a total of 25 taxa (see Table 1). Twenty taxa were present in Richland Creek, 17 were collected at WR 3 about eight km downstream, and only eight taxa could be found 250 m below the outfall. Mayflies and molluscs were fairly abundant upstream but were conspicuously absent immediately below the sewer plant. Gordon (1976, 1982) in studies of the Mollusca of the White River reported 47 species from the headwaters and noted the complete extirpation of species from below the Fayetteville sewage outfall to the headwaters of Beaver Reservoir. When he collected in this area, the Asiatic clam, Corbicula, was in Beaver but not above it in the headwaters. It was very abundant during this study upstream from the sewage plant (WR 1) but was absent from the other sampling stations (Table 1). Perhaps fishermen who use them for bait have unintentionally introduced them at this site.

The macroinvertebrate fauna was not very rich in species or numbers at any of the sampling stations, which indicates a generally depauperate situation within this reach of the stream. This observation is supported by the low species diversity indices given in Table 1. Willm and Dorris (1966) considered streams with a diversity index between one and three to be moderately polluted. Considering the other facts for this stream, including the absence of mayflies and molluscs below the sewage outfall and the recurrent fish kills, we would suggest that it is heavily polluted at the other sites. The Richland Creek site was primarily bedrock with little suitable habitat for benthos or it may have had a higher diversity. The Shannon-Weaver index is quite responsive to evenness (Willm, 1967), so the large number of Corbicula at the upstream site depressed the value there.

The White River is quite similar to the adjacent Illinois River regarding their topography, geology, and agricultural practices in their watersheds. However the Illinois receives less municipal sewage. A comparable fifth order site on the Illinois River had 53 species and a species diversity index of 2.49 despite the fact that only nine 0.05 m² samples were represented compared with 28 0.1 m² samples at each of the four sites on the White. The abundance and diversity (18 taxa) of mayflies attests to the relatively unpolluted status of the Illinois.

Table 1. Benthic macroinvertebrates distribution and abundance (N/M²) in the White River, Arkansas, upstream and downstream from the Fayetteville sewage discharge. See Figure 1 and the text for station locations.

<table>
<thead>
<tr>
<th>TAXA</th>
<th>WR1</th>
<th>WR2</th>
<th>WR3</th>
<th>RC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insecta</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ephemeroptera</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Baetis</td>
<td>9.99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isonychia</td>
<td>5.38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Simuliidae</td>
<td></td>
<td>3.46</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tipula</td>
<td>1.95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plecoptera</td>
<td></td>
<td>0.77</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diptera</td>
<td></td>
<td></td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>Megaloptera</td>
<td></td>
<td>13.45</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>Coleoptera</td>
<td></td>
<td></td>
<td></td>
<td>3.38</td>
</tr>
<tr>
<td>Hemiptera</td>
<td></td>
<td></td>
<td></td>
<td>2.38</td>
</tr>
<tr>
<td>Crustacea</td>
<td></td>
<td></td>
<td></td>
<td>6.53</td>
</tr>
<tr>
<td>Decapoda</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Orconectes hyma</td>
<td>0.38</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isopoda</td>
<td></td>
<td></td>
<td>1.15</td>
<td>0.38</td>
</tr>
<tr>
<td>Oligochaeta</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annulida</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 1.** Benthic macroinvertebrates distribution and abundance (N/M²) in the White River, Arkansas, upstream and downstream from the Fayetteville sewage discharge. See Figure 1 and the text for station locations.

The species diversity index of 2.49 despite the fact that only nine 0.05 m² samples were represented compared with 28 0.1 m² samples at each of the four sites on the White. The abundance and diversity (18 taxa) of mayflies attests to the relatively unpolluted status of the Illinois.

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Table 2. Physical and chemical characteristics of the White River, Arkansas, upstream and downstream from the Fayetteville sewage plant effluent discharge from April 1982 through March 1983. See text for station locations (WR 1, 2, 3, and RC).

<table>
<thead>
<tr>
<th>April 23</th>
<th>June 8</th>
<th>June 29</th>
</tr>
</thead>
<tbody>
<tr>
<td>WR1</td>
<td>WR2</td>
<td>WR3</td>
</tr>
<tr>
<td>DO (mg/l)</td>
<td>9.9</td>
<td>9.5</td>
</tr>
<tr>
<td>Conductivity (mhos/cm)</td>
<td>60</td>
<td>95</td>
</tr>
<tr>
<td>Turbidity (NPU)</td>
<td>24</td>
<td>26</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>O-Phosphate (mg/l)</td>
<td>0.05</td>
<td>0.05</td>
</tr>
<tr>
<td>NH₃ (mg/l)</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>NO₂ (mg/l)</td>
<td>0.60</td>
<td>0.60</td>
</tr>
<tr>
<td>FPOM (mg/l)</td>
<td>0.0004</td>
<td>0.0004</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>July 20</th>
<th>August 24</th>
<th>September 21</th>
</tr>
</thead>
<tbody>
<tr>
<td>WR1</td>
<td>WR2</td>
<td>WR3</td>
</tr>
<tr>
<td>DO (mg/l)</td>
<td>6.8</td>
<td>6.6</td>
</tr>
<tr>
<td>Conductivity (mhos/cm)</td>
<td>152</td>
<td>93</td>
</tr>
<tr>
<td>Turbidity (NPU)</td>
<td>17</td>
<td>16</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>21</td>
<td>29</td>
</tr>
<tr>
<td>O-Phosphate (mg/l)</td>
<td>0.12</td>
<td>0.37</td>
</tr>
<tr>
<td>NH₃ (mg/l)</td>
<td>0.22</td>
<td>0.10</td>
</tr>
<tr>
<td>NO₂ (mg/l)</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Cl⁻ (mg/l)</td>
<td>25</td>
<td>25</td>
</tr>
<tr>
<td>FPOM (mg/l)</td>
<td>0.0076</td>
<td>0.0070</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>October 21</th>
<th>January 5</th>
<th>March 26</th>
</tr>
</thead>
<tbody>
<tr>
<td>WR1</td>
<td>WR2</td>
<td>WR3</td>
</tr>
<tr>
<td>DO (mg/l)</td>
<td>9.1</td>
<td>7.3</td>
</tr>
<tr>
<td>Conductivity (mhos/cm)</td>
<td>120</td>
<td>260</td>
</tr>
<tr>
<td>Turbidity (NPU)</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>O-Phosphate (mg/l)</td>
<td>0.40</td>
<td>5.5</td>
</tr>
<tr>
<td>NH₃ (mg/l)</td>
<td>0</td>
<td>2.0</td>
</tr>
<tr>
<td>NO₂ (mg/l)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cl⁻ (mg/l)</td>
<td>25</td>
<td>75</td>
</tr>
<tr>
<td>FPOM (mg/l)</td>
<td>0.0096</td>
<td>0.0102</td>
</tr>
</tbody>
</table>

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The physical and chemical analyses corroborate with the other data to indicate that the effluent from Fayetteville's sewer plant is degrading the water quality of the White River and exceeding the standards set by the Arkansas Department of Pollution Control and Ecology (1981) (see Table 2). The abuses are especially severe during times of normal or low flow conditions. Substantial increases in orthophosphates, ammonia nitrogen, chlorides, conductivity and turbidity were observed downstream from the plant. Dissolved oxygen (DO) was considerably below recommended levels for this stream at the second station downstream during the August and September samples. The first station downstream may have been too near the outfall (250 m) to have been maximally affected regarding DO levels. During normal flow, oxygen depletion was just beginning as the water passes this station and was always lower at the second station except in April 1982, when the flow was above average. During the week of 12 September the DO consistently ranged from less than 1 to a maximum of 3 mg/l. for several kilometers below the outfall and resulted in a fish kill. We observed that most of the fish killed were carp (Cyprinus carpio) and green sunfish (Lepomis cyanellus) which are pollution tolerant species, although other less tolerant species were included. This could indicate that the reach of river no longer produces many game fish, or that the poor water quality developed gradually and the more sensitive species left before the conditions became lethal.

Results of this study indicate that the headwaters portion of the White River in the vicinity of the Fayetteville, Arkansas, sewage treatment facility has rather poor water quality and supports very few species of benthic macroinvertebrates in relation to an adjacent stream, the Illinois River. Effluent from the sewage treatment plant further degrades the stream at least as far as we have observed the upper reaches of the Beaver Reservoir. Oxygen depletion caused by the effluent resulted in a fish kill in September 1982 and similar conditions probably caused the fish kills in previous years in this stream. The depauperate condition of the aquatic invertebrate fauna upstream from the effluent discharge could be the result of nonpoint source agricultural pollution, faulty septic tanks and run off from small towns in the watershed. However, the fauna upstream could have been depleted by the harsh conditions downstream. Aquatic invertebrates drift downstream in large numbers (Waters, 1967, 1972; Miller, 1974) and the adults of aquatic insects then fly upstream to complete what Muller (1954, 1982) has called their recolonization cycle. If they are killed as they disperse downstream they can not subsequently recolonize upstream locations.

The benthic macroinvertebrate community structure distinctly indicated the water quality conditions at each station. Despite the poor water quality and the depauperate benthic fauna, the leaf detritus decomposition rates were very high, in fact there was some indication that the decomposition (processing) rate was enhanced by the effluent at station 3 downstream (see Fig. 2). This result was unexpected because benthic macroinvertebrates, especially shredders, are generally thought to strongly influence leaf decomposition rates (see Cummins, 1974, 1977; Vannote et al., 1980; and Minshall et al., 1983).

ACKNOWLEDGEMENTS

Funding for this project was provided by US/DOL/OWP Grant A-038 ARK through the Arkansas Water Resources Research Center. We thank Kristine Brown for typing and editing the manuscript. We also appreciate the constructive criticism of an anonymous reviewer.

LITERATURE CITED


Effects of Sewage Pollution in the White River, Arkansas


EVALUATION OF A FRAME Trawl AND TUCKER Trawl FOR SAMPLING YOUNG-OF-THE-YEAR FISH

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Arkadelphia, Arkansas 71923

ABSTRACT
Relative efficiencies of two trawls—a 1.88 m² frame trawl and a 2 m² Tucker trawl—were compared for sampling young-of-the-year (YOY) shad, Dorosoma sp., crappies, Promoxis sp., and sunfishes, Lepomis sp. Seven tests with six replicate hauls for each net in each test were analyzed by non-parametric techniques. Relative efficiency ratios, calculated from mean density estimates, were compared. The Tucker trawl was the more efficient for sampling YOY shad, its relative efficiency increasing as shad length increased. Results for the other two taxa were less consistent. The larger size range of YOY shad captured compared with the size ranges of fish of the other two taxa, seemingly increased the avoidance capabilities of the shad. The absence of a bridle and other boards on the Tucker trawl and towing the net away from the effect of the propeller wash contributed to its efficiency.

INTRODUCTION
Midwater trawling has been used since 1975 to study young-of-the-year (YOY) fish populations in DeGray Lake, Arkansas. A 1.88 m² frame trawl (Houser, 1972) was used for sampling in 1975-76 and a 2 m² Tucker trawl in 1977-80 (Hopkins et al., 1975). The objective of this study was to evaluate the two midwater trawls for sampling YOY fish and to develop correction factors to make catches from the two trawls comparable. Abundance estimates of shad, Dorosoma sp., crappies, Promoxis sp., and sunfishes, Lepomis sp. were analyzed. Although differences in the sampling efficiencies of small high-speed samplers have been investigated (Colton et al., 1961; Southward, 1962; and Noble, 1970), few comparisons have been made of the sampling efficiencies of midwater trawls. Sampling efficiency expresses the degree of avoidance by fish, and that degree may vary with each sampling device. The avoidance capability of an organism is theoretically related to sampler size, distance at which the organism perceives the sampler and the speed at which the sampler approaches (Barley, 1964). Unbridled nets have been shown to yield significantly higher catches than bridled nets (Quirk et al., 1975; Smith, 1972). Therefore, efficiency might differ between the frame trawl, which has two bridles, and the Tucker trawl, which has none.

METHODS
All trawling was conducted from an 8.5 m aluminum boat (3.2 m beam), powered by a diesel engine. Trawls were released and retrieved by two hydraulic winches. Seven nighttime tests were made during May or June 1977-80. Each test consisted of six hauls with one trawl followed immediately by six hauls with the other trawl in the same area. The frame trawl had a mesh size of 0.79 mm and the Tucker trawl, 0.50 mm. Sampling was conducted at a time when larvae were vulnerable to both mesh sizes. Oblique hauls to a depth of 7 m were made with both trawls.

When the Tucker trawl was used it was lowered in a closed position, opened, and retrieved at a 45° angle. Because of the steep angle of retrieval, the effective opening of the Tucker trawl was calculated to be only 1.5 m², whereas because of the much longer length of tow of the frame trawl, the effective opening varied little from 1.88 m². Both nets were towed at a speed of about 0.9 m/s. The frame trawl was towed directly astern, and the Tucker trawl off the starboard side, away from the propeller wash. When the Tucker trawl was used, a reinforced, perforated vinyl bag, 1.5 m long, was towed off the port side to offset the drag of the trawl. A General Oceanics flowmeter, suspended in the mouth of the net, was used to estimate the length of tows. The length of tow was multiplied by the effective opening of the net to determine volume of water sampled (about 45 m³) for the Tucker trawl and 400 m³ for the frame trawl.

Fish were preserved in 10% formalin and taken to the laboratory for identification and enumeration. Fish were identified to genus on the basis of taxonomic keys developed by May and Gasaway (1975) and Hogue et al., (1976). Subsamples from each haul were measured to the nearest 0.5 mm for larvae less than 20 mm long and to the nearest millimeter for specimens 20 mm long or longer. Because small gizzard shad (D. cepedianum) and threadfin shad (D. petenense) are very difficult to separate, data for the two species were pooled for all analyses. Catches of larval sunfishes, Lepomis sp., and crappies, Promoxis sp., were also compared.

Since variances were not always homogeneous, Wilcoxon's signed-rank tests (Sokol and Rohlf, 1969) were used to compare estimates of abundance. Mann-Whitney non-parametric tests (Steel and Torrie, 1960) were used to compare length frequencies of YOY shad. Due to the small range in lengths of the YOY sunfishes and paucity of crappies collected, length frequencies were not statistically compared for these two taxa.

The ratio of the mean density estimate (fish/m³) of the Tucker trawl for each test was divided by that of the frame trawl and termed relative efficiency (R E). This ratio was used to compare relative sampling efficiencies for YOY shad, crappies, and sunfishes. Relative efficiencies for YOY shad were pooled by 3 mm size group to assess changes in relative efficiency by size.

RESULTS
Mean density estimates of fish taken in the Tucker trawl were generally higher than those of the frame trawl (Table). Variances were less than the mean in all comparisons, indicating a relatively uniform distribution of YOY fishes (Elliot, 1971). Mean density estimates of shad based on catches in the Tucker trawl were always higher than those based on the frame trawl. The estimates were significantly higher (P < .05) in the Tucker trawl in six of the seven comparisons. The R E of the Tucker trawl was higher for all seven comparisons, ranging from 1.91 to 3.74 (Table). A significant positive correlation, indicating that the

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Published by Arkansas Academy of Science, 1983
Evaluation of a Frame Trawl and Tucker Trawl for Sampling Young-of-the-Year Fish

Table. Mean catch (fish/m²) of YOY shad, crappies and sunfishes and relative efficiency (R E) for a Tucker and a 1.88 m² frame trawl in seven tests, DeGray Lake, 1977-80.

<table>
<thead>
<tr>
<th>Sampling Date</th>
<th>Shad</th>
<th>Crappies</th>
<th>Sunfish</th>
<th>Total YOY</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tucker</td>
<td>Frame</td>
<td>RE</td>
<td>Tucker</td>
</tr>
<tr>
<td>25 May 1977</td>
<td>1.846/</td>
<td>0.695</td>
<td>2.66</td>
<td>0.183</td>
</tr>
<tr>
<td>22 June 1977</td>
<td>0.090</td>
<td>0.047</td>
<td>1.91</td>
<td>0.050</td>
</tr>
<tr>
<td>08 June 1978</td>
<td>6.387/</td>
<td>2.585</td>
<td>2.47</td>
<td>0.119</td>
</tr>
<tr>
<td>22 June 1978</td>
<td>1.031/</td>
<td>0.468</td>
<td>2.20</td>
<td>0.004</td>
</tr>
<tr>
<td>28 June 1979</td>
<td>2.452/</td>
<td>0.656</td>
<td>3.74</td>
<td>0.331/</td>
</tr>
<tr>
<td>27 May 1980</td>
<td>2.373/</td>
<td>1.202</td>
<td>2.27</td>
<td>0.749/</td>
</tr>
<tr>
<td>10 June 1980</td>
<td>0.749/</td>
<td>0.391</td>
<td>1.91</td>
<td>0.138</td>
</tr>
</tbody>
</table>

a/ Significantly greater (P < .05) than the frame trawl.

Tucker trawl was more efficient as fish length increased, was noted in only two of the seven comparisons when R E's were compared by 1 mm increments. When catches were combined from all tests and densities were pooled by 3 mm increments, a significant positive correlation was noted (Figure). When length frequencies were compared by the Mann-Whitney test, significant differences (P < .05) were noted in only three of the comparisons.

The Tucker trawl was more efficient than the frame trawl for crappies in five of the comparisons (Table). However, in only two instances were the catches of the Tucker trawl significantly higher (P < .05).

The Tucker trawl was nominally more efficient for YOY sunfishes than the frame trawl in five of the seven series and was significantly higher (P < .05) in four (Table). For all taxa combined, the Tucker trawl was significantly more efficient (P < .05) in all but one comparison (Table).

DISCUSSION

Differences in the relative sampling efficiencies of the two trawls are related to differences in trawl design, deployment of gear, size of YOY fish being sampled, and distributional patterns of fish. Our comparisons indicate that the Tucker trawl consistently captured larger numbers of YOY shad per unit of volume sampled (1.9 to 3.7 times greater) than the frame trawl. However, neither trawl was consistently more efficient in sampling YOY crappies and sunfishes. The differences in efficiency between taxa are partly due to the size of the fish. Lengths of YOY shad were 5 to 40 mm, those of most YOY crappies were 20 mm or less and those of most YOY sunfish were 10 mm or less. Barnes (1977) found that swimming speed more than doubled for shad 25 to 55 mm long in comparison with those less than 25 mm long. The difference should have a significant effect in avoidance of the trawl of YOY shad.
However, the Tucker trawl apparently reduces this avoidance to some extent, since the relative efficiency increased as shad length increased. For the smaller crappies and sunfish, differences between the two trawls were probably related to distributional patterns, and not to avoidance.

Factors other than fish size are also important in influencing sampling efficiency. Positioning the bridles and otter boards in advance of the frame trawl may decrease its sampling efficiency for some taxa. Bridles cause pressure waves in the mouth of the net which might influence net avoidance by larval fish being sampled (Clutter and Ankraku, 1968; Fleminger and Clutter, 1965). Lasker (1975) found that bridleless bongo nets made significantly greater catches of large larval anchovies than did standard meter nets.

Deployment may account for differences in sampling efficiency of the two trawls. The Tucker trawl was towed off the side of the boat away from the propeller wash, whereas the frame trawl was towed directly behind the boat. Bowles et al. (1978) reported that gear deployed over the stern of a vessel may yield biased samples due to active and passive avoidance responses to turbulent propeller wash.

At low towing speeds, the size of the net mouth is an important factor affecting sampling efficiency (Bowles et al., 1978). There was a 25 percent difference in the effective area of the mouth openings for the two trawls tested. However, we believe the size of the net mouth was not a major factor influencing sampling efficiency in these tests.

Speed of the tow can be increased to reduce gear avoidance by larger fish larvae (Aron et al., 1975; Noble, 1970; Bernalhard et al., 1973; Quirk, Lawler, and Matusky, 1974). However, speed of the tow was similar for both trawls tested.

The Tucker trawl was consistently more efficient in sampling YOY shad. Our research provides the correction factors necessary to compare catches of YOY shad from frame and Tucker trawls.

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EARLY PENNSYLVANIAN CONODONT-AMMONOID BIOSTRATIGRAPHY AND THE WITTS SPRINGS PROBLEM, NORTH-CENTRAL ARKANSAS

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Fayetteville, Arkansas 72701

ABSTRACT

The Witts Springs Formation was proposed as a lithostratigraphic unit in north-central Arkansas to include the interval from a horizon equivalent to the base of the Prairie Grove Member, Hale Formation to the top of the Bloyd Formation, of the type Morrowan Series, northwestern Arkansas. The top of the Witts Springs Formation was regarded as being unconformably succeeded by the middle Pennsylvanian Atoka Formation. Recent investigation of this unit in its type area has shown that the presumed Atokan Sandstone is actually a unit confined to the Bloyd Formation. Thus, the type section of the Witts Springs in Searcy County, Arkansas only comprises the Prairie Grove and Brentwood interval. This determination is supported by the recovery of the conodonts Idiognathoides sinuatus, Neognathodus symmetricus and Idiognathodus delicatus, and the ammonoids Arkanites, Banneroberica and Gastriceras from a succession of calcareous units below the middle Bloyd sandstone throughout the type Witts Springs and other sections in the type region. The Witts Springs should continue to be interpreted in the sense of its original definition, although a supplementary reference section is needed for the upper Witts Springs which spans the Morrowan-Atokan boundary with removal of the Trace Creek from the Morrowan.

INTRODUCTION

The lower and middle Pennsylvanian Hale and Bloyd Formations form the type Morrowan Series of northwest Arkansas. These rocks unconformably overlie Mississippian strata and they are succeeded unconformably by the Atoka Formation of middle Pennsylvanian age.

A dramatic facies change characterized by increased sandstone development occurs eastward across northern Arkansas in the Morrowan units. Only the Cane Hill Member of the Hale Formation is continuously mappable eastward and it has been raised to formation level in north-central Arkansas (Glick and others, 1964).

The Witts Springs Formation was proposed as the stratigraphic equivalent of the Prairie Grove Member of the Hale Formation and the entire overlying Bloyd Formation (Glick and others, 1964) in recognition of the facies changes occurring in the interval. In north-central Arkansas, the Witts Springs unconformably overlies the Cane Hill Formation and is overlain by the Atoka Formation.

A sandstone, informally called the middle Bloyd sandstone, caps most of the hills in north-central Arkansas and has been mistaken for the first Atokan sandstone (Zachry and Haley, 1975). Recent studies suggest that the middle Bloyd sandstones rather than the Atoka Formation, caps the Witts Springs at its type section. This situation alters the recognition of the Witts Springs as a formation and that problem has served as the focus of this study.

CONODONT AND AMMONOID BIOSTRATIGRAPHY

Both conodonts and ammonoids were recovered from calcareous lenses within the Witts Springs at its type section and other nearby localities (Fig. 1). Although biostratigraphic data is not as complete as desirable, zonations for both these faunal groups are well known from the type Morrowan succession.

The Morrowan conodont sequence of northwestern Arkansas was refined by Lane (1977) and two Morrowan conodont zones were identified with confidence. In addition, a third may be represented at the base of the Witts Springs at its primary reference section (RS). Figure 2 lists the sample horizons and abundances of the various conodont elements recovered in this study which are illustrated in figure 3.

Figure 1. Stratigraphic columns illustrating measured sections and conodont and ammonoid occurrences in the Witts Springs Formation in its type area.
Idiognathoides sinuatus Zone — The zonal name bearer (Fig. 3) was recovered from the base of section RS in association with the ammonoids Arkanites and Cancellioceras (Fig. 1). Isolated, impoverished assemblages with this form are difficult to date since it ranges into the Atokan Series. Arkanites and Cancellioceras normally occur with the conodont Neognathodus symmetricus which succeeds I. sinuatus as a zonal index in the type Morrowan sequence (Manger and Saunders, 1980). Thus, the base of section RS may fall in the N. symmetricus zone.

Neognathodus symmetricus Zone — This zone succeeds Idiognathoides sinuatus in the upper Prairie Grove and lower Brentwood at their type sections and therefore spans the Hale-Bloyd boundary (Lane, 1977). It ranges from the appearance of Neognathodus symmetricus to the first occurrence of Neognathodus bassleri (Lane, 1977). The lower part of this zone is typically coincident with the appearance of the Arkanites relicius-Cancellioceras huntsiulense ammonoid assemblage and that association was encountered at the type section of the Witts Springs (TWS, Fig. 1).

Idiognathodus delicatus Zone — This zone is defined by the overlapping ranges of Neognathodus bassleri and Idiognathodus delicatus. The upper part of the Branneroceras branneri-Gastrioceras fittsi ammonoid Zone correlates with the interval of this conodont zone. At the type Morrowan area, these zones occur in the upper Brentwood Member and elsewhere in strata thought to be marine equivalents of the Woolsey Member of the Bloyd Formation. This ammonoid and conodont association was found at section RS within the Witts Springs area (Fig. 1).

Ammonoid biostratigraphy of the Morrowan series has been discussed in detail by Saunders and others (1977) and Manger and Saunders (1980). Two ammonoid zones were identified with assurance while the zonal name bearers of two older zones were found together at the base of section WSE, but appear to be reworked.

Reitites-Quininites occurrence — Single specimens of Reitites semiretia and henbesti were found at the base of section WSE (Fig. 1). These taxa are the respective zonal name bearers of the basal two Morrowan ammonoid zones (Manger and Saunders, 1980). Both specimens are discolored, abraded and appear reworked. Unfortunately, no conodonts were recovered from the horizon.

Branneroceras branneri Zone — Branneroceras branneri was found at sections KMS and RS (Fig. 1). This distinctive form is a world-wide marker for the base of the Westphalian Series which also corresponds to the appearance of Gastrioceras. That form was found at section RS and WSN (Fig. 1). Both taxa appear at the top of the Brentwood Member at its type section and range through the marine equivalents of the Woolsey Member. The ammonoid association usually occurs with conodonts of the Neognathodus bassleri and succeeding Idiognathodus delicatus zone. At section WSN, Gastrioceras occurs with N. symmetricus; this association is not known in the type Morrowan region, and the N. symmetricus may be reworked.
Early Pennsylvanian Conodont-Ammonoid Biostratigraphy and the Witts Springs Problem, North-Central Arkansas

STRATIGRAPHIC IMPLICATIONS

The interval equivalent to portions of the Prairie Grove at the type Witts Springs appears to be essentially the same lithology as it is in Washington County, except for being much thinner. The *Arkaniites-Canceilloceras* ammonoid zone was found with the *Neopentacanthus symmetricalis* conodont zone at the base of the Witts Springs at the localities RS and TWS. This zone occupies the middle of the Prairie Grove Member of the Hale Formation, and lack of lower Prairie Grove age equivalents may be due to increased duration of erosion at the Cane Hill-Witts Springs contact. Reworking of ammonoids and conodonts at section WSE in the base of the Witts Springs supports this idea.

The interval equivalent to the Brentwood within the Witts Springs changes dramatically in appearance and thickness compared to the Brentwood at its type section. The Brentwood interval is nearly three times thicker in central Arkansas and changes from quartz-bearing limestone and shale to an alternation of sandstone and shale.

Conodonts and ammonoids indicate that the Witts Springs in its type area is equivalent to the Upper Prairie Grove and Brentwood interval of the type Morrowan succession. No conodonts or ammonoids suggestive of Morrowan intervals higher than the Brentwood were found in the type region of the Witts Springs Formation beneath the presumed middle Bloyd sandstone.

CONCLUSIONS

There seems to be little value in a lithostratigraphic unit equivalent only to the Prairie Grove-Brentwood interval. This situation would leave strata above the middle Bloyd sandstone unnamed and would be difficult to recognize with the absence of the middle Bloyd sandstone in the eastern portion of northern Arkansas. Therefore, the Witts Springs should be interpreted along the lines originally intended rather than relations at the type section. The formation is easily seen as a change from thin bedded shale-siltstone succession of the Cane Hill to the massive, conglomeratic, basal sandstone of the Witts Springs. The Morrowan sequence above the middle Bloyd sandstone is totally shale east of Madison County because the Kessler disappears. The loss of the Kessler causes the Morrowan-Atokan boundary to be a shale-on-shale contact. Therefore, the first massive sandstone of the Atoka should be chosen to represent the upper contact of the Witts Springs because of its mappability, although this proposal requires extensive study. By this definition, the Witts Springs Formation spans the Morrowan-Atokan boundary since the Trace Creek shale has been removed to the Atoka Formation (Sutherland and Manger, 1983).

ACKNOWLEDGEMENTS

We wish to thank Walker L. Manger, Professor of Geology, University of Arkansas for his help in the supervision of this research and the preparation of this manuscript. Thanks also to Kenneth F. Steele, Associate Editor for Geology for the helpful review of an earlier version. Murdaugh and Hawkins wish to thank Norman F. Williams, Arkansas Geological Commission for funding the field work upon which this study is based.

LITERATURE CITED


A COMPARISON OF TWO YEAR CLASSES OF HYBRID GRASS CARP AND GRASS CARP FOR AQUATIC PLANT CONTROL

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ABSTRACT

Two year classes of grass carp and F₁ hybrids resulting from bighead carp male x grass carp female were compared at various stocking densities for aquatic plant control. One and two year old grass carp exhibited higher survival rates and better growth rates than the same age hybrid grass carp. The presence of grass carp or hybrid grass carp decreased both Secchi disc transparencies and dissolved oxygen values. Grass carp had a greater negative effect upon these measurements because they removed the vegetation quicker than the hybrid grass carp. These apparent detrimental effects on water quality are necessary trade-offs for vegetation removal by any method.

Grass carp and hybrid grass carp utilized Chara sp., Potamogeton pectinatus, Hydrodictyon sp., Rhizoclonion sp., and Pithophora sp. Two year old hybrid grass carp required approximately twice as much time as the same age grass carp to eliminate dense growths of the vegetation listed above. One year old hybrid grass carp were slightly less effective than one year old grass carp at controlling these same plant species. However, it was extremely difficult for one or two year old hybrid grass carp to totally eliminate dense growths of these plant species except at high stocking densities. The use of mean vegetation heights to indirectly measure total plant biomass was unacceptable whenever unpreferred floating plant species were present. The hybrid grass carp appeared to be a poor alternative biological control for nuisance aquatic vegetation when compared directly to the grass carp.

INTRODUCTION

Problems with aquatic plant growths exist in most parts of the United States in varying degrees (Hamilton, 1977; Celle et al., 1978; Mitzen, 1978). Many problems plant are nonnative species that have spread at alarming rates in new environments. They abduct water flow, impede drainage, interfere with recreational uses, and occasionally pose health hazards.

The four basic methods of controlling noxious aquatic plants are chemical, mechanical, physical, and biological. Chemical control is costly, results are temporary, and in many cases control is not attained (Mitzen, 1978). Chemical control is also potentially hazardous to the ecological balance of a pond, lake, or river, as well as to man himself (Kilgen and Smitherman, 1971). Mechanical control is also very temporary and extremely expensive (Bailey, 1972). Physical manipulations are restricted by economical considerations, climatic conditions and the physical parameters of certain bodies of water. When physical manipulations are implemented, they can be quite effective. Biological control can be relatively inexpensive, long lasting, and ecologically safe.

Although several species of fishes have shown promise in controlling unwanted vegetation (Kilgen and Smitherman, 1971), the grass carp (Ctenopharyngodon idella) was reported by Swingle (1957) as one of the most promising fish species for controlling rooted aquatic species. Grass carp were first introduced into the United States in 1963 at the Fish Farming Experimental Station, Stuttgart, Arkansas, and at Auburn University, Auburn, Alabama (Stevenson, 1965; Guillory and Gasaway, 1978). Although two decades have passed since this introduction, grass carp have remained a highly controversial and emotional subject among fisheries administrators and biologists. At the base of this controversy is the fear that grass carp might become established in natural waters and compete with native species for food and living space (Kilgen and Smitherman, 1971; Forrester and Lawrence, 1978). Restrictions on the importation and possession of grass carp in many states (Cassani, 1981) have created a need for an alternative to the grass carp for biological control of nuisance aquatic vegetation.

Using the work of Marjan and Krasznai (1978) as a base, the Arkansas Game and Fish Commission produced the F₁ hybrid of female grass carp and male bighead carp (Aristichthys nobilis) in May 1979. Initially, all progeny of this cross were determined to be triploid and were, therefore, assumed to be sterile (Beck et al., 1980). Since the sterility of the hybrid grass carp would allay most of the fears associated with the natural reproduction and establishment of the normal diploid grass carp, the triploid hybrid was a suitable candidate for biological control of unwanted plants in managed and unmanaged waters.

Subsequent investigations (Drs. Beck and Biggers, pers. comm., Memphis State University, Memphis, Tennessee) have revealed that some F₁ hybrids are diploids. The percentage of diploids obtained is quite variable (near 100% to near 0%) and may be controlled by the mechanics of the hybridization production technique (Mr. J. M. Malone, pers. comm.).

Under controlled laboratory conditions, it has been reported that small triploid grass carp and triploid carp have similar vegetation preferences and food consumption rates (Kilambi and Zdlinaik, 1980), and exhibit similar feeding behavior (Cassani, 1981). However, a comparison of these two fishes in natural conditions and at different sizes was necessary, since the food preferences and consumption rates of triploid grass carp might change with fish size and age since several investigators have reported size related food preference and consumption rate changes in grass carp (Buck et al., 1975; Meyer et al., 1975; Stanley et al., 1978). This investigation was undertaken to compare two year classes of triploid hybrid grass carp and grass carp with respect to aquatic vegetation preference and consumption.

METHODS

Ten 0.4 ha earthen ponds at the Joe Hogan State Fish Hatchery in Lonoke, Arkansas, were filled with water and inoculated with several species of aquatic vegetation in March of 1981. Species introduced were Potamogeton pectinatus, Chara sp., Hydrodictyon sp., Pithophora sp., Rhizoclonion sp., and Spirogyra sp. These ponds averaged 0.98 m in water depth: water was periodically added to maintain equal water depths in all ponds.

Vegetation sampling was conducted at three week intervals starting on 24 April, 1981. Sampling methodology was similar to that of Buck et al. (1975), Celle et al. (1978), Mitzen (1978), and Lembi et al. (1978). This method consisted of making transects in each pond diagonally from...
A Comparison of Two Year Classes of Hybrid Grass Carp and Grass Carp for Aquatic Plant Control

In May of 1981, the 10 ponds were divided into four sets on the basis of preliminary vegetation sampling. Two sets of three ponds each and two sets of two ponds each were then randomly stocked with triploid grass carp hybrids, and grass carp from each of the two year classes. This grouping was done in order to insure that ponds dominated by the same plant species would be paired. One pond from each of the pond sets served as non-fish stocked controls.

Upon harvest, ploidy determination was made on approximately 50 hybrid grass carp from each year class by Andrew J. Mitchell of the Stuttgart Fish Farming Experimental Station utilizing the red blood cell nuclear volume technique described by Beck and Biggers (1981).

Table 1. Stocking parameters of grass carp and hybrid grass carp.

<table>
<thead>
<tr>
<th>Pond</th>
<th>Pond set</th>
<th>Species</th>
<th>Year</th>
<th>No. fish</th>
<th>Average total length (cm)</th>
<th>Average weight (g)</th>
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<tbody>
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<td>A</td>
<td>Grass carp</td>
<td>1979</td>
<td>951</td>
<td>365</td>
<td>426</td>
</tr>
<tr>
<td>14</td>
<td>A</td>
<td>Hybrid grass carp</td>
<td>1979</td>
<td>951</td>
<td>360</td>
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<td>1</td>
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<td>Grass carp</td>
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<td>370</td>
<td>365</td>
<td>426</td>
</tr>
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<td>19</td>
</tr>
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<td>918</td>
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<td>Hybrid grass carp</td>
<td>1980</td>
<td>404</td>
<td>224</td>
<td>107</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Fish

Stocking rates, survival percentages and growth data of the grass carp and the F1 hybrid are contained in Tables 1 and 2. There were no significant differences in initial stocking lengths or weights between 1979 year class grass carp and 1979 year class hybrid grass carp. However, the 1980 year class grass carp were significantly smaller (P < 0.05) in length and weight than the 1980 year class hybrid grass carp at stocking.

Ploidy determination of 44 hybrid grass carp from the 1979 year class revealed that 43 fish were positively triploid and that the remaining fish was probably a triploid. Fifty hybrid grass carp from the 1980 year class were also examined. Forty-eight of these fish were triploids, one fish was probably a triploid, and one fish was a diploid.

Grass carp survival rates exceeded 95% and were greater than those reported by Colle et al. (1978) or Lembí et al. (1978) for similar size fish. The 1979 year class hybrid grass carp exhibited a survival rate of 88.4%, while the smaller 1980 year class hybrid grass carp experienced a 65.5% survival rate. Since dead fish were not observed in any pond after initial stocking mortalities, these losses were probably the result of predation by mink, snakes, or wading birds (Colle et al., 1978; Lembí et al., 1978; Thomas et al., 1979). Hybrid grass carp may have been more susceptible to predation, since Secchi disc transparencies (Figure 1 and 2) were generally greater in hybrid grass carp ponds than in grass carp ponds.

Table 2. Harvest parameters of grass carp and hybrid grass carp.

<table>
<thead>
<tr>
<th>Pond</th>
<th>Pond set</th>
<th>Species</th>
<th>Year</th>
<th>Dms. fish</th>
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<th>Average weight (g)</th>
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<tr>
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<td>Hybrid grass carp</td>
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<td>C</td>
<td>Grass carp</td>
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<tr>
<td>5</td>
<td>D</td>
<td>Hybrid grass carp</td>
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<td>Hybrid grass carp</td>
<td>1980</td>
<td>404</td>
<td>224</td>
<td>107</td>
</tr>
</tbody>
</table>

Figure 1. Secchi disc transparencies at three week intervals beginning May 3, 1981, in ponds receiving no fish (3 and 15), 1979 grass carp (1 and 3), or 1979 hybrid grass carp (2 and 4). Ponds 1 and 2 received 61 fish per ha and ponds 16 and 14 received 156 fish per ha. Ponds 16, 15, and 14 constitute set A and ponds 1, 2, and 3 constitute set B.

Growth of grass carp and hybrid grass carp cannot be directly compared since the ponds were harvested at different times. However, average daily growth increments can be compared, since ample vegetation for fish growth was always present prior to harvest. The 1979 year class carp exhibited average daily length increments that were 2.5 and 3.4 times greater than those of 1979 year class hybrid grass carp at densities of 156 and 61 fish per ha, respectively, and average daily weight increases for 1979 year class grass carp at these respective densities were 4.7 and 4.8 times greater than those of 1979 year class grass carp (Table 2). Since the different initial sizes of 1980 year class grass carp and hybrid grass carp might distort comparisons between their daily growth rates, these comparisons are not presented. However, in all instances the 1980 year class grass carp exhibited greater daily increases in lengths and weights than the 1980 year class hybrid grass carp (Table 2).
Water Quality

Secchi disc transparencies (Figures 1 and 2) generally decreased in all ponds during the study. Decreases in Secchi disc transparencies greater than 25 cm were not noted in control ponds 3 and 15 until sample periods 5 and 6, respectively. Ponds containing fish, however, usually exhibited decreases greater than 25 cm much earlier. Lembi et al. (1978) observed increased turbidity levels in ponds containing grass carp. These increases correspond to decreased Secchi disc transparencies, since Secchi disc measurements are an indicator of visibility (Welch, 1983).

Within each set of ponds, grass carp depressed Secchi disc measurements earlier and to a greater extent than did hybrid grass carp. Since equal numbers of fish were stocked within a set, turbidity increases resulting from fish movements and activities probably would not have accounted for these differences. Although plankton populations were not monitored, it is believed that the grass carp exerted a greater negative effect upon Secchi disc transparencies than did the hybrid grass carp by stimulating plankton production through the release of nutrients from macrophytes. Decreases in total biomass of macrophytes within a pond (Figures 3, 4, and 5) were reflected by decreased Secchi disc values at the same or next sample period (Figures 1 and 2).

Ranges and means of surface temperatures and dissolved oxygen levels for the ponds are illustrated in Table 3. Pond temperatures ranged from 21 to 35 C and never differed among ponds by more than 2 C at any one sampling date. Pond temperatures were always greater than 14 C which Cole et al. (1978) reported as the temperature where grass carp exhibited a marked decrease in growth.

Dissolved oxygen levels were always above 4 ppm in all ponds which is sufficient to maintain fish. Within pond sets A and B, control ponds (15 and 3) exhibited the highest mean oxygen levels, hybrid grass carp ponds (14 and 2) had intermediate mean oxygen values, and grass carp ponds (16 and 1) exhibited the lowest mean oxygen values. Hybrid grass carp ponds (5 and 7) in sets C and D, also, had mean oxygen levels greater than their respective grass carp ponds (4 and 6). Thus, the presence of grass carp or hybrid grass carp decreased dissolved oxygen values. Grass carp had a greater negative impact upon these values than did hybrid grass carp. This reduction in dissolved oxygen levels is probably a necessary trade-off for vegetation removal.

Rottmann and Anderson (1977) observed that average dissolved oxygen concentrations were greater in ponds containing grass carp than in ponds not containing grass carp. Differences in sampling times may account somewhat for this discrepancy, since they obtained their oxygen concentrations immediately after dawn as opposed to 0600 hours when some photosynthesis would have already occurred. The stocking density utilized by Rottmann and Anderson of 233 fish per ha was lower than our minimum stocking density of 370 fish per ha. However, this difference in fish stocking rates should have only a minor effect on dissolved oxygen levels.
A Comparison of Two Year Classes of Hybrid Grass Carp and Grass Carp for Aquatic Plant Control

Table 3. Ranges and means recorded for dissolved oxygen and temperature values of the pond waters.

<table>
<thead>
<tr>
<th>Pond number</th>
<th>Set designation</th>
<th>Dissolved oxygen</th>
<th>Temperature (°C)</th>
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<td></td>
<td>range mean</td>
<td>range mean</td>
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<td>4.2-9.2 6.7</td>
<td>21-25 25.1</td>
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<td>A</td>
<td>4.0-12.0 7.3</td>
<td>21-26 27.0</td>
</tr>
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<td>A</td>
<td>4.4-10.0 7.4</td>
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<td>5.9-7.8 6.7</td>
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</tr>
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<td>B</td>
<td>6.0-11.0 8.5</td>
<td>21-26 28.0</td>
</tr>
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<td>B</td>
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<td>7</td>
<td>D</td>
<td>6.0-9.0 7.2</td>
<td>21-25 25.8</td>
</tr>
</tbody>
</table>

Figure 5. Plant biomass at three week intervals beginning May 3, 1981, in ponds receiving 1980 grass carp (4 and 6) or 1980 hybrid grass carp (5 and 7). Set C ponds (4 and 5) received 988 fish per ha and set D ponds (6 and 7) received 494 fish per ha.

Biomass Reduction

Plant biomass of all ponds utilized during the study is illustrated in Figures 3, 4, and 5. Fish were added to all ponds approximately one week prior to sample period one on May 6, 1981. Thus, any noticeable effects upon plant biomass probably would not be evident until four weeks later at sample period three (three week intervals between sample periods).

Species composition of plants within set A ponds varied from pond to pond as time progressed (Figure 5). At sample period one (24 April, 1981) Hydrodicton sp. dominated all set A ponds comprising at least 62.4% of the initial plant biomass in each pond. Ponds 14 and 16 in set A received 1979 year class fish at 951 fish per ha prior to sample period two. By sample period two Hydrodicton sp. and Potamogeton pectinatus were co-dominants in ponds 16 (51.1% and 48.9% respectively) and 14 (27.3% and 72.7% respectively), while Hydrodicton sp. still dominated control pond 15 (81.8% of plant biomass). Furthermore, Potamogeton pectinatus comprised at least 64.2% of the plant biomass in pond 14 with Rhiocolea sp. making up the remaining biomass present. Philoophora sp. accounted for at least 55.2% of the plant biomass in control pond 15 after sample period two. Potamogeton pectinatus and Chara sp. were also present in control pond 15, which exhibited the greatest species diversity of set A ponds.

All of the plant species present in set A ponds were readily consumed by grass carp and hybrid grass carp. Various studies have documented that grass carp will utilize Hydrodicton sp. (Lewis, 1978), Potamogeton pectinatus (Singh et al., 1967), Chara sp. (Kilgen et al., 1976), Philoophora sp. (Singh et al., 1967), and Chara sp. (Kilgen et al., 1976). The only information available concerning hybrid grass carp utilization of the plant species present in set A ponds was that Chara sp. was a preferred food (Cassani, 1981).

Species diversity of plants within set B ponds was quite complex. At sample periods one and two, ponds 1 and 2 were dominated by Potamogeton pectinatus, which comprised at least 61.7% of the biomass in each pond. At sample period two, pond 1 also contained significant amounts of Hydrodicton sp. (31.4%) and Chara sp. (6.9%) while pond 2 contained significant amounts of Rhiocolea sp. (11.8%) and Chara sp. (10.3%). By sample period three in pond 1 and by sample period four in pond 2 only Potamogeton pectinatus and Rhiocolea sp. remained as co-dominants in each pond. Hydrodicton sp. comprised 87.2% and 72.0% of the plant biomass in control pond 3 at sample periods one and two, respectively. However, by sample period three, Hydrodicton sp. was no longer present in control pond 3 which contained 42.8% Rhiocolea sp., 36.2% Potamogeton pectinatus, and 20.92% Chara sp. By sample period six, Philoophora sp. made up 66.1% of the plant biomass in control pond 3 with Potamogeton pectinatus accounting for the remaining 33.9%.

Ponds 1 and 2 in set B (Figure 4) received 1979 year class fish at 370 fish per ha. The two year old grass carp eliminated the vegetation in pond 1 by sample period four but vegetation was still present at project termination in pond 2 which contained the two year old hybrid grass carp. After sample period two, control pond 3 exhibited the highest plant biomass of set B ponds.

By examining peak biomass occurrences for each plant species in ponds containing fish compared to fish free control ponds, certain feeding selectivities were observed. At the lower stocking density utilized in set B ponds (370 fish/ha) the two year old grass carp exhibited a preference for Potamogeton pectinatus and Chara sp. over Hydrodicton sp. Chara sp. (Menta et al., 1976) also observed a similar preference for small grass carp for Chara sp. and Potamogeton pectinatus. The two year old hybrid grass carp at the same stocking rate selected Potamogeton pectinatus over Rhiocolea sp. and Chara. This was contrasted to the observations of Cassani (1981) who reported that Chara sp. was preferred by hybrid grass carp over six other submerged plant species. The higher stocking density utilized in set A ponds (971 fish/ha) prevented feeding selectivities from being observed since biomass reduction occurred quickly.

Ponds 4 and 5 in set C were dominated throughout the study by Chara sp. which comprised at least 73.6% of the biomass present. Both ponds received the higher stocking density of 1980 fish at 988 fish per ha. The one year old grass carp eliminated all vegetation in pond 4 by sample period four (Figure 5) and the one year old hybrid grass carp eliminated all vegetation in pond 5 by sample period five. As previously stated, Chara sp. is utilized by both grass carp (Kilgen and Smitherman, 1971), Willey et al., 1974, Menta et al., 1976, (Kilgen et al., 1976) and hybrid grass carp (Cassani, 1978).

Ponds 6 and 7 in set D (Figure 5) were stocked with one year old fish at the rate of 494 per ha. These two ponds developed dense plankton blooms immediately after fish stocking as measured by Secchi disc transparency. (Figure 2). Dense growths of aquatic macrophytes did not occur prior to or after fish introduction, so little can be stated concerning their reduction.

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Vegetation Height
Average heights of vegetation in all ponds utilized in the study are depicted in Figures 6, 7, and 8. Vegetation heights were greatly influenced by the plant species present, since the occurrence of floating species resulted in increased heights. Wind direction and intensity, also, affected vegetation heights by windrowing the floating species along pond edges.

Vegetation heights in set A (Figure 6) and set B (Figure 7) ponds which contained the 1979 year class of fish stocked at 951 and 370 fish per ha generally reflected the same trends as the plant biomasses in these ponds (Figures 3 and 4). Set A ponds always contained large amounts of the floating species: Hydrodictyon sp., Pithophora sp. and Rhizoclonia sp. Pond 2 which contained the lower stocking density of 1979 hybrid grass carp showed an increase in vegetation height at each period until sample period six. An inverse relationship occurred in pond 2 between vegetation height and plant biomass (Figure 4) due to a sparse covering of Rhizoclonia sp. in pond 2 during the study.

Mean vegetation heights of set C and D ponds (Figure 8), which received the 1980 year class of fish at 988 and 494 fish per ha reflected the plant biomasses of these ponds (Figure 5). The similarity in trends between mean vegetation height and plant biomass in these ponds probably resulted from the fact that their biomasses were comprised primarily of the submerged plant species: Chara sp. and Potamogeton perfoliatus. Mean vegetation height does not adequately reflect plant biomass when unpreferred floating plants comprise a larger portion of the plant biomass present.

CONCLUSIONS
The hybrid grass carp, while not as effective as the grass carp in controlling aquatic macrophytes, appears to be an alternative biological control for nuisance aquatic vegetation. Stocking rates for the hybrid grass carp will have to be higher than for grass carp to obtain the same degree of control as with the grass carp. The effectiveness of hybrid grass carp at lower stocking densities over longer time periods needs to be further evaluated.

Figure 7. Mean vegetation height at three week intervals beginning May 3, 1981, in set B ponds receiving no fish (3), 1979 grass carp (1), or 1979 hybrid grass carp (2). Ponds 1 and 2 received 370 fish per ha.

Figure 6. Mean vegetation height at three week intervals beginning May 3, 1981, in set A ponds receiving no fish (15), 1979 grass carp (16) or 1979 hybrid grass carp (14). Ponds 16 and 14 received 951 fish per ha.

Figure 8. Mean vegetation height at three week intervals beginning May 3, 1981, in ponds receiving 1980 grass carp (4 and 6) or 1980 hybrid grass carp (5 and 7). Set C ponds (4 and 5) received 988 fish per ha and set D ponds (6 and 7) received 494 fish per ha.
ACKNOWLEDGMENTS

The authors acknowledge the assistance of Andrew Mitchell in determining fish ploidy and the assistance of Tommie Crawford, Mike Verter, and Jan Collin in collecting and processing vegetation samples. We are also indebted to Bill Keith, Harry Dupree, Andrew Mitchell, and Jim Collins for reviewing the manuscript. Last but not least, we wish to thank Kay Hester, Rita Corley and Bobbie Pack for typing the manuscript.

LITERATURE CITED


SPAWNING THE GRASS CARP FEMALE X BIGHEAD CARP MALE

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ABSTRACT
Methods and procedures for artificially spawning the female grass carp (Ctenopharyngodon idella) with male bighead carp (Aristichthys nobilis) are described. Broodstock selection and treatment, hormone injections, ovulation, fertilization, hatching techniques and stocking rates are discussed. This paper outlines the procedures necessary to successfully produce hybrid grass carp.

INTRODUCTION
Several fish species have been tested to control aquatic vegetation (Kilgen and Smithertner, 1971), but the grass carp (Ctenopharyngodon idella) has been reported to be one of the most promising (Swingle, 1957). Grass carp were introduced into the United States in 1963 by personnel at the U. S. Fish and Wildlife Service's Fish Farming Experimental Station, Stuttgart, Arkansas and at Auburn University, Auburn, Alabama (Stevenson, 1965; Guillory and Gasaway, 1978). Although two decades have passed since this introduction (Baily, 1974), the grass carp remains highly controversial because some biologists fear that this fish may reproduce and become established in natural waters (Kilgen and Smithertner, 1971; Forester and Lawrence, 1978). Restrictions on the importation of grass carp in many states (Cassani, 1981) created a need for an alternative species for nuisance aquatic vegetation control that would alay most fears associated with the grass carp, primarily reproduction and environmental degradation. Therefore, in May 1979, the Arkansas Game and Fish Commission produced the F₁ hybrid of female grass carp and male bighead carp (Aristichthys nobilis). The Fish Farming Experiment Station working in conjunction with J. M. Malone, a commercial fish farmer, produced the hybrid during the same season. Marian and Krasnai (1978) had reported the successful production of this intergeneric hybrid in Hungary and their work stimulated the initial interest in this hybrid in the U. S.

Although the total progeny of the 1979 year-class cross were initially reported to be triploid and expected to be sterile (Beck et al. 1980), subsequent investigations (Drs. Beck and Biggers pers. comm.) revealed that some hybrids in the 1980 and 1981 year classes were diploids. It has not been confirmed that the 2N (diploid) hybrid is sterile although Tom Jackson, Columbia National Fisheries Center, U. S. Fish and Wildlife Service, Denver, speculates that the diploid hybrid is sterile based on other available literature (pers. comm.). Acceptability of the hybrid as a substitute for grass carp will be directly linked to the question of sterility, since most fears associated with grass carp concern its reproductive potential (Bailey, 1972). Many researchers are investigating the efficacy of the hybrid grass carp for aquatic vegetation control as evidenced by a special session on the “Hybrid Grass Carp: Biology, Management, and Potential for Aquatic Plant Control” conducted at the 11th Annual Meeting of the American Fisheries Society, 1981.

At the Joe Hogan State Fish Hatchery in Lonoke, numerous inquiries have been received from federal, state, and private facilities concerning specific procedures for production of the hybrid grass carp. A report on spawning and rearing of grass carp in Arkansas (Bailey and Boyd, 1970) describing initial attempts at spawning the grass carp and a publication containing information on spawning the bighead carp (Henderson, 1979) have been the only sources of available information that could be furnished to interested persons. Procedures outlined in these publications must be combined and modified to be used successfully. Information concerning the spawning of the hybrid grass carp has not been previously published. This paper consolidates information from publications by Bailey and Boyd (1970) and Henderson (1979) and incorporates several refined procedures for the production of hybrid grass carp.

BROODSTOCK SELECTION AND TREATMENT
The selection of gravid, mature, healthy broodstock cannot be over emphasized. Most unsuccessful attempts at producing hybrid grass carp can be attributed directly to fish that were immature or in poor condition. Broodfish can be maintained throughout the year at the rate of 250 individuals per ha or at 25 individuals per ha in polyculture with catfish broodstock. Grass carp or grass carp and catfish in polyculture should be fed daily a manufactured extruded (floating) catfish feed at about 3.0% of their body weight or 35 kg per ha, whichever is less. Feeding should be discontinued when dissolved oxygen levels in the pond are less than 3 ppm. During the winter months, feeding rates should be reduced to 2.0% of body weight or 10 kg per ha, whichever is less.

Many bighead males are sexually mature at year three, but grass carp females typically do not mature sexually until year four. Sexually active bighead carp males exhibit pearl organs on the dorsal side of the pectoral fins: these fins are rough and abrasive in the spring. Male bighead carp can usually be manipulated in the spring (even before a hormone injection) to release a small amount of milt. On the basis of these two characteristics, it is easy to separate sexually active male bighead carp from females and sexually inactive males.

Sexually mature female grass carp exhibit distended abdomens that are flaccid as a result of egg content. For fry production purposes, grass carp females heavier than 3 kg are preferred over smaller females. In Arkansas, broodstock selection and spawning is usually performed in early May. Brood ponds are seeded and fish carried in wet burlap bags to tanks containing oxygenated pond water for transport to the spawning building. Generally, the male bighead carp and female grass carp are held in separate tanks during the hormone injection phase. All brood fish should be held in water at temperatures near 23°C during the hormone injection series. Sufficient agitation, aeration, and water exchange must be provided to maintain dissolved oxygen levels above 5 ppm. Holding tanks must be covered to prevent broodfish from jumping out of the tanks.

Broodstock may be treated daily with a prophylactic continuous bath treatment of 500 ppm furacin or 1 ppm acriflavine before hormone injection is administered. After the injection series has been initiated, all treatments should be discontinued since the fish should be disturbed as little as possible. Generally, broodfish should be kept in holding facilities for only a few hours before starting the injection series since the fish may become quickly damaged, especially in concrete tanks.
HORMONE INJECTIONS
The Arkansas Game and Fish Commission has evaluated several hormone dosage levels and injection schedules (Bailey and Boyd, 1971; Henderson, 1979) and found the procedure presented in Table 1 to be the most predictable even though others have been used satisfactorily. Fish are captured head first and restrained in burlap sacks during the injection period. The human chorionic gonadotropin preparation is administered intramuscularly with a 22-gauge needle into the dorsal musculature. The dry carp pituitary preparation is administered intraperitonely with an 18-gauge needle through the base of a pelvic fin. The larger needle is necessary for the pituitary preparation, since the acetone dried pituitary is suspended in sterile water and does not dissolve. Any large clumps of pituitary tissue that will not go through the needle may be discarded. No more than 2 cm³ of liquid per injection should be given to a fish.

Although male bighead carp receive only a single injection of either hCG or dry carp pituitary, female grass carp receive a series of three injections at intervals of 24 h. It is advisable to vary the last injection given to the female grass carp so that no more than two or three fish are scheduled to ovulate at one time. The time adjustment of this last injection (+ 6 h from the stipulated 24 h interval) does not appear to adversely affect ovulation success. If male bighead carp are limited, they may be re-injected with 220 IU/kg of hCG each day for reuse the next day.

Table 1. Hormone Injection Schedule for Grass Carp Females and Bighead Carp Males.

<table>
<thead>
<tr>
<th>Age</th>
<th>Schedules</th>
<th>Time of Injection</th>
<th>Amount of Injection</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 years</td>
<td>Female</td>
<td>24 h</td>
<td>2.5 mg/kg (1 IU/lb)</td>
</tr>
<tr>
<td>5 years</td>
<td>Male</td>
<td>24 h</td>
<td>2.5 mg/kg (1 IU/lb)</td>
</tr>
</tbody>
</table>

OVULATION AND FERTILIZATION
Female grass carp should be examined beginning at 6 h after the last (third) injection; they usually ovulate from 10 to 12 h after the last injection. However, ovulation may sometimes be delayed as much as 18 h. The abdomen of a female grass carp becomes quite flaccid when ovulation is complete, so by simply "pattting" a fish on the abdomen as she swims by, one can determine whether ovulation has occurred. Fish that are near ovulation usually are sluggish and remain near the surface.

When ovulation is suspected, the fish should be placed head first in a burlap sack and turned upside down. If ovulation is complete, the fish will usually become quite rigid and begin to expel eggs in a sudden gush. The vent should then be held shut to prevent the further discharge of eggs until the female can be anesthetized and dried. The eggs should flow freely into the collecting pan when the head is held higher than the vent. Generally, at least two male fish should be used for each female fish. Males will have to be manually manipulated to induce the milt discharge into the egg pan.

We prefer the dry method of fertilization (Bonn et al., 1976); sperm and eggs are simultaneously placed in a dry container and stirred dry for about one minute before water is added. Sufficient water should be added to completely cover the eggs, and then the eggs and water mixed. During the following 10 minute period for water hardening, the water on the eggs should be decanted and fresh water added two to three times to remove blood, dead eggs and other tissues and fluids. The number of eggs can be estimated volumetrically after water hardening and, if McDonald hatching jars are used, about 100,000 eggs can be put in each jar.

HATCHING AND STOCKING
Grass carp eggs are semilucent and if heated water supersaturated with gases is used to hatch the eggs, it is practically impossible to keep the eggs in the hatching jars. Therefore, eggs may be allowed to overflow into aquaria where actual hatching will take place in 24 to 36 hours at water temperatures between 22 and 24 °C. In some facilities, a head trough with agitation has been employed to "beat out" the excess gases and to ensure that the dissolved oxygen level is near saturation. Each 381 aquarium can accommodate 100,000 to 150,000 fry. Water inflow into the aquaria should be manipulated so that the eggs are constantly in motion and water outlets should be screened to prevent egg loss. During hatching, these screens must be cleaned periodically to prevent overflow and loss of eggs and fry.

Fry ponds should be fertilized and insect predators controlled as outlined for striped bass fry culture (Bonn et al., 1976). Fry should be stocked into prepared ponds four days after hatching at a rate of about 250,000 fry per ha. Hybrid grass carp fry do not require supplemental feeding unless natural food is limited or survival is greater than 50%. They will readily accept any commercial minnow meal. Hybrid grass carp survival from fry to fingerlings are in the range of 0.5% to 5% due to a high incidence of lethal deformities among post-larvae and juveniles.

CONCLUSIONS
By following these procedures it should be possible to satisfactorily produce grass carp female x bighead carp male hybrids. Production of hybrid grass carp by the Arkansas Game and Fish Commission has become fairly routine with a spawning success rate of about 80% for female grass carp and a return rate of 0.5 to 5% for the pond stocked fry.

ACKNOWLEDGMENTS
The authors wish to thank Dr. Bill Keith of the Arkansas Game and Fish Commission and Dr. Harry Dupree and Dr. Drew Mitchell of the U. S. Fish and Wildlife’s Fish Farming Experimental Station at Stuttgart, Arkansas, for their valuable suggestions in the preparation of this manuscript. Also, we wish to thank Miss Kay Hester, Mrs. Rita Corley and Mrs. Bobbie Pack for typing the manuscript.

LITERATURE CITED


SIZE VARIATION OF UNGRADED AND GRADED CHANNEL CATFISH REARED IN CAGES*

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ABSTRACT

Graded and ungraded channel catfish (Ictalurus punctatus) fingerlings stocked in three partitioned floating cages were reared for 140 days during the summer, 1982. Fish were fed to satiation once daily with a commercial pelleted ration. At harvest, graded fish averaged 403 g and ungraded 382 g. Coefficients of variation indicated graded fish were more uniform in size and a significantly greater proportion of the graded fish were of salable size (>340 g).

INTRODUCTION

Reducing size variations in cage reared channel catfish (Ictalurus punctatus, Rafinsque) should result in increased numbers of marketable fish at harvest. The technique commonly used to produce fish of uniform size is to stock cages with graded fish. In order to reduce fish handling stress and grading costs, it may be feasible to develop culture methods to rear ungraded fingerlings to uniform size. One possibility, the practice of feeding to satiation, would theoretically allow all fish, regardless of size, to realize their growth potential. This management practice, if proven effective, could readily be applied by farmers raising catfish in cages.

Lewis (1969) noted a relationship between variation in channel catfish size and fighting and suggested that this was the result of the establishment of a "pecking order." Fighting was more severe in shallow cages (0.6 m deep), but differences in growth were more evident in deeper cages (1.1-1.5 m deep). He postulated that small fish in deep cages could escape to the bottom more readily and elude fighting. Knable (1972), who studied the feeding responses of caged channel catfish in relation to several factors, concluded that feeding response and food intake varied markedly from cage to cage. No differences were observed in rations eaten by yearling males and females, and the presence of large catfish did not adversely affect the food intake of small fish. Robison and Newton (1982) observed that stocking cages with ungraded catfish fingerlings resulted in large size variations among fish at harvest.

Konikoff and Lewis (1974) reported that in cage reared channel catfish with a high initial size variation, the relative variation decreased by harvest time. They attributed the reduction in size variation to the faster growth rate of smaller fish. In their study, cages were fed all the feed they would eat in 30 min, once daily. Collins (1971) also favored a feeding method whereby the amount fed was increased daily to allow for continuous fish growth.

A cooperative study to compare the production of graded versus nongraded catfish was conducted during 1982 by the Department of Agriculture, University of Arkansas at Pine Bluff and the U.S. Fish and Wildlife Service, Fish Farming Experimental Station, Stuttgart, Arkansas.

MATERIALS AND METHODS

Three floating cages, 1.9 x 0.9 x 1.0 m, each partitioned into two compartments of 0.86 m², were used for the study. Cages were constructed of plastic coated wire mesh, 1.2 x 2.5 cm, and were anchored on individual tethers in a 1.2 ha pond. On 13 May 1982 one compartment in each cage was stocked with 300 graded channel catfish and the other with 300 ungraded channel catfish (stocking rate, 350 fish/m²). Fish were fed with conventional box graders with bar spacings from 1.7 to 2.3 cm. Fish were individually weighed at stocking and at harvest, 140 days later. They were fed to satiation once daily with 32% crude protein, floating, pelleted ration. The satiation feeding method was applied to reduce the effect of food availability as a limiting factor. Each lot of fish was given an amount of feed equal to that consumed on the previous day and additional feed was provided in 50 g increments until feeding ceased. Comparisons of coefficients of variation for individual fish weights, and the proportion of graded and ungraded fish that reached marketable size were used to evaluate this management technique. Statistical tests were evaluated at the P > 0.05 level of significance (Snedecor, 1966).

RESULTS

Survival was nearly identical, averaging 95% for ungraded and 97% for graded fish (Table). Average weight at stocking was 40 g for the ungraded fish and 48 g for the graded ones (Table). At harvest, ungraded fish averaged 362 g and graded fish 403 g (Table). Neither average stocking nor harvest weights of the ungraded or graded groups differed significantly. Net yields were not significantly different, averaging 92 and 102 kg for the ungraded and graded lots, respectively (Table). The coefficients of variation for individual weights of the two groups at stocking and at harvest (Table) were significantly different, as shown

<table>
<thead>
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<th>Category</th>
<th>Weight (g)</th>
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<th>Range</th>
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</table>

*Published with the approval of the Director of the Arkansas Agricultural Experiment Station.
DISCUSSION AND MANAGEMENT IMPLICATIONS

Ungraded fish, fed to satiation, increased in size uniformity, as indicated by a decline in their coefficients of variation at harvest. This increased uniformity was presumably attributable to the faster growth of smaller fish, as postulated by Konikoff and Lewis (1974). The increased growth was not sufficient, however, to offset benefits of grading, which included higher survival, greater total yields, larger individuals, and more marketable fish. A longer growing season would obviously have resulted in the production of more marketable fish in both groups. During the study period, average fish weight doubled about every 45 days. Extending the growing period from 140 to 180-210 days (more typical for Arkansas) would have enabled more of the fish, either graded or ungraded, to equal or exceed marketable size. A longer growth time would probably have resulted in a slight additional reduction in size variability for ungraded fish and a slight additional increase in that of graded fish.

In this study, graded fish were more uniform in size at harvest and a larger proportion of them were of marketable size. Therefore, the expense and handling stress of grading seemed well justified. Arkansas fish farmers have estimated that they would charge an additional $0.005 per fish for grading to remove those too large or too small. On the basis of this cost and the production data, stocking of graded fish resulted in an additional 46 salable fish per cage; thus, grading produced 22 kg more marketable fish per cage for the grading investment of $1.50 per cage.

LITERATURE CITED


SELECTION OF SCALES FOR GROWTH ANALYSIS OF LARGEMOUTH BASS

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ABSTRACT

Scales from four regions of the body of largemouth bass were compared for efficacy in estimating fish length at the time of scale formation and at capture. The scales from above and below the lateral line in the pectoral and caudal peduncle regions yielded intercepts of 64.73, 52.36, 19.77 and 25.81 respectively for the total length-scale radius relationship. These intercept values represent the fish length at the time of scale formation. By the regression of estimated lengths at capture on empirical lengths it was found that the caudal peduncle scales were better suited in predicting fish length.

INTRODUCTION

Scales have been used extensively in growth dynamics studies of fishes. Scale reading remains somewhat subjective and requires experience. Errors are common (Carlander, 1974; Carlander, 1982; Heidinger, 1975; Le Cren, 1974; Prather, 1967). Quite often errors are not due to techniques but to procurement of scales from different body regions at different times during the life history of fish, resulting in different graphic records of growth and proportionality relationships (Bennett, 1948; Carlander, 1974; Carlander, 1982; Clugston, 1964; Hofstad, 1974; Le Cren, 1974; Ricker and Lagler, 1942; Whitney and Carlander, 1956).

The total length-body scale regression method of back calculating fish length yields inconsistent length estimates depending upon the body region from which scales are taken (Whitney and Carlander, 1956) and in some fish the estimated length at the last annulus may be larger than the length at capture (Carlander, 1981; Carlander, 1982). Evaluation by the regression method of small samples or even large samples with small size ranges of fish can introduce errors in growth computations (Whitney and Carlander, 1956). The intercept value of regression equations has been interpreted as the length of the fish when the scales first formed on the fish. Such being the case, scales from a body region where scales first appear may yield an intercept value closer to the actual fish size at the time of scale formation. Studies to evaluate this hypothesis and the efficacy of scales from four body regions of largemouth bass (Micropterus salmoides) estimating fish length at time of scale formation and at capture were conducted in 1981 and 1982.

METHODS

Eighty-eight largemouth bass (TL = 140-480 mm) were collected in 1981 and 1982 by electroshocking from Lake Elmdale, Washington County, Arkansas. Total length for each fish was measured to the nearest millimeter. Scales were taken from the left side of the fish from four body regions:

1. Above the lateral line at the tip of the appressed pectoral fin (Pectoral Upper),
2. Below the lateral line at the tip of the appressed pectoral fin (Pectoral Lower),
3. Above the lateral line in the middle of the caudal peduncle (Caudal Upper),
4. Below the lateral line in the middle of the caudal peduncle (Caudal Lower).

Six scales from each body region for each fish were selected at random and impressed on plastic slides. The scale radius, distance from focus to the anterior-lateral edge, was measured at 40X using an Eberbach Scale projector. Total length-scale radius relationship was expressed as \( L = a + bR \), where \( L = \) total length of fish (mm), \( R = \) scale radius (mm) and \( a \) and \( b \) = intercept and regression coefficients respectively.

Total lengths of bass at capture were estimated by the total length-scale radius relationships. The efficiency of estimating length was evaluated by the regression formula \( L = a + bL \) where \( L = \) estimated total length, \( L = \) observed total length, and \( a \) and \( b \) are constants. In this equation, perfect estimates of length with reference to observed length will have a unit regression coefficient (\( b = 1.0 \)) and zero intercept (\( a = 0 \)).

RESULTS

Comparison to total length-scale radius relationship between the sexes yielded no significant differences (\( P < 0.01 \)) for the scales from the pectoral region below the lateral line and the two caudal regions. The scales from the pectoral area above the lateral line yielded no significant sex difference in the regression coefficients (\( P < 0.05 \)) and the intercepts were significantly different at the 0.01 level, but not at the 0.05 level. The data for the sexes were pooled for each of the body regions and the statistics for the total length-scale radius relationship are listed in Table 1. Based on low standard error of estimates (\( S_a \)) and correlation coefficients (\( r \)), scales from the caudal peduncle areas describe the total length-scale radius relationship better than the scales from the pectoral regions.

The total lengths of largemouth bass at capture were estimated using the respective total length-scale radius relationships. The estimated lengths were regressed on the empirical lengths at capture and the covariance analysis showed significant difference between the four body regions (\( P < 0.01 \)). Further analysis indicated no significant differences at the 0.05 level either between the pectoral regions or between the caudal peduncle regions. Details of the statistics for the estimated length-empirical length regression are listed in Table 2. The regression coefficient (0.93) for the caudal peduncle was not significantly different from 1.00 (\( P < 0.001 \)) while the coefficient was significantly lower for the pectoral region (\( P > 0.001 \)). It is evident from the \( S_a \), \( b \), and \( r \) values that the scales from the caudal peduncle gave the best estimates.

| Table 1. Statistics of total length-scale radius (\( L = a + bR \)) relationship. |
|---|---|---|---|
| Body Region | \( a \) | \( b \) | \( S_a \) | \( r \) |
| Pectoral Upper | 64.73 | 1.39 | 21.76 | 0.91 |
| Pectoral Lower | 52.36 | 1.16 | 24.22 | 0.91 |
| Caudal Upper | 19.37 | 1.84 | 16.93 | 0.96 |
| Caudal Lower | 25.81 | 1.68 | 19.14 | 0.95 |

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Table 2. Statistics of estimated total length-observed total length ($L = a + bL$) relationship.

<table>
<thead>
<tr>
<th>Body region</th>
<th>$a$</th>
<th>$b$</th>
<th>$s_{yx}$</th>
<th>$z$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pectoral (Combined)</td>
<td>52.18</td>
<td>0.79</td>
<td>10.73</td>
<td>0.94</td>
</tr>
<tr>
<td>Caudal (Combined)</td>
<td>15.36</td>
<td>0.93</td>
<td>17.06</td>
<td>0.96</td>
</tr>
</tbody>
</table>

**DISCUSSION**

Scales of largemouth bass have traditionally been selected from the pectoral region (Carlander, 1982; Bryant and Houser, 1971; Kilambi et al., 1978; Padfield, 1951; Prather, 1967). The intercept of the length-scale radius relationships has been interpreted frequently as the length of the fish at the time of scale formation.

Everhart (1949) reported that in the smallmouth bass, *Micropterus dolomieu* (and probably reflective of the genus *Micropterus*) the scales first appear on the caudal peduncle at an average total length of $20.2 \pm 1.0$ mm and scale formation then proceeds anteriorly. Carlander (1982) reported a mean intercept value of 20.9 mm from a sample of 32 largemouth bass and recommended 20.0 mm as a standard to be employed. Our study, based on scales from four body regions, yielded increased intercept values of the total length-scale radius relationship from caudal to pectoral regions indicating that in largemouth bass, scales form first on the caudal peduncle and then on the pectoral region. The intercept values of 19.77 and 25.81 mm for the scales from above and below the lateral line of the caudal peduncle, respectively, were similar to the fish length at the time of scale formation reported by Everhart (1949) and Carlander (1982).

Our study revealed that scales from the caudal peduncle are better suited than pectoral region scales for studies of largemouth bass growth. Information on the fish length at which scales first appear may be a primary requirement for identifying the body region for scale selection to predict growth relationships for any species of fish.

One of the primary criteria of utilizing fish scales in growth studies is that the estimated lengths represent the observed lengths. The statistical parameters (Table 2) and the tests in our study indicated that total lengths of largemouth bass at capture were best estimated by scales taken from the caudal peduncle.

**ACKNOWLEDGEMENTS**

Special thanks are extended to Marvin Galloway, Paul Polechla, John Briggs, and Alex Zdinak for their help in the collection of fish.

**LITERATURE CITED**


SUCCESS OF WILD-TRAPPED COMPARED TO CAPTIVITY-RAISED BIRDS IN RESTORING WILD TURKEY POPULATIONS TO NORTHWESTERN ARKANSAS

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ABSTRACT

Reintroduction of wild turkeys into northwestern Arkansas was studied at 10 release sites in the late 1950's. Native birds trapped in southern Arkansas were released at five study areas, and birds from wild Pennsylvania stock reared in captivity were released in five other areas. Although both types of turkeys reproduced, most populations of captivity-raised turkeys decreased sharply whereas all populations of wild-trapped birds exhibited marked increases. Range extension averaged nearly 2.5 miles per year in expanding wild-trapped populations. Captivity-raised birds were comparatively tame and often were found near human habitation. Current expanding turkey populations in the Arkansas Ozarks undoubtedly are due to the introductions of wild-trapped birds.

INTRODUCTION

Holder (1951) documented the past history of decline in turkey populations in the Ozarks through the 1940's. In 1957 at the onset of the present study, an inventory of existing turkey populations in the Ozarks was completed (James and Preston, 1959). The findings showed that in the region surveyed the nearly 1000 birds reported by Holder (1951) had declined to about 39 flocks, which equals a total of a little over 300 birds using the average value of 8 turkeys per flock reported by James and Preston (1959). Of these, only about half the birds were in areas where indigenous Ozark populations formerly had occurred. The rest existed at release sites where introductions of wild birds from southern Arkansas had begun in the early and mid 1950's. Thus apparently only about one-tenth of the original Ozark stock reported by Holder in the 1940's persisted to the late 1950's.

Kaffka (1979) recently described the increase in numbers of wild turkeys (Meleagris gallopavo) that has occurred in Arkansas since the 1950's. This statewide trend also was evident in the Ozark Plateaus Region where in 1950 only four wild turkeys were taken by hunters (Holder, 1951), but in Spring 1979, according to information from the Arkansas Game and Fish Commission, hunters harvested 804. Two approaches to restoring turkeys to the Ozarks were attempted in the 1950's. One method was to release wild birds native to Arkansas that were trapped from high density populations in the southern part of the state. The other technique involved the release of artificially propagated wild turkeys raised from eggs of the hybrid strain developed in Pennsylvania (Kozicky and Metz, 1948). Leopold (1944) described the method of producing the wild strains of turkeys reared in captivity. The present study was designed to evaluate the relative success of the two methods of turkey introductions in the Arkansas Ozarks.

The study was conducted from July 1957 through June 1961, and this paper mainly includes findings from the initiation date to June 1960.

After June 1961 the study was terminated with the expectation of continuing it again to evaluate the situation after several years, but this never materialized. Therefore, the initial findings are now presented. Even though there have been other comparisons of the relative success of reintroductions of wild-trapped and captivity-raised turkeys in the Ozarks (Leopold and Dalke, 1943; Leopold, 1944; Dalke et al., 1946; Holder, 1951; Lewis, 1957; 1961) and elsewhere (Dennett and McKibben, 1970; Wunz, 1971) our study is the only one where moderate numbers of both wild-trapped and captivity-raised birds were released over relatively the same time period at several separated sites in the same general region. It thus represents the field-experimental, test with replication, of Leopold's (1944) expectations. Also this study provides a historical prospective documenting the sources of the present thriving wild turkey populations in the Arkansas Ozarks.

STUDY AREAS

Five study areas were established for each of the two types of turkeys released. Native birds from southern Arkansas, hereafter called wild-trapped turkeys, were studied at the following sites, 1) Black Mountain, in the Ozark National Forest west of Cass in Franklin Co., 2) Buffalo Tower, in the Ozark National Forest east of Redstar, but in Newton Co., 3) Devil's Den, in the Ozark National Forest near Devil's Den State Park in Washington Co., 4) McIroy Wildlife Management Area, between Forum and Rockhouse in Madison Co., and 5) Wedington, in the Ozark National Forest west of Savoy in Washington and Benton Counties. Since the turkey releases at Buffalo Tower were too late in the study to be investigated adequately, this site will be omitted from further consideration, and is mentioned only for the historical record.

The five study areas for releases of turkeys of the Pennsylvania strain raised in captivity, hereafter called captivity-raised turkeys, were as follows, 1) Bellefonte, 6 miles south of Bellefonte on Boat Mountain near the junction of Boone and Newton Counties, 2) Carrollton, near the border of Carroll and Boone Counties east of Carrollton, 3) Fort...
METHODS

The distribution and abundance of turkeys in the vicinity of study areas were determined through personal interviews with local residents, hunters, and with personnel of the Arkansas Game and Fish Commission and National Forest Service. Addressed post card questionnaires for reporting turkey sightings were distributed to residents living in areas inhabited by turkeys and to personnel working there. This assistance was supplemented by intensive searches in the field for turkeys and turkey signs conducted by project personnel at all seasons.

Population estimates were determined from appraisal of maps of study areas showing locations of reported turkey sightings. From these plotted records duplication in observations were detected and eliminated, which improved accuracy in population estimations. If it was not known whether two reports in close proximity were separate flocks, they were assumed to be different only if the localities were separated by at least two miles. This is based on the findings of Mosby and Handley (1943) that a turkey flock has a cruising radius of two miles.

When flock size was not recorded, or when only turkey signs were reported, the number of turkeys in a flock was assumed equal to the average flock size (see below) observed in the particular study area during the various autums and winters of the study. When in final analysis it was not clear if one or two flocks were involved, or when flock size estimates were contradictory, minimum and maximum population values were calculated. This pertained only to wild-trapped birds, which were elusive and difficult to survey. Captivity-raised birds were characteristically wary and easy to approach, so direct counts could be made.

Estimates of turkey range expansion from release sites were made in each study area. This was done by locating on a map a point of origin central to the cluster of various release sites in a particular study area and measuring the distance of the most distant turkey dispersal points from the point of origin. The least distance measured and average dispersal distances also were obtained for captivity-raised turkeys for reasons to be explained later. Since release sites were in areas that were devoid of existing wild turkeys, the dispersed turkey sightings through the years in these areas were assumed to be associated with the corresponding releases.

The incidence of reproduction was detected through reports of broods of turkey poult encountered in study areas. Many nests of captivity-raised turkeys were found and monitored by repeated visits.

RESULTS

Populations Levels: Basic information concerning the numbers of wild-trapped turkeys in the study areas is shown in Table 1. This includes number released, year of releases, estimates of minimum and maximum numbers, and percent increase, based on surveys completed in the autumn months of 1959 and winter of 1959-60. The important finding is that in all areas numbers of turkeys increased significantly from the number released. The average increase was 225% (Table 1), and the biggest increases were at Black Mountain and Devil's Den deep in the Ozark National Forest, the most isolated study areas.

On the other hand, the captivity-raised birds did not show significant increases in any study area (Table 2) based on a survey in summer 1959. Although young birds were produced in all areas, this was not sufficient to replace the disappearance of adults. Thus populations decreased sharply after release in 3 areas, and remained relatively unchanged in the other two.

Average flock sizes in autumn and winter in the study areas with wild-trapped turkeys were 12.3 birds at Black Mountain, 10.3 at Devil's Den, 5.3 at McIlroy, and 7.5 at Wedington. Combining all areas, a total of 73 flocks was observed averaging 8.6 birds per flock, and ranging in size from two to 30 birds.

Range Expansion: The mileage values for wild-trapped birds represent true range expansions (Table 3) whereas the same information for captivity-raised birds (Table 4) are simply dispersal rates. This difference is explained further later.

Table 1. Turkey numbers determined during fall 1959 and winter 1959-60 in the study areas where wild-trapped turkeys were released.

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Number Released</th>
<th>Number Present in July</th>
<th>Maximum Range Expansion</th>
<th>Average Range Expansion per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Mountain</td>
<td>37 (100)</td>
<td>13 (100)</td>
<td>12.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Devil's Den</td>
<td>35 (200)</td>
<td>15 (100)</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>McIlroy</td>
<td>11 (150)</td>
<td>2.2 (150)</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Wedington</td>
<td>14 (150)</td>
<td>2.1 (150)</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Total</td>
<td>107 (1000)</td>
<td>51 (1000)</td>
<td>2.3</td>
<td>2.3</td>
</tr>
</tbody>
</table>

Table 2. Status of turkey populations in July 1959 in the study areas where captivity-raised turkeys were released in March 1958 and February 1959.

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Number Released</th>
<th>Number Present in July</th>
<th>Maximum Range Expansion</th>
<th>Average Range Expansion per year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Mountain</td>
<td>40</td>
<td>12</td>
<td>3.0</td>
<td>3.0</td>
</tr>
<tr>
<td>Devil's Den</td>
<td>8</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>McIlroy</td>
<td>6</td>
<td>3</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Wedington</td>
<td>4</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>58</td>
<td>17</td>
<td>3.0</td>
<td>3.0</td>
</tr>
</tbody>
</table>

Table 4. Dispersal rates from release sites exhibited by captivity-raised turkeys after date of release through January 1960.

<table>
<thead>
<tr>
<th>Study Area</th>
<th>Number of Records</th>
<th>Number of Flocks</th>
<th>Dispersal (in months)</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Mountain</td>
<td>4</td>
<td>4</td>
<td>2.3</td>
<td>2.3</td>
</tr>
<tr>
<td>Devil's Den</td>
<td>11</td>
<td>11</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>McIlroy</td>
<td>6</td>
<td>6</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Wedington</td>
<td>4</td>
<td>4</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Total</td>
<td>30</td>
<td>30</td>
<td>2.3</td>
<td>2.3</td>
</tr>
</tbody>
</table>

* Mean average for all records at site.
Success of Wild-Trapped Compared to Captivity-Raised Birds in Restoring Wild Turkey Populations

Maximum rates of range expansion in wild-trapped turkeys from release points varied from 1.4 miles per year at Black Mountain and Wedington, to 3.8 miles per year at the Melroy study area (Table 3). The average rate was 2.4 miles per year.

The same calculation for captivity-raised turkeys (divide the maximum column by the years column in Table 4) produced an average dispersal rate of 3.2 miles per year, which is greater though not significantly different from the wild-trapped birds ($t = 0.824, df = 7, P > 0.3$). However, it may be more appropriate to compare the average dispersal rates in captivity-raised birds (Table 4) with the maximum rates in wild-trapped ones. This is because the areas occupied by populations of wild-trapped birds enlarged gradually due to increasing population pressures (Table 1), a true range expansion. The captivity-raised populations, however, were not increasing (Table 2). Thus the movements were just widespread wanderings or scatterings from the release site, best represented by an average value, and best called a “dispersal!” (Table 4).

Leopold (1944) and Holder (1951) noted these wanderings in captivity-raised birds but Proud (1969) found they were rather sedentary. The matter is further confounded by the ease in finding the flocks of the comparatively tame captivity-raised birds that often sought areas of human habitation.

The overall average dispersal rate for captivity-raised birds was 1.5 miles per year (Table 4). This is lower but still not significantly different from wild-trapped rates (Table 3, $t = 1.476, df = 7, P > 0.2$).

By the end of the study the ranges of the Black Mountain and Devil’s Den turkeys had expanded to merge in the Lake Fort Smith area. Also, the Black Mountain birds had become well established east of state highways. This was because of the enclosure of the Black Mountain area being built west of the highway.

**Reproduction:** Young birds were seen in all study areas. Obviously reproduction was high in the wild-trapped turkeys because a large population increase was exhibited in the first two summers (1959 and 1958) (Table 1). It was noted that since only 22 broods were observed in the four areas over the two summers in 1959 and 1958, the contrast with a total of 30 actual nests found in one year, summer 1959, for captivity-raised hens (out of a total 175 females released). These rather tame birds nested in conspicuous places. Eighteen of the 30 nesting female turkeys did hatch young, and for 16 of these the average brood size four days after hatching for the five study areas was 6.9 pouls per brood. Nevertheless, the captivity-raised populations did not increase (Table 2). Apparently later survival of young was too low to compensate for the adult rate of disappearance shown in Table 2 (compare the number released with adults present in July) and the population declined.

**DISCUSSION**

The results of the present study show that wild-trapped turkeys were highly successful in becoming established in the Ozarks after release, while the captivity-raised birds were not. The important difference in the turkeys from the two sources was evident only in the population studies following release (Tables 1 and 2). The studies of range expansion and dispersal rates, and incidence of reproduction, none of which were notably different in the groups of turkeys, produced confounding results that did not reflect relative success of establishment and subsequent population increase. Therefore, it is recommended that future studies of this kind focus only on population level investigations.

Based on this study, it is evident that the current restoration of viable wild turkey populations in the Arkansas Ozarks resulted mainly from the introduction of wild-trapped birds obtained in the southern part of the state. The failure of captivity-raised birds in this regard also was noted by Leopold and Dalke (1943), Leopold (1944), Dalke et al. (1946) and Lewis (1957, 1961) in the Missouri Ozarks, and by Holder (1951) in the Arkansas Ozarks, and by Donohoe (1965) in Ohio. The reason for this failure has been amply traced to inherited physiological and behavioral difficulties in the captivity-raised birds (Leopold, 1944). In the present study, the extreme tameness of the released captivity-raised birds probably led to the lack of success. Released birds commonly frequented barnyards and the like at all release sites and persisted there, sometimes roosting with hens in barns, and one even was suspected of breeding with a domesticated turkey. Mortality factors were analyzed too but were difficult to appraise accurately. At one phase in the study, 17 out of 72 released captivity-raised birds were found dead within seven months of release. Deaths were due to various causes less than half of which were attributed to predation. The success of released wild-trapped birds in colonizing new turkey ranges was shown in most of the studies cited above and has been repeated in Texas (Gore, 1970), Alabama (Speake et al., 1970, 1975), Florida (Powell, 1965), West Virginia (Bailey and Rineill, 1968), Iowa (Little, 1980; Little and Varland, 1981), Minnesota (Porter, 1977), Nebraska (Suetsugu and Menzel, 1963) and elsewhere (Schorger, 1966). In Texas it was found that establishment depended on releasing the appropriate subspecies of wild-trapped turkey for the habitat concerned (Gore, 1970).

Both types of turkeys in the present study showed somewhat greater overall movements (Tables 3 and 4) than did telemetered wild-trapped turkeys released in Iowa (Little and Varland, 1981). However, overall rates of movement in Arkansas populations were comparable to movements shown by individual telemetered birds in Georgia (Eichholz and Marchinton, 1976).

**ACKNOWLEDGEMENTS**

This research was supported by the Arkansas Game and Fish Commission under Project No. PR-W-50-R and PR-W-56-R. Assistance from Harold Alexander of the Commission especially was appreciated. We are grateful too for help from personnel of the Commission and National Forest Service, and from numerous residents of the Ozarks in providing turkey survey information. Charles Cland and Wayne James served as project personnel during phases of the study and compiled some of the information presented in this paper.

**LITERATURE CITED**


DISTRIBUTION AND SEASONAL OCCURRENCE
OF THE SCUTELLERIDAE, CORIMELAENIDAE
AND CYDNIDAE OF ARKANSAS

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ABSTRACT

A total of 16 genera and 37 species and subspecies of Corimelaenidae, Cydnidae and Scutelleridae is recorded as occurring or possibly occurring in Arkansas. Nine species of Scutelleridae contained in six genera, 13 species and subspecies in three genera of Corimelaenidae (= Thyreocoridae) and 15 species and subspecies of Cydnidae found in seven genera are reported as occurring or possibly occurring in Arkansas.

Twenty-seven species and subspecies contained in 13 genera were collected or recorded from entomological holdings within the state. Two species in two genera were reported in the literature as occurring in Arkansas. Based on distribution records in the literature, eight species in eight genera are listed as probably occurring in the state. Seasonal occurrence and county distribution records are reported for each species and subspecies.

INTRODUCTION

Major taxonomic investigations concerning Heteroptera were reported by Blatchley (1926), McAttee and Malloch (1933), Torre-Bueno (1939), Froeschner (1960), Lattin (1964) and Slater and Baronowski (1978). McPherson (1982) supplied an excellent account of the Pentatomoida (Scutelleridae) of southeastern North America. State-wide investigations of the occurrence and distribution of Pentatomidae were reported by Hart (1919) for Illinois, Stoner (1920) for Iowa, Froeschner (1941) for Missouri, McPherson (1970) for Michigan and Hoffman (1971) for Virginia. Hart's (1919) list of Pentatomidae was updated by McPherson (1979a). McPherson (1980) also updated the distribution of Pentatomidae as reported by Van Duzee (1917) for the northeastern United States.


Recent records of new species or reidentification of species found in Arkansas include: Sailer (1940), McPherson and Sailer (1978) and McPherson (1980).

References to Arkansas Cydnidae, Corimelaenidae and Scutelleridae are scarce, since prior studies were not concentrated in this state. This paper summarizes, to date, number of species and subspecies, seasonal occurrence and geographical distribution of these three families in Arkansas. In conjunction with a similar investigation of the Pentatomidae of Arkansas by Barton and Lee (1981), this study completes the faunistic survey of the Pentatomidae of Arkansas.

RESULTS AND DISCUSSION

County distributions are shown in Figures 2-10. The monthly occurrence of each species and subspecies is indicated in the species list. Figure 1 supplies a key to the Arkansas counties.

ARKANSAS COUNTIES

Figure 1. The counties of Arkansas.
Linda A. Lee and Harvey E. Barton

Figure 2. Acantholomidea denticulata (O), Dioicis chrysorrhoeus (□), Pangaeus bilmannus (■), and Sehirus marmorata (●).

Figure 3. Amnesticus pusillus (△), Corimelaena marginella (●), Crytomenus mirabilis (O), Homaemus bifugis (■), Tejra bipunctata (□), and Tominotus communis (△).

Figure 4. Amnesticus basidentatus (□), Galgupha loboprostethia (□), Homaemus parvulus (●), and Melanaethus cavicolis (O).

Figure 5. Corimelaena harti (O), Galgupha carinata (△), and Melanaethus robustus (●).

Figure 6. Corimelaena lateralis lateralis (O) and Crytomenus ciliatus (●).

Figure 7. Corimelaena pulicaria (■), Melanaethus pensylvanicus (●), and Melanaethus subpunctatus (O).

Figure 8. Amnesticus spinifrons (O), Corimelaena obscura (□) and Galgupha aterrima (●).

Figure 9. Galgupha atra (●) and Galgupha ovatis (O).

Figure 10. Amnesticus pallidus (O) and Sehirus cinctus cinctus (●).
Distribution and Seasonal Occurrence of the Scutellerae, Corimelaenidae and Cydnidae of Arkansas

holdings. Based on the known distribution of each species in neighboring states, eight additional species and subspecies should and probably do occur in the state, which would be represented by two Cydnidae, three Corimelaenidae and three Scutellerae species and subspecies.

In the Corimelaenidae fauna, Corimelaena pulcicia was found to be the most abundantly collected species in the state. Corimelaena lateralis, Corimelaena marginata, Corimelaena pulcicia, Galgupha aterrima, Galgupha atra, Galgupha carinata and Galgupha ovalis are expected to occur state-wide based on their known distribution and abundance.

In the Cydnidae fauna, Sehirus cinctus cinctus was found to be collected most abundantly. Ammoxestus pusillus, Melanactus robustus, Ptomius bilineatus and Sehirus cinctus cinctus are believed to occur throughout the state.

In the family Scutellerae, Homaemus parvulus is the most commonly collected species in the state. Both Stethaulax marmorata and Homaemus parvulus are expected to occur throughout Arkansas.

Additional records will undoubtedly be obtained through further investigations of the seasonal occurrence and county distribution of Scutellerae, Corimelaenidae and Cydnidae in Arkansas. Further investigations of these three families are needed in addition to Barton and Lee’s (1981) study of the Pentatomidae of Arkansas, to aid our understanding of seasonal occurrence and distribution patterns, ecological relationships and taxonomic status of the Pentatomoidea of the state, particularly lesser known species.

ACKNOWLEDGMENTS

We wish to express our appreciation to Dr. Robert T. Allen, University of Arkansas at Fayetteville and Dr. Robert L. Watson, University of Arkansas at Little Rock for allowing us to examine Cydnidae, Corimelaenidae and Scutellerae holdings at their respective institutions. We thank Dr. J. E. McPherson, Southern Illinois University at Carbondale, for aid in identification of Galgupha species.

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Amended Species List

Scutelleridae

Acantholomidae denticuicata (Stal). Figure 2. April-June.

Acantholomidae porose (Germar). Lat. 1964 reported this species as occurring in Missouri, Kansas, Utah and Mexico, and ranging from Virginia south to Florida, west through Texas and Arizona to California and up the Pacific Coast to Vancouver Island. It probably will be found in Arkansas.

Camerus porosus (Germar). Blatchley (1926) listed this species as occurring in California, Texas and Florida. Froeschner (1941) reports it as being apparently rare, but represented in Missouri. Its occurrence in Arkansas is probable.

Dolius chrysorrhoeus (Fabricius). Figure 2. We have examined three specimens from the University of Arkansas at Little Rock for which seasonal occurrence data were not available. One specimen was collected in 1974 in Pulaski County, Arkansas. The other two specimens were not labeled.

Homoneus omnonous (Say). Lat. 1964 stated the range of this species is from northeastern Nova Scotia south to Tennessee and western North Carolina, and as occurring in Arkansas. Froeschner (1941) reported this species as being listed for Illinois and Nebraska and its possible occurrence in northern Missouri. It possibly occurs in Arkansas.

Homoneus bigyris Uhler. Figure 3. April, November.

Homoneus parvulus (Germar). Figure 4. April-July, September-November. This is the most abundantly collected species of Scutelleridae in the state. It undoubtedly occurs state-wide.

Sedthaulax marmorata (Say). Figure 2. February-May, September-November. This species unquesionably occurs state-wide.

Tetra bipunctata (Herrich-Schaeffer). Figure 3. April, September-November.

Corimelanidae

Corimelaena aegrella McAtee. Froeschner (1941) reported this species (as Allacorys aegrella) for Maryland, Virginia, Kentucky and Texas, and as occurring in Missouri. It possibly occurs in Arkansas.

Corimelaena hartii Malloch. Figure 5. February, June.

Corimelaena laterale laterale (Fabricius). Figure 6. May-October. This subspecies undoubtedly occurs state-wide.

Corimelaena marginella Dallas. Figure 3. April, June-July. This species probably occurs throughout the state.

Corimelaena obscura McPherson and Sailer. Figure 8. August.

Corimelaena pulicaria (Germar). Figure 7. January, March-July. This is the most abundantly collected species of Corimelanidae collected by us in the state. State-wide occurrence of this species is probable.

Cydnoides ciliatus orientus McAtee and Malloch. McAtee and Malloch (1933) and Torre-Bueno (1939) reported this subspecies in Florida, Missouri, Nebraska, Colorado, Texas, Minnesota, and Kansas. Its occurrence in Arkansas is probable.

Galupha abertina Malloch. Figure 8. February, April-July. This species undoubtedly occurs throughout the state.

Galupha atra Amyot and Serville. Figure 9. January, February, April, June-August, November. State-wide occurrence of this species is probable.

Galupha corinata McAtee and Malloch. Figure 5. February-April, June, July, November. State-wide occurrence of this species is highly probable.

Galupha donudatea (Uhler). McAtee and Malloch (1913) reported this species occurring in the District of Columbia, Virginia, South Carolina, Georgia, Florida, Alabama, Mississippi, Louisiana and Texas. McPherson (1982) reported this species as occurring in southern Illinois. It probably occurs in Arkansas.

Galupha loboprostetha Sailer. Figure 4. February-May.

Galupha ovata Hissey. Figure 9. April, June-August, November. State-wide occurrence of this species is probable.

Cydniidae

Amnestes basidentatus Froeschner. Figure 4. February, May-October. Froeschner (1960) reported this species as occurring in Arkansas.

Amnestes pallidus Zimmer. Figure 10. December. One specimen was examined by us in the University of Arkansas at Fayetteville collection.

Amnestes pusillus Uhler. Figure 3. April, June-August, October. State-wide occurrence of this species is probable.

Amnestes spinifrons (Say). Figure 8. February, May.

Cydniinae

Cyrtomenus citutilus (Palisot de Beauvois). Figure 6. July, August, October.

Cyrtomenus mirabilis (Perty). Figure 3. June-August.

Meanaethus cacticola (Blatchley). Figure 4. February. A single specimen was examined in the University of Arkansas at Fayetteville collection.

Meanaethus pensylvanicus (Signoret). Figure 7. February, May, July, September, December.

Meanaethus robustus Uhler. Figure 5. February, March, July, November, December. State-wide occurrence of this species is probable.

Meanaethus subsequulantus (Blatchley). Figure 7. May. Froeschner (1960) reported this species as occurring in Arkansas.

Microporus obliquus Uhler. Froeschner (1960) reported this species as occurring in Arizona, California, Colorado, Idaho, Illinois, Indiana, Iowa, Kansas, Louisiana, Missouri, Nevada, New Mexico, Oklahoma, Oregon, South Carolina, South Dakota, Texas, Utah, Virginia, Washington and Mexico. Its occurrence in Arkansas is probable.

Pangaeus bilineatus (Say). Figure 2. February, March, May, July-November. State-wide occurrence of this species is probable.

Pangaeus discrepans Uhler. Blatchley (1926) reported the recorded range to extend from Indiana and Tennessee, west and south to California and Texas. It probably occurs in Arkansas.

Tominotus communis (Uhler). Figure 3. February.

Schirinae

Scopha cineta cineta (Palisot de Beauvois). Figure 10. March-August. State-wide occurrence of this species is probable. This is the most abundant subspecies of Cydnidae collected by us in the state.

A total of 37 species and subspecies of Corimelanidae, Cydnidae and Scutelleridae contained in 16 genera is recorded as occurring or possibly occurring in Arkansas. Thirteen species and subspecies of Corimelanidae in three genera, 15 species and subspecies of Cydnidae in seven genera and nine species of Scutelleridae in six genera are listed as occurring or possibly occurring in the state. Amnestes basidentatus and Meanaethus subsequulantus have been reported in the literature as occurring in Arkansas (Froeschner 1960). Twenty-seven species and subspecies in 13 genera were collected or recorded from entomological
Distribution and Seasonal Occurrence of the Scutelleridae, Corimelaenidae and Cydnidae of Arkansas


SHORT CREEK OOLITE (LOWER MISSISSIPPIAN) DEPOSITION, WAR EAGLE QUARRY, MADISON COUNTY, ARKANSAS

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ABSTRACT

The Short Creek Oolite is the only formally designated member of the Lower Mississippian Boone Formation. Although oolite deposits are often considered to be formed in shoal areas, detailed study of the War Eagle Short Creek disclosed characteristics incompatible with deposition as an oolite shoal. At the War Eagle Quarry, the Short Creek Oolite occurs between deep water strata and there is a conspicuous absence of cross-stratification and other shallow water bedding features. Modal analysis revealed a lower oolith content than found in Recent oolite shoals or in the Short Creek Oolite of Missouri, which has been interpreted as a shoal previously. These data suggest that the War Eagle Short Creek may have been deposited as a turbidite which brought ooliths from the Missouri - Kansas oolite shoal into the deeper water foreslope environment of northwest Arkansas.

INTRODUCTION

The Short Creek Oolite is a member of the Boone Formation which is included in the Osagean Series of the lower Mississippian System. The lower Mississippian is a carbonate package consisting of an upper chert-bearing interval called the Boone Formation (Branner, 1891; Penrose, 1891; Simonds, 1891) and a lower, relatively chert free interval called the St. Joe Formation. The lower Mississippian unconformably overlies Chattanooga or older strata and is unconformably overlain by Meramecian or younger strata. The Boone Formation consists of alternating layers of limestone and chert which vary in proportions laterally and vertically. The limestones include mudstones, wackestones, packstones and infrequent grainstones. Fossil assemblages consist principally of crinoid and bryozoan detritus, spiriferid and productivity brachiopods, and trilobite remains. The Boone outcrops in an east-west trending belt across northern Arkansas that extends into northeast Oklahoma. Its equivalents are recognized in southeastern Kansas and southwestern Missouri. In northern Arkansas the Boone ranges in thickness from 300 to 400 feet (90-120 meters). Attempts to recognize lithostratigraphic units from surrounding states within the Boone interval in Arkansas have been unsuccessful with the exception of the Short Creek Oolite.

Siebenthal (1907) proposed the name Short Creek for an oolitic interval near the top of the Boone in southeastern Kansas and southwestern Missouri. The oolitic facies is light tan on a weathered surface and light to medium gray on a fresh surface. Allochems consist of sand size ooliths and crinoidal detritus. At the War Eagle Quarry, the Short Creek Oolite is massively bedded and persistent throughout the quarry. The Short Creek Oolite is widely developed in southeast Kansas and southwest Missouri, where it ranges in thickness from five to ten feet (1.5 to 3 meters) (Greenberg, 1981). In northwest Arkansas and adjacent Oklahoma the oolitic interval varies from five to 25 feet (1.5 to 7.5 meters) in thickness and is of sporadic occurrence. The Short Creek Oolite occurs about 100 to 125 feet (30 to 38 meters) below the top of the Boone Formation.

METHODS

Samples were collected from a single exposure at War Eagle Quarry, 23/4 miles east of Huntsville, Arkansas on Highway 68. The quarry is located in the NW 1/4, SW 1/4, sec. 19, T17N, R25W, Madison County. The quarry is in fine-grained carbonate rock interbedded with calcitic chert. The oolitic interval occurs about 20 feet (6 meters) above the quarry floor and is 25 feet (7.5 meters) in thickness (Figure 1). Samples (Figure 1) were taken from immediately below and above the oolitic section, and within the oolitic zone, at three foot (1 meter) vertical intervals. From these samples, acetate peels and standard thin sections were prepared and stained with Alizarin Red S and potassium ferricyanide.

DEPOSITIONAL INTERPRETATION

The Boone Formation was deposited on the southern margin of a broad shallow platform, called the Burlington Shelf (Land and De Keyser, 1980). Transgression and regression of this extensive carbonate shelf during late Osagean time resulted in the succession of Boone lithologies. Vertically, the succession of lime mudstones, wackestones, packstones and occasional grainstones represents deposition in environments ranging from deep shelf margin to open marine shallow edge (Liner, 1980). Liner (1980) interpreted the mud-supported facies as deep water, open marine sediments. The lack of extensive pelleting, an indigenous marine fauna and algae suggests that these mud-supported lithologies are not of lagoonal origin. The Short Creek Oolite in Kansas and Missouri seems to have developed during a regressive sequence in response to initiation of the proper hydrographic setting. The Short Creek is continuous throughout the War Eagle Quarry. Absence of cross bedding and ripple bed forms was noted. The lower
and upper contacts of the oolitic interval are sharp and carbonate lithologies above and below are identical mudstone. Greenberg (1981) interpreted deposition of the Short Creek Oolite as a marine sand belt or a tidal bar belt near an open shelf. High oolith content and cross-bedding in the Missouri Short Creek support his interpretation, but are lacking at War Eagle Quarry.

Oolith content of the War Eagle Short Creek Oolite ranges from five to 59 percent (Figure 1). Imbrie and Newell (1964) report that thin sections prepared from sediment samples collected on Bahamian oolite shoals invariably contain more than 90 percent ooliths. Recent oolite shoals are also characterized by high energy features such as ripples and cross stratification. Lower oolith content and the absence of cross-bedding in the Arkansas Short Creek suggest it is not the site of an ancient oolite shoal.

At the base of the War Eagle Short Creek, virtually no ooliths are present. Thin sections show crinoidal detritus, syntaxial cement, and matrix to be the dominant constituents (Figure 2A). Freeman (1962) discusses the formation of quiet water ooliths in Laguna Madre, Texas with a mud content of 10 to 16 percent by weight. These quiet water ooliths are often asymmetrical as a result of a single oolitic accretion (Freeman, 1962). This type of asymmetry was not observed in the War Eagle Short Creek. Figure 1 shows two peaks where oolith percentage reaches 59 percent and 45.7 percent (Figure 2B), separated by an interval where the oolith content drops to 13 percent (Figure 2C). At the base and top of the oolitic interval crinoid detritus percentage is greatest suggesting “Boone” type deposition (Figure 2A).

Figure 3 compares modal analyses of the War Eagle Short Creek Oolite with the Missouri Short Creek, described by Greenberg (1981). Differences in characteristics of the two oolites suggest different modes of deposition. The Short Creek Oolite in Missouri accumulated in a high energy, shallow water shelf margin environment (marine sand belt or tidal bar belt) during progradation of Burlington shelf deposits. The Short Creek occurs in the War Eagle Quarry between deep water open marine sediments and has a markedly lower oolith content than its Missouri counterpart, which is interpreted as a shoal (Greenberg, 1981). This relationship suggests a turbidite origin for the War Eagle Short Creek in a deep marine shelf environment. Although carbonate shelves are relatively flat, storm activity may transport sediments across the shelf proximal to a channel or steeper slope where turbidite processes might occur. Spherical ooliths would settle out before crinoid detritus, which are platy and of a lower specific gravity. The two peaks in Figure 1 may represent two turbidity flows. Absence of cross-stratification and other bedding features support the interpretation that the Arkansas Short Creek was transported to its site of deposition.

CONCLUSION

Study of the War Eagle Short Creek reveals it is not an oolitic grainstone, but an oolitic crinoidal packstone. This conclusion is based on the low oolith content and the lack of cross stratification. Bounding lithologies suggest interruption of deep water deposition rather than shallowing associated with oolite shoal development. Data suggest that the War Eagle Short Creek may have been deposited as a turbidite which brought ooliths from the Kansas - Missouri oolith shoal (Greenberg, 1981) into the deeper water foreslope environment of northwest Arkansas. Evidence supporting this conclusion is low oolith percentage and the variation in oolith content. Lack of current structure and deep water strata bounding the War Eagle Short Creek support this conclusion.
ACKNOWLEDGMENTS

I wish to thank Dr. Walter L. Manger for his guidance throughout this project. Without his help and encouragement this endeavor would not have been completed. His advice and suggestions are greatly appreciated.

LITERATURE CITED


MENSURAL DISCRIMINATION OF THE SKULLS OF ARKANSAS PEROMYSCUS

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ABSTRACT

Twelve parameters were measured on skulls of four species of Peromyscus from Arkansas. Univariate statistical tests, multivariate analyses of variance, and principal axis factor analyses were performed on the data set and/or subsets in a search for species-level discriminating characters. Total length of skull was found to discriminate between skulls of P. maniculatus, P. leucopus, and a combined group of P. attwateri and P. gossypinus. Furthermore, the ratio of interorbital width and length of nasal bone was found to adequately discriminate between skulls of P. attwateri and P. gossypinus.

INTRODUCTION

Individual specimens of white-footed mice (Peromyscus) are notoriously difficult to discriminate to the species level from regions containing two or more species (Choate, 1973; Choate et al., 1979; Thompson and Conley, 1983). Arkansas is such a region, with four species of Peromyscus ranging throughout at least portions of the state (Seislander, 1979); the deer mouse, P. maniculatus (Wagner), the smallest member of the group and normally having a well furred, short, and distinctly bicolored tail; the white-footed mouse, P. leucopus (Rafinesque), somewhat larger and having a relatively longer and less furred tail; the Texas mouse, P. attwateri J. A. Allen, a large member of the genus and having a long and terminally tufted tail; and the cotton mouse, P. gossypinus (LeConte), another large member of the genus and having a tail with no terminal tuft. A closely related species, the golden mouse, Ochrotomys nutalli (Harlan), superficially complicates the identification dilemma, but is readily discriminated by its more posteriorly lying posterior palatal foramen and its anteriorly perpendicular infraorbital plate (Lowery, 1974).

While the skins of specimens of the four species of Peromyscus are, with practice, relatively easy to discriminate among, and while the species are fairly distinct ecologically (Seislander, 1979; Schwartz and Schwartz, 1981), attempts to accurately identify individual skulls can be frustrating and may result in only low probabilities of accurate classification. This study, then, was designed to search for a character and/or group of characters that would, with a very high degree of probability of accuracy, discriminate among the skulls of the four Arkansas species of Peromyscus.

METHODS AND MATERIALS

Adult, unbroken skulls of both sexes were selected from clearly diagnostic skins. Specimens were from throughout the Arkansas ranges of the species, and all are housed in the Collection of Recent Mammals of the Arkansas State University Museum of Zoology (ASUMZ). Our sample included: 41 specimens of P. maniculatus, 41 specimens of P. leucopus, 40 specimens of P. attwateri, and 31 specimens of P. gossypinus.

Twelve parameters were measured on each skull to the nearest 20th of a mm with dial calipers. Parameters were as defined by DeBlase and Martin (1974) and included: (A) length of maxillary tooth row, (B) total length of skull, (C) basional length, (D) breadth of palate at molar one, (E) breadth of palate at molar three, (F) width of interorbital constriction, (G) length of bony palate, (H) length of nasal bone, (I) zygomatic breadth, (J) greatest rostral width, (K) breadth of braincase, and (L) length of anterior palatine foramen.

All numerical analyses were performed on SAS (SAS Institute Inc., 1979) through the University of Arkansas Computing Center. Analyses included routines computing simple univariate statistics, multivariate analyses of variance (acronymed MANOVA), and principal axis factor analyses.

RESULTS AND DISCUSSION

Investigation began with a multivariate analysis of variance performed on a combined data set of all four species. All 12 variables generated high F-values indicating that significant (at the 0.0001 level) variation existed among the species over all variables. MANOVA was followed by principal axis factor analysis on the combined data set. Factor loading scores were plotted along the first two principal factor axes (Fig. 1).

Figure 1. Factor loading scores for four species of Peromyscus plotted along the first and second principal factor axes. Alphabetic characters (A-L) as defined in Methods and Materials.

http://scholarworks.uark.edu/jaas/vol37/iss1/1
All variables correlated highly (0.7 or higher) with the first principal axis, and only weakly with the second principal axis (<0.5). This factor pattern is typical for craniometric data and suggests that factor axis 1 represents an axis of general skull size. Factor axis 1 accounted for 80.2% of the observed variation, while the second factor axis accounted for only an additional 6.3% of the observed variation. The lack of any well correlated variables prevents a reasonable biological interpretation of factor axis 2.

A plot of factor scores by species along the first and second principal factor axes revealed good separation along factor axis 1 of P. maniculatus, P. leucopus, and a combined group of P. attwateri and P. gossypinus (Fig. 2). In a multivariate sense, then, skulls of Arkansas specimens of Peromyscus can be reliably discriminated as belonging to one of three groups on the basis of general size. In this scheme, the smallest skulls are of P. maniculatus, the intermediate skulls are of P. leucopus, and the largest skulls are of P. attwateri and/or P. gossypinus.

In subsequent analyses, relationships and multivariate overlaps of pairs of species were examined more closely. Although some degree of overlap existed among factor scores of P. maniculatus and P. leucopus (Fig. 3), the degree of overlap is quite small (in a multivariate sense) and discrimination at the species level is acceptably reliable as indicated by MANOVA generated F values at the 0.0001 level. Never-the-less, a check of univariate data revealed that no single parameter totally discriminates between the two species. Several characters, though, approached good (95% level) discriminatory power, including greatest length of skull (Fig. 4).

Slight overlap also existed among factor scores of P. leucopus and P. attwateri (Fig. 5). Again, multivariate overlap was slight and MANOVA generated F values were high for all variables except length of bony palate and greatest rostral width. Greatest length of skull again discriminated between the species at the 95% level (Fig. 4).

At this point, only P. attwateri and P. gossypinus remained to be discriminated between. Examination of a plot of factor loading scores for these species (Fig. 6) revealed a considerably different pattern of variation than that observed for all four species together (Fig. 1). Factor axis 1 appears to be related to parameters of skull length, while factor axis 2 appears to correlate best with parameters of post-nasal width of the skull. A plot of the factor scores of these two species (Fig. 7) revealed only fair separation along factor axis 1. Overlap of the species appeared to be visually significant, and in fact, two specimens (6% of the sample) of P. gossypinus and four specimens (10% of the sample) of P. attwateri are represented in the overlap zone. Testing by MANOVA, however, revealed significant differences between the species.
Mensural Discrimination of the Skulls of Arkansas Peromyscus

Figure 6. Factor loading scores for *P. attwateri* and *P. gossypinus* plotted along the first and second principal factor axes. Alphabetic characters as in Fig. 1.

Figure 7. Factor scores of *P. attwateri* and *P. gossypinus*, as represented on Fig. 2. The dashed perpendicular line represents the mid-point along axis 1 between the means of the two species. The heavy arrows indicate the number of individuals from the samples falling beyond the mid-point.

In an attempt to further discriminate among the skulls of *P. attwateri* and *P. gossypinus*, ratios were computed of one parameter against another. Eventually, the ratio demonstrating the highest discriminatory power turned out to be minimum interorbital distance divided by length of the nasal bone (Fig. 8).

![Figure 8. Bar-histogram of values of minimum interorbital distance divided by length of nasal bone for *P. attwateri* and *P. gossypinus*.](image)

As a result of these analyses, it was possible to prepare a key (Fig. 9) to the adult skulls of species of *Peromyscus* occurring in Arkansas and having at least a 95% reliability factor. Total length of skull discriminates between *P. maniculatus* (X = 22.8mm), *P. leucopus* (X = 25.4mm), and a combined group of *P. attwateri* (X = 27.7mm) and *P. gossypinus* (X = 28.7mm). The ratio of interorbital width and length of nasal bone discriminates reasonably well between skulls of *P. attwateri* (0.41 to 0.48) and *P. gossypinus* (0.33 to 0.41).

Finally, it must be stressed that results of this analysis are fully predicated on the assumption that initial discrimination among these species was correct. To validate this assumption, specimens were intentionally selected only when skin characteristics made specific assignment positive. A potential problem inherent in this process would be the imposition of artificial limits to the cranial variation present in the samples. It seems doubtful, though, that limits imposed by skin characteristics would represent limits of cranio-metric variation as well. Interestingly, examination of coefficient of variation values revealed that for all variables except breadth of palate at molar three, skulls of *P. maniculatus* generated the highest values. For breadth of palate at molar three, skulls of *P. leucopus* generated the highest value.

**SUMMARY**

While the skulls of the species of *Peromyscus* occurring in Arkansas are difficult to distinguish between, total length of skull will discriminate between *P. maniculatus*, *P. leucopus*, and a combined group of *P. attwateri* and *P. gossypinus*. Subsequently, the ratio of interorbital width and length of nasal bone will adequately discriminate between skulls of *P. attwateri* and *P. gossypinus*.

**ACKNOWLEDGMENT**

The authors thank J. D. and M. R. Wilhide for their unselfish help during several phases of this project.
LITERATURE CITED


THE RELATIONSHIP BETWEEN PHYSICAL CONDITIONING AND PLASMA HIGH DENSITY LIPOPROTEIN-CHOLESTEROL CONCENTRATION

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ABSTRACT

Five subjects (three females and two males) took part in an exercise regimen in order to determine if aerobic exercise results in an increase in high-density lipoprotein-cholesterol levels (HDL-C) in the plasma.

The exercise regimen consisted of running three miles a day, five days per week for six months. Running speed was at such a pace that the subjects attained a minimum of 60% of their maximal heart rate reserve (MHRR). Before the training program began the following parameters were measured in all of the subjects: height, weight, percent body fat, maximal oxygen consumption (V0₂ max), vital capacity, resting heart rate, resting blood pressure, HDL-C, plasma triglycerides (TG), and plasma cholesterol (TC). These same measurements were retaken every two months and at the conclusion of the study.

The exercise protocol produced significant changes in V0₂ max and resting heart rate. None of the other parameters were significantly changed.

The results of this study have shown that aerobic exercise does not cause significant changes in HDL-C levels.

INTRODUCTION

HDL-C has been shown to be inversely related to the incidence of cardiovascular disease (Castelli et al., 1977; Gordon et al., 1977; Miller and Miller, 1975; Rhoads et al., 1976). It has also been shown that an increase in the HDL-C/TC ratio and a reduction in TG level (which may occur with an increase in HDL-C concentration) may be important indicators of reduced coronary artery disease (Carlson and Ericsson, 1975; Hartung et al., 1981; Huttunen et al., 1979). Physically well-trained individuals have higher levels of HDL-C than sedentary people (Enger et al., 1977; Lehtonen and Valkari, 1978; Lopez-S. et al., 1974; Wood et al., 1976). However, it is not known with certainty that high levels of HDL-C are due to physical activity per se. Other parameters, such as genetic factors, may be involved. The effects of aerobic exercise regimens on HDL-C concentrations have shown conflicting results, with some of the studies showing an increase in HDL-C concentrations (Altekruse and Wilmore, 1971; Huttunen et al., 1978) while others have recorded no change (Lipson et al., 1979; Squires et al., 1979; Weltman et al., 1978). Most of the studies completed thus far have been concerned with the effects of rather short term exercise programs on HDL-C concentrations (Enger et al., 1980; Hartung et al., 1981; Lipson et al., 1980).

The primary objective of the present study was to determine the effects of aerobic exercise on plasma lipids and lipoproteins. We were particularly interested in noting the effects of aerobic exercise on plasma HDL-C levels. In addition, we wished to see if an aerobic exercise program resulted in changes in plasma cholesterol and triglyceride levels.

METHODS AND MATERIALS

Five sedentary volunteers were studied, three females and two males, ages 21-44. None of the subjects smoked and all were of normal body weight according to the Metropolitan Life weight tables. Before the training program began, the following parameters were measured in all of the subjects: height, weight, percent body fat, V0₂ max, vital capacity, resting heart rate, resting blood pressure, plasma HDL-C, plasma TG, and total plasma TC. The same parameters were also measured at 60, 120 and 180 day intervals during the exercise program. Percent body fat was determined with a skinfold caliper. In the males, skinfold measurements were taken over the chest, abdomen, and thigh while in the female the measurements were recorded over the triceps, thigh, and suprailium (Baun, et al., 1981).

Maximal oxygen consumption was estimated by using the Balke treadmill test (Ellestad, 1980). Our laboratory has no instrumentation for measuring oxygen consumption directly. However, the Balke protocol corrects for this situation since it has determined (by directly measuring oxygen consumption in a large sample population) the oxygen consumption required during each stage of the test. The test was terminated when the heart rate reached 170. Heart rates during the test were recorded with three chest leads hooked to a cardiac preamplifier. The preamplifier in turn was connected to a Physiograph for visual display (Navco Biosystems, Houston, TX).

Vital capacity was determined with a six liter spirometer. The subject first inspired maximally and the amount of gas collected following a maximal exhalation was recorded as the vital capacity. Resting heart rate was measured by direct palpation of the radial artery and resting blood pressure was recorded with a sphygmomanometer.

Blood for lipid determination was drawn from the antecubital vein after a 12-14 h fast. Samples, drawn on two days (within a week of each other), were averaged to provide baseline values. High density lipoproteins were determined by using a heparin-manganese precipitation procedure (Warnick and Albers, 1978). Total cholesterol concentrations were measured by using the ortho-phthaldehyde technique (Rudel and Morris, 1975). Serum triglycerides were analyzed by the method described by Sardesai and Manning (1965).

The training protocol consisted of having the subjects run for three miles per day, five times per week for six months. Since the subjects had previously led a sedentary life style it took them one to two months to build their stamina to the point that they could complete their daily exercise regimen without stopping. The subjects were encouraged to run at a speed that would exert a minimum of 60% of their MHRR. This was calculated in the following manner: 60% MHRR = MHRR - RHR × 0.6 + RHR where MHRR equals maximal heart rate...
reserve, MHR equals maximum heart rate and RHR equals resting heart rate (Karvonen, et al., 1957). Maximal heart rate was calculated by subtracting the subject's age from 220.

Statistical significance (P < 0.05) between means was determined with a t-test. Results are expressed as mean ± standard deviation.

RESULTS

Physical characteristics for the subjects are shown in Table 1. The exercise program did not result in a significant change in weight, percent body fat, vital capacity or resting blood pressure in any of the subjects. A significant change in resting heart rate however, was recorded.

Table 2 shows the changes that occurred in the VO2 max during the study. The post-training VO2 max of 56.8 ml/kg/min was significantly greater than the pre-training mean of 50.0. One subject (#5) had to discontinue running after four months because of a cold weather induced asthmatic condition. Therefore a fourth month VO2 max figure was used as the final reading in this case.

The changes that occurred in TC, HDL-C, and TG during the study are reflected in Table 3. TC levels fell from 175.6 ± 9.2 to 167.8 ± 23.8 mg/dl. HDL-C levels declined from 56.6 ± 8.9 to 51.6 ± 9.8 mg/dl. TG decreased from 50.6 ± 30.9 to 42.6 ± 9.8 mg/dl. However, none of these changes were significant. One subject (#3) had started on a protein sparing diet a short time before the conclusion of the project. The diet probably caused the massive changes seen in his blood chemistry profile.

Table 1. Physical characteristics for individual subjects at the beginning (B) and end (E) of the experiment.

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Table 2. Changes in VO2 max (ml/kg/min) during the study.

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DISCUSSION

A negative correlation between coronary artery disease (CAD) and plasma HDL-C levels has been well documented (Castelli et al., 1977; Gofman et al., 1966; Gordon et al., 1977). In addition, Rhoads et al. (1976) demonstrated that the negative correlation between CAD and HDL-C was independent of other chemical or risk factors. In the 1950's and 1960's several investigators also discovered a negative correlation between high levels of physical activity and CAD (Breslow and Buell, 1960; McDonough et al., 1965; Morris et al., 1953; Morris and Crawford, 1938; Taylor et al., 1962).

Recently several studies have focused on the possible relationship between exercise and HDL-C levels. Cross sectional studies, in which different populations are compared, have revealed that middle-aged runners and cross country skiers have significantly higher levels of HDL-C than do their more sedentary counterparts (Enger et al., 1977; Hartung et al., 1978; Wood et al., 1976). Cross sectional studies, however, do not reveal whether the high levels of HDL-C observed in physically active people are the result of exercise or some other mediator, perhaps genetic in nature (Hartung et al., 1980). Several studies have indicated that increased levels of physical activity cause increases in HDL-C levels (Alkerusre and Wilmore, 1973; Enger et al., 1980; Lopez-S, et al., 1974). In contrast to these findings, the present study revealed no correlation between HDL-C levels and physical activity. Even after an increase in aerobic fitness was clearly established, there was no corresponding increase in HDL-C levels in any of our five subjects.

There are two possible explanations for the discrepancies between the present study and earlier studies in regard to the correlation between physical activity and HDL-C levels. First, the earlier studies were not conducted for as long a period of time as our study. It has been shown that increases in VO2 max do not start to appear until after 15 to 20 weeks of exercise (Pollock et al., 1969; and Pollock et al., 1969). None of the earlier studies exceeded three months in duration while our study was conducted over a six month time period. Secondly, in the earlier studies there was always a weight loss associated with the increased physical activity. Many investigations have shown that HDL-C is inversely related to body weight and this may explain the increased HDL-C levels recorded in the earlier studies (Avgar et al., 1978; Carlson and Ericsson, 1975; Gordon et al., 1977; Hulley et al., 1979; Rhoads et al., 1976). There was no significant weight loss in our study or in a study conducted by Lipson et al. (1980) in which the diet was rigidly controlled. Finally, Lipson et al. (1980) also did not find an increase in HDL-C levels as a result of exercise.

There were no significant changes in TG or TC levels in this study. Other investigations have shown that along with an increase in HDL-C concentrations, there is also an increase in the HDL-C/TC ratio and a decrease in the TG levels (Carlson and Ericsson, 1975; Hartung et al., 1981; Huttunen et al., 1979). However, those types of findings could not be confirmed in our study since there were no significant changes in HDL-C, TC, or TG levels.

In summary, the exercise regimen utilized in the present study resulted in an increased level of aerobic fitness after 180 days as revealed by the significantly increased VO2 max in all five subjects. The TG and TC

Table 3. Changes in TC, HDL-C and TG that occurred during the experiment. B designates beginning and E designates the end of the study.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Weight</th>
<th>Height</th>
<th>HDL-C</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>65</td>
<td>170</td>
<td>50</td>
<td>200</td>
</tr>
<tr>
<td>2</td>
<td>22</td>
<td>70</td>
<td>175</td>
<td>55</td>
<td>190</td>
</tr>
<tr>
<td>3</td>
<td>24</td>
<td>80</td>
<td>180</td>
<td>60</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>26</td>
<td>85</td>
<td>185</td>
<td>65</td>
<td>170</td>
</tr>
<tr>
<td>5</td>
<td>28</td>
<td>90</td>
<td>190</td>
<td>70</td>
<td>160</td>
</tr>
</tbody>
</table>

95% confidence interval
levels of the plasma, however, remained unchanged throughout the study. Likewise, we could not establish a positive relationship between aerobic fitness and HDL-C levels.

ACKNOWLEDGEMENTS

This project was sponsored, in part, by the Office of Research in Science and Technology at the University of Arkansas at Little Rock.

LITERATURE CITED


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ABUNDANCE AND SEASONAL OCCURRENCE OF PSOROPHORA COLUMBIAE (DIPTERA: CULICIDAE) IN A NORTHEAST ARKANSAS RICEFIELD COMMUNITY

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ABSTRACT

Increased population levels of the dark ricefield mosquito, Psorophora columbiae (Dyar and Knab), have been shown to be associated with rice cultivation in Arkansas and several other states. Four standard New Jersey light traps were operated daily between May 30 and October 2 of 1981 and 1982 to determine the relative abundance and seasonal occurrence of this species in NE Arkansas. The effect of trap distance from nearby rice on the number of adult P. columbiae collected was assessed by comparing weekly totals from 2 traps located within 0.9 km of rice fields with totals from 2 traps situated beyond 1.2 km. A total of 68,155 mosquitoes representing five genera was trapped during this study. Of this number, 45,760 (67.1% of all mosquitoes captured) were P. columbiae. Female adults comprised 98.8% of the trapped ricefield mosquitoes. The peak period of abundance for this species was found to occur between mid-July and late August and was closely associated with area rice-culture practices. The capture of more than 95.0% of all P. columbiae adults within 0.9 km of rice fields confirmed the reported short flight range of this species.

INTRODUCTION

Since rice was first grown as a commercial crop in Arkansas in 1904 (Whitehead, 1951b), Arkansas has become one of the five leading rice-producing states in the U.S. with ca. 6,000,000 ha in rice production (Meisch et al., 1980). Although some rice acreage exists in central Arkansas counties bordering the Arkansas River, and some occurs in the southwestern counties, most rice cultivation is limited to the eastern half of the state. The largest rice-growing region in E Arkansas is centered in the "Grand Prairie" area which includes Arkansas, Lonoke, Monroe, and Prairie counties. In Craighead County in NE Arkansas, 33,590 ha of rice were planted in 1981 and 33,376 ha were grown in 1982 (Fagala, pers. comm.). Of this amount, an estimated 7,500 ha in 1981 and 7,000 ha in 1982 were cultivated within a 2.5 km radius of Jonesboro.

It has been well established that the rice agroecosystem provides suitable breeding sites for several mosquito species including the dark ricefield mosquito, Psorophora columbiae (Dyar and Knab). Schwartz (1939) and Horsfall (1942b) reported that P. columbiae was the dominant mosquito species in Arkansas rice-producing areas and that rice-culture conditions permit the development of several generations of this species during the growing season. The suddenness with which a local population of this mosquito may increase further emphasizes its importance. Whitehead (1951b) stated that ricefield mosquitoes in Arkansas have increased in direct proportion to the state's increased rice acreage and that mosquitoes present a serious problem wherever rice is grown. Studies of the flight habits of ricefield mosquitoes by Horsfall (1942a), Quaterman et al. (1955), and Whitehead (1957) have shown that the majority of mosquitoes produced by rice fields remain within 1.2 km of the field in which they developed and are more likely to be of importance near rice acreage.

Host-preference precipitin was conducted by Whitehead (1951a) indicated that cattle serve as the major bloodmeal source for female P. columbiae. Experiments by Suda et al. (1971) showed that this species was capable of transmitting Venezuelan equine encephalitis (VEE) and that it was an important vector of VEE in nature. Steelman et al. (1972, 1973) and Steelman and Schilling (1977) reported that mosquitoes produced in Louisiana rice-growing areas could be important vectors of anaplasmosis to cattle and cause significant and economically-damaging reductions in the average daily weight gain of cattle. Additionally, Meisch and Coombes (1975) have reported that P. columbiae in Arkansas have a population peak from mid-June to mid-July which can be an extreme nuisance to farmers and residents near rice fields.

Several Arkansas investigators, including Schwardt (1939) and Horsfall (1937, 1942a) have published lists of mosquito species collected with light traps in Arkansas rice-growing regions. However, no light trap studies of mosquitoes in NE Arkansas have been reported and there are no reports of identified mosquito species collected from the NE rice section (Meisch et al., 1980). The primary objective of this two-year study was to determine the relative abundance and seasonal occurrence of adults, P. columbiae, in a NE Arkansas rice-producing area using the New Jersey trap as a sampling device. Previous investigations in the "Grand Prairie" region of Arkansas have shown that there is a rather abrupt decrease in the number of ricefield mosquitoes collected as distance from rice fields is increased. Therefore, a secondary aim of this study was to evaluate the effect of light trap location, with respect to nearby rice acreage, on the number of P. columbiae collected in a NE Arkansas ricefield community.

MATERIALS AND METHODS

To assess P. columbiae abundance and seasonal occurrence, a standard New Jersey light trap was placed at each of four locations within the city limits of Jonesboro, Arkansas in 1981 and 1982. The effect of relative distance from surrounding rice fields on the number of adults collected was evaluated by placing two traps near the periphery and two traps closer to the center of the city.

One of the two peripheral traps (designated Airport) was located on the SW corner of the Jonesboro Municipal Airport. This trap was in an open, grassy area isolated from competing light sources and was within 0.3 km of a large rice field. The power source for this trap was regulated by a photocell. The second peripheral trap (designated Race Street) was also situated in a relatively remote area and was photocell controlled. This trap was within 0.9 km of several rice fields and was immediately surrounded by grassy patches intermixed with brush and clumps of small trees.

A third light trap (designated ASU, and one of the two central traps) was located on the campus of Arkansas State University in a grassy area and near several large buildings. Lack of photocell necessitated operation of this trap on a continuous basis. Although there was some
attraction competition from nearby lights, it was considered to be minimal. The nearest rice field was over 1.2 km away. The second centrally-located trap (designated Culberhouse Street) was at the margin of a small park and also was operated continuously. The distance from this trap to the nearest rice field exceeded 1.9 km.

Light trap catches from all locations were collected daily between May 30 and October 2 during both study years. Mosquitoes in each sample were sorted and identified utilizing the taxonomic keys of Carpenter et al. (1946), Carpenter and LaCasse (1955), and Stojanovich (1960). Daily trap totals were summed for each week of the 18-week study period.

RESULTS AND DISCUSSION

A total of 68,155 mosquitoes representing five genera was collected in four light traps during the two years of sampling. Of this total, 34,041 (49.9%) and 34,114 (50.1%) were captured in 1981 and 1982, respectively. It should be noted that all traps were in areas subjected to periodic applications of a mosquito adulticide by ground-operated, ULV cold-aerosol generators. This undoubtedly lowered the total number of mosquitoes collected during the study and may have had more of an impact on the central trap locations which were farther from the source of reinfection.

The two-year total for the number of P. columbiae was trapped was 45,760, which represented 61.9% of all mosquitoes captured. The remaining 32.9% of the two-year total was composed of the genera Anopheles (16.6%), Aedes (8.5%), Culex (7.1%), and Culiseta (0.1%). The high percentage of the mosquito population attributable to P. columbiae in this study generally corresponds with the results of Schwartz (1939) and Horsfall (1942), who reported percentages ranging from 37 to 90% of the mosquito fauna in the "Grand Prairie" region. These data also confirm the conclusions of Whitehead (1957) and Meisch and Coombes (1975) that P. columbiae is the primary pest-mosquito species associated with rice culture in Arkansas.

In 1981, a total of 20,085 P. columbiae was collected and this number represented 61.8% of all mosquitoes captured for that year. In 1982, 24,675 were trapped representing 72.3% of the year’s total catch. The periods of greatest abundance for this species in each of the two years were generally between late June and late August (Figs. 1 & 2).

![Figure 1. Comparison of weekly totals of adult Psorophora columbiae with all adult mosquitoes trapped at four locations in Jonesboro, Arkansas in 1981. (Semi-Log. Scale)](image)

![Figure 2. Comparison of weekly totals of adult Psorophora columbiae with all adult mosquitoes trapped at four locations in Jonesboro, Arkansas in 1982. (Semi-Log. Scale)](image)

This finding is in agreement with results published by Schwartz (1939), Horsfall (1942), Whitehead (1957), and Meisch and Coombes (1975). It also is consistent with observations made by the authors in Craighead County between 1975 and 1980.

In 1982, the highest weekly total for P. columbiae (5,227) was collected during the first week in August (Fig. 1). In 1982, population peaks of 4,492 and 3,452 occurred in late July and late August, respectively (Fig. 2). The gradual rise and rather sharp fall of the P. columbiae population in both years was closely associated with area rice-culture practices. The population increased quite rapidly in late June and early July of both years as more fields were flooded. The abrupt decline of ricefield mosquito numbers in late August of each year corresponded closely with fall drainage. According to Horsfall (1942a), P. columbiae normally exhibits two periods of maximum abundance during the summer. Variation in the timing of these peaks and the extent of their overlapping is primarily determined by the spread of rice planting dates over a given area. A short planting interval, as occurred in 1982 in NE Arkansas, will result in two definite peaks of abundance because adults emerging after the initial flood will have largely disappeared before the second peak of abundance appears following normal, mid-season cultural drainage and reflooding. When the planting interval extends over several weeks, as it did in 1981 due to frequent rains, the two peak periods of abundance will overlap because adults produced by early-planted fields that have been reflooded after cultural drainage will be emerging at the same time as those coming from the initial flooding of late planted fields.

The relatively higher numbers of P. columbiae in early June of 1981 were believed to be the result of a greater amount of rainfall (21.13 cm) in May of that year than that experienced in May of 1982 (12.60 cm). Following the decline of ricefield mosquitoes in September of both years, Culex, Aedes, and Anopheles mosquitoes represented the main components of the population.

Figures 3 and 4 present a comparison of the combined adult male and female P. columbiae collected in the two peripherally-located traps (Airport and Race Street) with those captured by the centrally-located traps (ASU and Culberhouse Street) for 1981 and 1982, respectively. In both years, the data clearly indicated that light traps located within 0.9 km of rice fields caught a significantly greater number of P. columbiae than did traps situated from 1.5 km to 1.9 km away. This
finding further substantiated earlier work by several investigators in Arkansas including Schwartz (1939), Horsfall (1942a), Quartermann et al. (1955), and Whitehead (1957). A more detailed comparison of the number of P. columbiae collected in the peripheral and centrally-located traps is presented in the Table. In 1981, the two peripheral traps, which were within 0.9 km of several rice fields, accounted for 95.8% of the adults captured. In 1982, the same peripheral traps caught 95.6% of all ricefield mosquitoes collected. The two centrally-located traps, which were 1.2 km to 1.9 km from the nearest rice, caught only 4.2% of the 1981 P. columbiae adults and 4.4% in 1982.

In addition to the effects of trap distance from rice acreage, it is believed that competing light sources and the physical barriers presented by trees and buildings may have had a negative influence on the number of ricefield mosquitoes found in the central traps. Horsfall (1942a) concluded that this species does not readily enter wooded areas and the tendency of females to fly close to the ground for host and oviposition-site location may restrict their movements to more open, treeless regions between wooded areas.

The Table also shows that 98.0% of the captured P. columbiae adults in 1981 were females as were 98.7% in 1982. Reasons for the comparatively low numbers of males in all traps in both years are not completely understood. However, in ricefield mosquito flight-habit studies by Horsfall (1942a), it was noted that the majority of the males normally do not fly over 274 m from their breeding sites. In samples with whirling-cone traps at 1.2 m and 2.4 m levels, it was found that 73.0% of all males were collected at the highest elevation. It also was suggested that males may fly in greater numbers still higher than 2.4 m thus reducing the chances of their being taken in a standard light trap.

In summary, our data support the conclusion that P. columbiae is the main component of the mosquito fauna in the rice-growing region of NE Arkansas. The period of peak abundance for this species occurs

Table. Comparison of numbers of adult female and male Psorophora columbiae collected at four locations in Jonesboro, Arkansas in 1981 and 1982.

|-------|-----------------------|--------------------|-----------------------|--------------------|-------|
between mid-July and late August and is closely associated with area rice-cultivation practices. The trapping of more than 95.0\% of all \textit{P. columbiae} adults within 0.9 km of rice fields confirms the previously-reported short flight range of this species.

**ACKNOWLEDGEMENTS**

A special note of appreciation is extended to Dr. Harvey E. Barton, Department of Biological Sciences, Arkansas State University, for his unselfish contribution of time, professional abilities, and illustrative expertise.

**LITERATURE CITED**


COMPUTER PATTERN RECOGNITION
OF ACTION POTENTIALS

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ABSTRACT

A general method of pattern recognition was applied to the problem of recognizing extracellularly-recorded neuronal action potentials in the presence of noise and other pulses. A PDP11/23 performed the calculations. There were four stages: 1) A bandpass filter attenuated noise; 2) the data input program digitized the signal every 55 μsec. If the signal exceeded a threshold, 12 samples of the signal and the time when they were written onto the disk; 3) the pulse discriminating program recognized an action potential by fitting the 12 points with this function:

\[ v(t) = (a + bt + ct^2) \exp(-t/\tau). \]

For each pulse the computer determined values of the parameters giving the best fit through use of the least squares technique. For acceptance, the total pulse height and the position of the zeroes of \( v(t) \) must fall within limits; 4) occasionally a pulse may be missed or an extra one recorded. The computer displayed the complete pulse train and the operator moved a cursor to insert or delete pulses.

INTRODUCTION

Signals in the nervous system are transmitted along axons as pulses of electricity called action potentials. If a microelectrode is inserted inside a neuronal cell body or axon, a resting potential of about -60 mV is measured with respect to the extracellular fluid. The resting potential is a thermodynamic consequence of the fact that the intracellular potassium concentration is much HIGHER than outside. In contrast, the intracellular sodium concentration is much LOWER than outside. These concentrations are maintained by the cell's sodium-potassium pump.

An action potential is a positive-going pulse of about 100 mV amplitude and about 0.5 msec duration superimposed upon the resting level (Ganong, 1981). The rising phase of an action potential occurs when membrane channels selectively permeable to sodium ions open and sodium ions rush into the cell. This inrush of positive charges causes the membrane potential to go positive. The falling phase is caused by the sodium channels closing and potassium channels opening. The outflow of potassium ions leaves a net negative charge inside, causing the membrane potential to return to its negative resting potential. This voltage wave propagates rapidly down the axon at speeds up to 120 m/sec with no attenuation in amplitude. Action potentials are usually initiated by excitatory synapses. Standard textbooks give further details (Ganong, 1981).

An intracellular recording of action potentials is difficult to obtain in the alert, behaving animal because the microelectrode is easily jarred out of the cell. It is easier to record action potentials extracellularly by inserting a microelectrode into the brain to within 50 μm of a neuronal cell body. The pulses are ~1 mV in amplitude and generally negative-positive biphasic waves. The negative phase is caused by sodium ions moving away from the microelectrode into the cell. The positive phase is caused by potassium ions moving out of the cell towards the microelectrode.

Typically the height of recorded action potentials is only 3-20 times the noise level of 30 μV. This noise is caused by the thermal motion of charges in the electrode and amplifier. The usual method to distinguish between neuronal pulses and noise is to use an electronic circuit called a discriminator, which gives an output pulse only when the signal exceeds a preset voltage. However, sometimes a large noise transient is mistaken for an action potential.

We present a new method for distinguishing between action potentials of interest and noise and background units. The method has four stages: 1) an analog bandpass filter attenuates the noise; 2) the computer writes onto disk 12 digitized samples of each pulse; 3) offline the computer fits this function to the 12 points:

\[ v(t) = (a + bt + ct^2) \exp(-t/\tau). \]

This function was chosen because it has a biphasic shape which is very similar to that of an extracellularly recorded action potential. The pulse is rejected if its height or if the shape of \( v(t) \) deviates beyond limits; 4) another computer program allows editing the data file for apparently missing or extra pulses. More details have been presented in another publication (Remmel, 1983).

MATERIALS AND METHODS

Action potentials were recorded extracellularly with glass microelectrodes in the pons of alert cats making eye movements (Remmel and Skinner, 1981). We recorded the neuronal signal in direct mode on a TEAC A-2340SX high-fidelity tape recorder for computer analysis at a later time. The computer belongs to the NSF EPSCOR Program (Neuroscience Component) and is a D.E.C. PDP11/23 (MINC-11) with the following equipment:

- 128 KByte of MOS-FET memory (only 64 KByte used)
- dual RL01 disk drives (5 MByte each)
- ADV11-A analog-to-digital converter (A/D)
- KEF11-AA floating point processor
- VT105 graphics terminal
- Nicolet Zeta plotter

The bandpass filter

Electrode and amplifier noise, a major source of spurious pulses, is attenuated by the analog bandpass filter (Fig. 1a). Component values were selected to optimize the pulse height relative to white noise (equal noise energy at all frequencies). The filter passes 300-3000 hz (Fig. 1b); the pulse (Fig. 1c), although attenuated to 40%, is qualitatively unchanged.

The data input program

This MACRO-11 program digitizes data in real time and stores it on the disk for later analysis. The operator types in the trigger level,

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Figure 1. A bandpass filter for action potentials (A). The unity-gain amplifier (National type LF355H) functions to drive subsequent circuits. The filter has sharp cut-off at high frequencies (Bode plot, B) in order to attenuate electrode and amplifier noise. The filter blocks D.C. and attenuates low frequencies such as 60 Hz. For a biphasic pulse put into the filter (C), a computer program numerically solved the differential equations to give the output pulse shape. It is attenuated to 40% but otherwise little changed.

which is set low but not so low that the computer is inundated with small noise pulses. The A/D converter samples the signal every 55 μsec. If the sample exceeds the trigger level, more samples are taken until 12 are accumulated, including the one preceding the trigger. We call these samples \( y_i \) (i = 1 to 12). The 12 samples and the time of the pulse are written onto disk. One disk can hold about 30 min. of data.

The pulse discriminating program

This FORTRAN program reads a disk file, rejects bad pulses, and writes only the time of accepted pulses back onto the disk. The following function is fit to the 12 voltage samples for each pulse by the least squares technique:

\[ v(t) = (a + bt + ct^2) \exp(-t/r). \]

The polynomial is an inverted parabola (one maximum and two zeroes);

\[ v(t) = \frac{1}{t_1 - t_0} \sum_{i=1}^{12} (v_i - v(t_i))^2. \]

where \( t_1 = 0 \mu\text{sec}, t_2 = 55 \mu\text{sec}, \text{etc.} \)

For acceptance, the locations of the zeroes of \( v(t) \) must fall within the limits specified by the operator. The height of the pulse also must fall within limits. Summary statistics printed at the end show the number of accepted and rejected pulses and histograms of the pulse heights and of the two zeroes. This program takes 80 msec/pulse.

The pulse insertion-deletion program

Sometimes a pulse is missed or an extra one recorded. This program displays a graph of the instantaneous interspike frequency (ISF, which equals \( 1/\Delta t_1 \), where \( \Delta t \) is the time between two pulses). If the neuron fires at a steady rate, the missing or extra pulses are easily seen on this graph. The operator moves a cursor to point to the location of the defect and the computer inserts or deletes pulses.
Computer Pattern Recognition of Action Potentials

RESULTS

The operator can view on the graphics terminal the 12 voltage samples and the fitted function \( v(t) \) for accepted and/or rejected pulses (Fig. 2). For this neuron, the threshold was set to \(-32 \mu V\). The \( t \) was set to 150 \( \mu \)sec, a value giving good fits. The reasons for rejecting pulses C-H are given in the caption. For accepted pulses (A,B) the fitted curve showed little variation in shape from pulse to pulse. The most sensitive measure of shape was found to be the time difference between the two zeroes on the abscissa, which was \( 243 \pm 17 \mu \)sec (av. and std. dev. for 27,147 good pulses for the neuron of Fig. 2). The 17 \( \mu \)sec standard deviation is much less than the 55 \( \mu \)sec between samples, implying that the computer had "interpolated" between points. For this neuron the total pulse height (difference between the maximum and minimum) was \( 165 \pm 44 \mu V\) on the average for good pulses and fluctuated during the recording because the microelectrode moved relative to the cell. Thus although the pulse height fluctuated, the zeroes varied little.

DISCUSSION

Pattern recognition involves determining how similar the pattern of measured points is to a model pattern. Let us call those points \((x_i, y_i)\) for \( n \) points. A general procedure is to describe the model pattern by a mathematical function \( v(x, a, b, \ldots) \), which may have one or more adjustable parameters \( a, b, \ldots \). This function is fit to the points by the least squares method, i.e., the following function is minimized by adjusting \( a, b, \ldots \):

\[
S = \sum_{i=1}^{n} (y_i - v(x_i, a, b, \ldots))^2.
\]

(The least squares method is nearly identical to the chi-square method, the latter simply having statistical weights multiplying each term.) The minimization in our case involves solving 3X3 matrix equations, for which a subroutine is available. If the fit is bad (sum of squares large) or if the parameters deviate beyond prescribed limits, the event is rejected — it's not like the pattern. I have previously used this method for testing whether millions of particle reactions detected in a high-energy physics experiment were consistent with a reaction in which a positive kaon decayed into three charged pions (Ford et al., 1972).

My method fits 12 points with a 4-parameter function. More details of the pulse shape can be fit by the template method of Prochazka and Kornhuber (1973), which is a least squares method. The contour-fitted amplitude window used by Kent (1971) tests complex waveforms without much computer times, but does no smoothing as is done by this least squares method. Other methods extract features of the pulse from the digitized points. For instance, the methods of Mishelevich (1970) and of Vibert and Costa (1979) calculate the maximum and minimum amplitudes, the time between the maximum and the subsequent zero crossing, and the time between the maximum and the minimum. These methods provide no smoothing nor interpolation of points.

My method employs a least-squares fit of a 4-parameter function having a biphasic shape which is very similar to that of an action potential. Pattern recognition is accomplished as follows: An action potential is represented as a point in a 4-dimensional space; those points falling outside of a certain volume in that space are rejected as being unlike the pattern. This method of pattern recognition is widely applicable.

ACKNOWLEDGMENTS

R. D. Skinner and P. G. Pal participated in gathering the data. This investigation was supported by NSF Grant ISP-8011447, NIMH Grant MH3639 and NIH Grant RR05350.

LITERATURE CITED


http://scholarworks.arkansas.edu/jaas/vol37/iss1/4
ZOOPA\-\-\-LANKTON COMMUNITY STRUCTURE IN DARDANELLE RESERVOIR, ARKANSAS, 1975-1982

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ABSTRACT

Zooplankton was collected at 10 stations in Dardanelle Reservoir from 1975 to 1982. Current data were compared to a five-year preoperational study phase. Rotifer taxa strongly dominated the community. Over-all abundance was higher, varying about the same and diversity lower than those of comparable studies. Thermal discharges caused a dominance shift between two rotifer taxa, slightly depressed abundance and variety, did not noticeably affect diversity and elevated the phytoplankton/zooplankton ratio. Heated effluent also stimulated stronger fluctuations in abundance and variety. Other studies indicate that in upper sections of the Arkansas River drainage, microcrustaceans dominate lake habitats whereas rotifers dominate river habitats. In similar northern and eastern habitats, microcrustaceans were generally dominant.

INTRODUCTION

Much of the basic descriptive work in Arkansas with zooplankton was done under the auspices of the Water Resources Research Center (Schmitz, 1974, 1975, 1978). Sinclair and Watson (1978) conducted a five-year survey of the zooplankton community composition in Dardanelle Reservoir prior to the beginning of power generation by Arkansas Nuclear One (ANO) Unit 1. Palko (1970) collected and identified zooplankton from two stations in the upper Illinois Bayou arm of Dardanelle Reservoir during the summer and autumn of 1969. Numerous reports attempting to describe and quantify the impacts of thermal discharges have come from other states (Carlson, 1974; Gehrs, 1974; Anderson and Leary, 1978; Miller et al., 1976; Edmondson, 1965). Analysis of the structure of zooplankton communities should receive much more research effort than in the past. This report is a general examination of data collected over an eight-year period, 1975-1982, during which ANO Unit 1 was operative. We will attempt to describe basic community structure and relate such to thermal discharges. Main points to be addressed in this report are (1) seasonality or periodicity of community diversity, (2) which taxa are dominant and when, (3) changes in abundance and diversity related to season and location with respect to power plant discharge, and (4) evidence of long-term trends or shifts in community structure.

MATERIALS AND METHODS

Zooplankton samples were collected in January, April, July and October of the years 1975-1982 by straining 10.1 of water through a standard No. 20 Wisconsin-style plankton net. The water column was sampled by taking 2.1 of water each from near the bottom, mid-depth and 0.6 m. plus 4.1 from the surface. Ten stations were sampled quarterly and the samples preserved in Meyer's Fixative. Figure 1 is a line map of the reservoir showing the locations of the sampling stations. Close stations (1,2,3,5,10) were those affected by effluent from the power plant as determined by the thermal measurements, however not all five stations were necessarily affected at any one time. For example, a southeast wind tended to move the effluent toward Sta. 2 away from Sta. 10. Distant stations (11,14,15,16,21) were not measurably affected by the discharge.

In the lab a 1 ml. aliquot was transferred to a Sedgwick-Rafter counting cell, and quantitative evaluation was made by counting randomly-spaced strips across the counting cell until approximately 40 percent of the area was examined. Organisms were identified to genera where possible and reported as organisms per liter. Statistical procedures included calculation of the number of taxa (genera), number of individuals, mean number of individuals per taxon and community diversity at the genus level. Diversity was calculated with the Shannon Index, \[ I = -\sum p_i \log_2 p_i \], where \( n \) is the number of organisms in each taxon in turn, and \( N \) is the total number of organisms in the sample (per liter). Values are positive; the larger ones indicating greater diversity.

RESULTS AND DISCUSSION

Table 1 lists the genera of zooplankton collected during the study period (excluding unidentified specimens, nauplii and eggs). Quite often the nauplii and/or eggs counted comprised a significant proportion of the sample. Twenty-six genera representing 22 families in three phyla were identified. Rotatoria contained 46.2 percent of the genera and 40.9 percent of the families. Wilhm et al. (1977) collected 27 genera in the Arkansas River near Ponca City, Oklahoma (excluding unidentified taxa). They obtained three genera of Protozoa, seven of Rotatoria and four of microcrustacea not obtained in our study, whereas our study obtained eight genera of Protozoa, three of Rotatoria and two of microcrustacea not obtained in theirs. Palko (1970) reported three genera of Protozoa (all Ciliata), one genus of Cladocera (Diaphanosoma) and 11 genera of rotifers not recorded in this study.

Table 2 contains mean numbers of organisms and taxa, number per taxon and diversity values grouped by season. Although there was considerable fluctuation from year to year within a given season, the means show the greatest overall abundance occurred in July and the lowest in October. That close stations had more organisms than distant stations in January and April was probably due to the heated water which elevated metabolism allowing them to take greater advantage of available...
Zooplankton Community Structure in Dardanelle Reservoir, Arkansas, 1975-1982


<table>
<thead>
<tr>
<th>Phylum Prototaza</th>
<th>Phylum Arthropoda</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class Harpadonida</td>
<td>Class Crustacea</td>
</tr>
<tr>
<td>Family Actinophryidae</td>
<td>Family Bominiaida</td>
</tr>
<tr>
<td>1. Actinothricium</td>
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</tr>
<tr>
<td>Family Diffracidae</td>
<td>22. Baphnia</td>
</tr>
<tr>
<td>2. Diffraxia</td>
<td>23. Helopedina</td>
</tr>
<tr>
<td>Class Ciliata</td>
<td>Family Polychaetidae</td>
</tr>
<tr>
<td>Family Dididae</td>
<td>29. Polychaetum</td>
</tr>
<tr>
<td>3. Didina</td>
<td>30. Didapta</td>
</tr>
<tr>
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<td>31. Enteroplea</td>
</tr>
<tr>
<td>4. Epistyla</td>
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</tr>
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<tr>
<td>5. Goniadina</td>
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</tr>
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<td>36. Heterida</td>
</tr>
<tr>
<td>Family Vorticellidae</td>
<td>37. Heterida</td>
</tr>
<tr>
<td>7. Vorticella</td>
<td>38. Heterida</td>
</tr>
<tr>
<td>Class Suctoria</td>
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<td>Family Podophryidae</td>
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</tr>
<tr>
<td>8. Podophrya</td>
<td>40. Podophrya</td>
</tr>
</tbody>
</table>

Phytoplankton food sources. Wilhm et al. (1977) obtained considerably fewer organisms, but their maximum density was also observed in summer. Smith et al. (1979) obtained maximum biomass in June and July in a small pond in north-central Texas. Kochsiek et al. (1971) obtained up to 267 organisms per liter in Keystone Reservoir, Oklahoma; a value closer to the numbers obtained in our study.

The greatest fluctuation (31-fold) over the entire study period occurred in January, whereas the smallest fluctuation of 2.7x occurred in September. Figure 2 shows mean numbers of organisms in chronological sequence. The peaks of abundance were not closely correlated with season, but four peaks at close stations occurred in January, two in April and one in July. At the distant stations six peaks occurred in July and three in January. Distant stations had greater abundance 19 times of 32 possible and were greater by an average of 64 organisms. When close stations showed greater abundance, they were greater by an average of 115 organisms. Fluctuations can sometimes be partially explained by normal patchiness of distribution (Bowles and Wilhm, 1977). In Dardanelle Reservoir, the heated effluent apparently stimulated stronger fluctuations perhaps by increasing the patchiness of the distribution which could result from the mixing of the heated effluent with reservoir water. The effluent also caused a slight depression of numbers of organisms in July and October.

Figure 3 shows the variety (mean number of taxa) of zooplankton in chronological order. At close stations six or 10 peaks occurred in July, two in January and one each in April and October, whereas at distance stations four peaks were in July, two in October and one each in January and April. Distant stations had greater variety 19 times. Figure 4 shows the mean number of individuals per taxon. Four of eight peaks occurred in January at close stations whereas four of nine peaks were in January at distant stations. Distant stations were greater than close stations 20 times out of 32, but were greater by only 8.6. When close stations were greater, the difference was 21.8. Again their in-

Table 2. Summary of zooplankton abundance, variety, number per taxon and community diversity, Dardanelle Reservoir, Arkansas, 1975-1982.

<table>
<thead>
<tr>
<th>JULY</th>
<th>Year</th>
<th>Stations</th>
<th>Number of Organisms</th>
<th>Number of taxa</th>
<th>Number per taxon</th>
<th>Diversity</th>
</tr>
</thead>
<tbody>
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<td>236</td>
<td>12.3</td>
<td>99</td>
<td>1.27</td>
<td>1.27</td>
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<tr>
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<td>76</td>
<td>1.26</td>
<td>1.26</td>
</tr>
<tr>
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<td>26</td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td>1976</td>
<td>Distant</td>
<td>119</td>
<td>7.0</td>
<td>22</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
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<td>Close</td>
<td>481</td>
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<td>53</td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
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<td>1.15</td>
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<td>49</td>
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<td>1.07</td>
</tr>
<tr>
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<td>1.05</td>
<td>1.05</td>
</tr>
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<td>23</td>
<td>1.18</td>
<td>1.18</td>
</tr>
<tr>
<td>1979</td>
<td>Distant</td>
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<td>29</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
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<td>1.15</td>
<td>1.15</td>
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<tr>
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<td>1.15</td>
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<tr>
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</tr>
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<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
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<td>Close</td>
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<td>63</td>
<td>1.28</td>
<td>1.28</td>
</tr>
<tr>
<td>Mean</td>
<td>Distant</td>
<td>529</td>
<td>8.7</td>
<td>61</td>
<td>1.41</td>
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<table>
<thead>
<tr>
<th>OCTOBER</th>
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<th>Number of taxa</th>
<th>Number per taxon</th>
<th>Diversity</th>
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<td>Close</td>
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<td>1.20</td>
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<tr>
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<td>1.20</td>
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<tr>
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<td>9.2</td>
<td>39</td>
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<td>1.20</td>
</tr>
<tr>
<td>1976</td>
<td>Distant</td>
<td>436</td>
<td>10.2</td>
<td>63</td>
<td>1.25</td>
<td>1.25</td>
</tr>
<tr>
<td>1977</td>
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<td>50</td>
<td>1.17</td>
<td>1.17</td>
</tr>
<tr>
<td>1977</td>
<td>Distant</td>
<td>407</td>
<td>8.2</td>
<td>44</td>
<td>1.15</td>
<td>1.15</td>
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<td>36</td>
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<td>1.15</td>
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<tr>
<td>1978</td>
<td>Distant</td>
<td>205</td>
<td>8.6</td>
<td>25</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>1979</td>
<td>Close</td>
<td>235</td>
<td>7.4</td>
<td>32</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>1979</td>
<td>Distant</td>
<td>279</td>
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<td>37</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>1980</td>
<td>Close</td>
<td>179</td>
<td>4.9</td>
<td>41</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>1980</td>
<td>Distant</td>
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<td>52</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>1981</td>
<td>Close</td>
<td>237</td>
<td>5.8</td>
<td>43</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>1981</td>
<td>Distant</td>
<td>239</td>
<td>5.8</td>
<td>47</td>
<td>1.15</td>
<td>1.15</td>
</tr>
<tr>
<td>Mean</td>
<td>Close</td>
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<td>4.6</td>
<td>112</td>
<td>1.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Mean</td>
<td>Distant</td>
<td>330</td>
<td>8.0</td>
<td>43</td>
<td>1.40</td>
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</tr>
</tbody>
</table>
Figure 2. Mean number of zooplankton organisms for close vs. distant stations in chronological sequence in Dardanelle Reservoir, Arkansas, 1975-1982.

Figure 3. Mean number of zooplankton taxa for close vs. distant stations in chronological sequence in Dardanelle Reservoir, Arkansas, 1975-1982.

Figure 4. Mean number of zooplankton organisms per taxon for close vs. distant stations in chronological sequence in Dardanelle Reservoir, Arkansas, 1975-1982.

Figure 5. Diversity values of zooplankton for close vs. distant stations in chronological sequence in Dardanelle Reservoir, Arkansas, 1975-1982.

dication that the warm water stimulated fluctuations or patchiness of distribution.

Figure 5 shows the chronological sequence of diversity values. Six of eight peaks at close stations occurred in April and July (three each), whereas seven of 11 peaks (three and four, respectively) occurred in these two months at distant stations. Smith et al. (1979) also obtained greater diversity in the summer months. Diversity values apparently vary more in rivers than in riverine reservoirs (Wilhm et al., 1977). Kochsiek et al. (1971) obtained values from 2.45 to 2.61 near the dam in Keystone Reservoir, Oklahoma, and Prather and Prophet (1969) obtained values from 2.19 to 3.02. Dardanelle zooplankton diversity ranged from 0.71 to 1.82.

In the upper Arkansas drainage apparently rotifers dominate river zooplankton but microcrustaceans dominate in lakes (Hynes, 1972; Kochsiek et al., 1971; Yacovino, 1970). In the Arkansas River within Arkansas, rotifers are dominate in lakes as well as the river sections (Williams, 1963). In Dardanelle Reservoir, rotifers were strongly dominant. Considering individual sampling stations quarterly during the study period, *Polyarthra* was dominant 105 times, *Keratella* 70, *Brachionus* 66 and *Asplanchna* 24 (Table 3). *Polyarthra* was strongly dominant in January, *Keratella* was dominant in April, *Brachionus* and *Polyarthra* shared dominance in July, and *Keratella* and *Polyarthra* shared in October. Palko (1970) also gives data indicating that rotifers were strongly dominant in Dardanelle.

That most phytoplankton is directly used as food by most zooplankton is generally agreed. Therefore, the comparative concentrations of

Table 3. Number of times each taxon was dominant, by quarter, in Dardanelle Reservoir, Arkansas, 1975-1982.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>January</th>
<th>April</th>
<th>July</th>
<th>October</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyarthra</td>
<td>48</td>
<td>7</td>
<td>28</td>
<td>22</td>
<td>105</td>
</tr>
<tr>
<td>Keratella</td>
<td>10</td>
<td>32</td>
<td>1</td>
<td>27</td>
<td>70</td>
</tr>
<tr>
<td>Brachionus</td>
<td>7</td>
<td>13</td>
<td>33</td>
<td>13</td>
<td>66</td>
</tr>
<tr>
<td>Asplanchna</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td>9</td>
<td>24</td>
</tr>
<tr>
<td>Rotifer sp.</td>
<td>0</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>15</td>
</tr>
<tr>
<td>Miscellaneous (includes other rotifer genera)</td>
<td>6</td>
<td>22</td>
<td>15</td>
<td>21</td>
<td>64</td>
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</tbody>
</table>
phytoplankton and zooplankton (P/Z ratio) could be used as an indicator of community quality or stability. O'Brien and deNoyelles (1974) showed that the filtering rate of *Ceriodaphnia reticulata* was directly proportional to the concentration of phytoplankton. P/Z ratios for Dardanelle Reservoir are given in Table 4. Close stations had larger ratios than distant stations 19.3 times (one tie) of 32 possibilities. For close and distant stations combined, most peaks occurred in January and July. In general close stations showed higher P/Z ratios. A sharp downward fluctuation occurred in October 1980 through April 1981 as a result of the drought during the summer of 1980 when fewer nutrients were being added from the watershed. The phytoplankton rebounded to a higher than normal density in July 1981.

Table 4. Phytoplankton/zooplankton ratios (using mean abundance) in chronological order, Dardanelle Reservoir, Arkansas, 1975-1982.

<table>
<thead>
<tr>
<th>Date</th>
<th>Station</th>
<th>Close</th>
<th>Distant</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/75</td>
<td>40.9</td>
<td>15.6</td>
<td></td>
</tr>
<tr>
<td>4/75</td>
<td>21.4</td>
<td>17.3</td>
<td></td>
</tr>
<tr>
<td>7/75</td>
<td>5.0</td>
<td>4.8</td>
<td></td>
</tr>
<tr>
<td>10/75</td>
<td>6.7</td>
<td>6.8</td>
<td></td>
</tr>
<tr>
<td>1/76</td>
<td>12.3</td>
<td>15.3</td>
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</tr>
<tr>
<td>4/76</td>
<td>6.3</td>
<td>6.3</td>
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<td>7/76</td>
<td>9.5</td>
<td>15.8</td>
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</tr>
<tr>
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<td>7.1</td>
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<td>10/77</td>
<td>9.9</td>
<td>7.5</td>
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<tr>
<td>1/78</td>
<td>11.2</td>
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<td>18.1</td>
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<td>1/79</td>
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<td>4/79</td>
<td>18.9</td>
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<td>1/80</td>
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<td>8.3</td>
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</tr>
<tr>
<td>7/80</td>
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<td>10/80</td>
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</tr>
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<td>1/81</td>
<td>0.08</td>
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<td>4/81</td>
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<tr>
<td>10/82</td>
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<td>9.1</td>
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</tbody>
</table>

**THERMAL IMPACT**

Eight genera of zooplankton, including five of rotifers, were considered to be a major taxon in Dardanelle Reservoir by Sinclair and Watson (1978) during five pre-operational years. They ranked each taxon with respect to its annual abundance and listed the month when its peak abundance occurred. We calculated a mean rank for each taxon and listed the months of peak abundances (Table 5). During the eight years of operation, Polyarthra replaced *Brachionus* as the most frequently dominant taxon, Keratella remained second, and microcrustaceans were virtually eliminated as dominant taxa. There was no significant difference between close and distant stations. Drenner et al. (1981) studied a similar situation in northeast Kansas. The normal July maximum total abundant shifted to May and April after start-up (1973 and 1974, respectively). The overall community abundance increased somewhat, but the heat-tolerant *Boamnia longirostris* exhibited a very strong peak in April 1974. In their study rotifers were unimportant as dominant zooplankton taxa.

Miller et al. (1976) studied the discharge of a power plant on the Ohio River and found the zooplankton community declined from 200 organisms per liter to 10 per liter in a discharge canal with average ΔTs of 7 to 8 °C. Part was due to natural seasonal mortality, and part was due to elevated temperatures. This mortality was also taxon selective affecting large cladocerans most. Under experimental conditions in New York, Carlson (1974) obtained increases in microcrustacean diversity with temperatures up to 5 °C above ambient. This reduced to 13.5 °C above ambient. The most successful species overall was *Ceriodaphnia quadrangula*. In eastern Tennessee, Gehris (1974) determined that heated water caused deeper vertical migration of two species of *Daphnia*. This action might contribute to decreased productivity.

Anderson and Lenat (1978) noticed an increase in overall density of *Hexarthra* and *Polyura* and an increase in winter density of *Polyarthra* due to heated effluent in Belows Lakes, North Carolina. They also noticed greater spatial and seasonal homogeneity in heated surface water which may have been due, in part, to the forced circulation.

A noteworthy concern has been the effects of plant shutdown once the aquatic community has become adjusted to the thermal discharge. Although a sudden decline in temperature narcotizes threadfin shad (Dorosoma petenense), fluctuations in the zooplankton community were not attributable to the same.

**CONCLUSIONS**

A major difficulty of this type of study is the scarcity of comparable data. Most projects of this nature have occurred in the northeastern part of the United States where microcrustaceans taxa seem to be routinely dominant. In the Arkansas River drainage microcrustaceans trade off with rotifers. From northeast Oklahoma upstream, rotifers dominate truly riverine sections, whereas microcrustaceans dominate lakes. However, within Arkansas (and possibly part of Oklahoma) rotifers seem to dominate in both major habitats.

In general the annual abundance peak occurred in July in Dardanelle Reservoir, but it wasn’t particularly strong. Variety was also greatest in July. Community diversity was lowest in January and about constant the rest of the year. P/Z ratios were highly variable exhibiting peaks in January and July (except the uncommonly steep slump in January 1981).

Plant start-up and thermal discharge caused a dominance shift between the rotifer genera *Brachionus* and *Polyarthra* (the latter

Table 5. Mean abundance rank and timing of peak abundances of eight major zooplankton taxa, Dardanelle Reservoir, Arkansas, 1970-1974. (Data from Sinclair and Watson 1978).

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Mean Rank</th>
<th>Month(s) of Peak Abundance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Brachionus</em></td>
<td>1.4</td>
<td>MayMayJunJulSep</td>
</tr>
<tr>
<td><em>Keratella</em></td>
<td>2.4</td>
<td>MarAprMaySepDec</td>
</tr>
<tr>
<td><em>Polyarthra</em></td>
<td>4.6</td>
<td>JunJulSepDec</td>
</tr>
<tr>
<td><em>Cyclops</em></td>
<td>4.6</td>
<td>AprAprJulSep</td>
</tr>
<tr>
<td><em>Boamnia</em></td>
<td>4.8</td>
<td>MarAprMayJun</td>
</tr>
<tr>
<td><em>Amphipora</em></td>
<td>7.2</td>
<td>MayMayJunAug</td>
</tr>
<tr>
<td><em>Filinia</em></td>
<td>8.4</td>
<td>MarAprJulAug</td>
</tr>
<tr>
<td><em>Daphnia</em></td>
<td>9.2</td>
<td>MayMayJulAug</td>
</tr>
</tbody>
</table>
moved from third to first). Heated effluent also slightly suppressed overall abundance and variety but had no obvious effect on diversity. Other studies have shown that slight temperature increases stimulated zooplankton, but they dealt with communities in which microcrustaceans were dominant. Similar data on rotifer-dominated communities were unavailable. In Dardanelle Reservoir the P/Z ratios were generally greater at close stations indicating the phytoplankton was stimulated or zooplankton was depressed or both. The phytoplankton data indicated both phenomena occurred.

ACKNOWLEDGMENTS

The authors wish to thank the late Clarence B. Sinclair and William R. Bowen for performing the analyses of the samples and the numerous staff and students who assisted field collections from time to time. Financial support was provided by Arkansas Power and Light Company.

LITERATURE CITED


PHYTOPLANKTON COMMUNITY STRUCTURE IN DARDANELLE RESERVOIR, ARKANSAS, 1975-1982

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Little Rock, Arkansas 72204

ABSTRACT

Phytoplankton data were collected with standard equipment and procedures over an eight-year period (1975-1982) in Dardanelle Reservoir, Arkansas. Community abundance and diversity at the genus level are described. Sixty-five genera representing 35 families and five divisions were identified. Total phytoplankton abundance and diversity were quite uniform among the stations but fluctuated considerably with time. These fluctuations did not correspond clearly with season. Dominant taxa were seasonal, though, with diatoms being usually dominant in January, April and October, and blue-greens dominant in July. The phytoplankton community structure has not been significantly altered by the operation of ANO Unit I.

INTRODUCTION

Information about phytoplankton community structure in Arkansas reservoirs is quite scarce. Some of the earlier papers (Meyer, 1969; Meyer et al., 1970) dealt only with checklists, whereas others studied algae in relation to certain water quality parameters (Meyer, 1971; Rice and Meyer, 1977). Still other studies emphasized phytoplankton populations related to certain anthropogenic inputs, e.g., thermal discharge. Sinclair and Watson (1978) conducted such a survey in Dardanelle Reservoir for five years immediately prior to the operation of Arkansas Power and Light Company's Arkansas Nuclear One (ANO) Unit I. Numerous papers have appeared concerning thermal disturbance in specific locations in other states (Gibbons and Sharitz, 1974; Esch and McFarlane, 1976). There is a definite lack in Arkansas of work describing phytoplankton community structure and dynamics and the impacts of thermal effluents. This report is a superficial analysis of data gathered in Dardanelle Reservoir over an eight-year post-operational period of ANO Unit I. The main points to be addressed in this paper are (1) seasonality or periodicity of community diversity and which taxa were dominant and when, (2) changes in abundance and diversity related to season and location with respect to thermal discharge, and (3) evidence of long-term trends or shifts in community structure.

METHODS AND MATERIALS

Phytoplankton samples were collected in January, April, July and October of the years 1975-1982 and strained through a standard No. 20 Wisconsin-style plankton net. The water column at each station and date was sampled by taking 2.1 of water each from near the bottom, mid-depth and 0.6 m, and 4 l from the surface, constituting a 10 l sample. With rare exceptions, 10 stations were sampled quarterly (Figure 1) and the samples preserved in Meyer's Fixative (0.76% H2O2, 0.38% KI, 3.8% glacial acetic acid, 19% concentrated formalin and 76% D.H.O, by weight).

In the lab the samples were diluted to 10 ml (if needed), and a 1 ml aliquot was removed and placed in a Sedgwick-Rafter counting cell. Quantitative evaluation was determined by counting randomly spaced strips across the counting cell to cover 38.9% of the area. Then a total quantitative cross-check was made by counting 10 randomly chosen fields. Colonial forms were counted as single cells, and organisms were identified to genus where possible and reported as number per liter.

Statistical procedures included calculation of the number of taxa, number of individuals, mean number of individuals per taxon and community diversity at the generic level. Diversity was calculated using the Shannon Index, \( H = -\sum (n_i / N) \ln (n_i / N) \), where \( N \) is the total number of organisms in each taxon. Values are positive, the larger ones indicating greater community diversity.

RESULTS AND DISCUSSION

Sixty-five genera representing 35 families and five divisions were identified (Table 1). Forty-six percent of the genera were in Chlorophyta, 31 were in Chrysophyta, 17 were in Cyanophyta, and Euglenophyta and Pyrrophyta were represented by three percent each of the genera. Meyer (1969) reported 82 genera as occurring in Arkansas; 29 of which were present in this study. Meyer et al., (1970) reported an additional 34 Arkansas genera, eight of which are reported in this study. Nelson and Harp (1972) reported four additional genera which were obtained in our study. This study presents 24 genera not reported by any of the three foregoing papers.

Table 2 is a summary by season (quarter) of individuals, number of taxa, individuals per taxon and diversity values listing stations close to and distant from the point of thermal discharge. Close stations (Nos. 1, 2, 3, 5, 10) were those generally influenced by thermal loading, whereas distant stations (Nos. 11, 14, 15, 16, 21) were those not apparently influenced (Rickett, 1981). A cursory examination of Table 2 reveals considerable fluctuation from quarter to quarter and from year to year. On the average, July samples contained the largest populations, numerically, the greatest number of taxa and the largest number per taxon, but the greatest community diversity indices were observed in October. Phytoplankton was very dense in July 1978, exhibited a serious decline in January 1981 and a rapid recovery between April and July 1981. The decline was probably a delayed response to the very hot and dry summer of 1980. Total phytoplankton peaked six times in July, four times in January and once in April. The peaks were spread by six to 12 months, so there was not a precise coincidence with season.
Distant stations showed the same peaking sequence as close stations. Close stations had more total organisms 18 of 32 times with an average difference of 534 cells, however when distant stations had more cells, the average difference was 589. With respect to total phytoplankton, there was apparently little impact from thermal discharge.

At close stations six peaks in the average number of taxa occurred in July and two in April, whereas at distant stations seven peaks occurred in July and two in April, whereas at distant stations even peaks occurred in July, two in January and one in October. It seemed the heated water had some stimulating influence on the number of taxa comprising the community. Distant stations exhibited a larger number of taxa 16.5 times of 32 (three ties), the average difference being 1.08 taxa. When close stations were greater, the difference was 1.28 taxa.

At close stations five peaks in the average number of organisms per taxon occurred in July, four in January, and two in April, whereas at distant stations there was one less peak in January. Close stations had more individuals per taxon 16.5 times of 32 (one tie), the average difference being 39.1. When distant stations showed the greater number, the difference was 22.8.

At close stations, diversity occurred six times in October, five times in April, and once in July, whereas at distant stations diversity peaked five times in October, twice each in April and July, and once in January.
Phytoplankton Community Structure in Dardanelle Reservoir, Arkansas, 1975-1982

The major community growth occurred in July with a minor growth period in January. Olsen and Sommerfeld (1976) obtained similar periods of abundance and depression in Canyon Lake, Arizona. They also noted that the early spring peak was composed primarily of centric diatoms, whereas the mid-to late-summer peak was dominated by filamentous Cyanophyceae.

Between July and October there was a decline in both numbers of organisms and taxa, but the former apparently experienced a disproportionate decline which caused higher diversity values. This also happened somewhat between January and April. Both normal seasonal decline and zooplankton cropping may have been the cause. Table 3 shows dominance timing and frequency of nine major genera during the study period considering each station each quarter. Cyclotella was the dominant (representing the greatest number of cells) 86 times, far more than any other taxon, and its favored time was October (47.7% of total for Cyclotella). Melosira and Oscillatoria were dominant with about the same frequency (54 and 53 times, respectively) but favored different times — January for Melosira (38.9%) and July for Oscillatoria (77.4%). Tribonema was dominant 34 times (58.8% of the time in January), while Asterionella and Navicula were dominant 13 times each. Asterionella favored April (100%), whereas Navicula favored October (84.6%).

Table 3. Dominance timing and frequency of major phytoplankton taxa in Dardanelle Reservoir, Arkansas, 1975-1982.

<table>
<thead>
<tr>
<th>Dominant taxon</th>
<th>Number of times dominant per quarter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>JAN</td>
</tr>
<tr>
<td>Cyclotella (Chrysophyta)</td>
<td>11</td>
</tr>
<tr>
<td>Melosira (Chrysophyta)</td>
<td>21</td>
</tr>
<tr>
<td>Oscillatoria (Chrysophyta)</td>
<td>1</td>
</tr>
<tr>
<td>Tribonema (Chrysophyta)</td>
<td>20</td>
</tr>
<tr>
<td>Asterionella (Chrysophyta)</td>
<td>3</td>
</tr>
<tr>
<td>Navicula (Chrysophyta)</td>
<td>1</td>
</tr>
<tr>
<td>Ankistrodesmus (Chlorophyta)</td>
<td>3</td>
</tr>
<tr>
<td>Anabaena (Chrysophyta)</td>
<td>0</td>
</tr>
<tr>
<td>Chlamydomonas (Chlorophyta)</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>57</td>
</tr>
</tbody>
</table>

In January Melosira, Tribonema and Cyclotella were dominant 36.8, 35.1 and 19.3 % of the time, respectively. In April Cyclotella, Melosira, Asterionella and Tribonema were dominant 33.8, 38.9, 18.3 and 18.3 %, respectively. In July Oscillatoria, Melosira and Cyclotella were dominant 56.2, 21.9 and 13.7 %, respectively, whereas in October Cyclotella, Navicula and Anabaena were dominant 53.2, 14.3 and 11.7 %, respectively. In January, April and October, Cyclotella were strongly dominant, whereas Cyanophyta dominated in July. Evidence of the dominance shift back to Chrysophyta was seen in October. Data collected by Sinclair and Watson (1978) during pre-operational years (1970-74) showed the same dominance trends for the diatoms (Chrysophyta) versus the blue-greens (Cyanophyta). Chrysophyta was represented less strongly in spite of having the greatest number of genera. A considerable number of researchers have attempted to assess and quantify the impacts of thermal discharges, mostly from generating stations into natural waters. Miller et al. (1976) worked with actual ΔTs between 8.5 and 15°C and concluded that smaller ΔTs that did not push the ambient temperature above 25°C were stimulatory, but 34°C was definitely inhibitory. One of their major problems was separating the effects of thermal discharge and normal ambient variation. At ANO Unit 1 during periods of operation, the average ΔTs were 8.20, 7.44 and 5.99°C for 1980, 1981 and 1982, respectively. Gurtz and Weiss (1974) studied experimental ΔTs of 5.6, 11.1 and 16.7°C and observed continually increasing inhibition of phytoplankton productivity. Tilly (1974) obtained an average 20% increase in autotrophic respiration in ΔTs ranging up to 3.3°C while there was no significant increase in photosynthesis. Patrick (1974) summarized by pointing out that small ΔTs stimulate while large ΔTs inhibit and cause changes in the species composition of the community to favor blue-green algae. Thermal shock usually had detrimental effects. Most of these studies have been conducted in eastern or northeastern United States, so these conclusions may not necessarily apply here. More geographic variation has been observed than was expected.

SUMMARY

It is always difficult to separate variables, especially when so many are present. In addition to daily temperature variations, wind velocity and direction, solar radiation and physico-chemical characteristics further confound the understanding. Add to this the fact that Dardanelle Reservoir has two distinct areas, and water from one (Illinois Bayou) is pumped through the plant into the other (Arkansas River mainstream), thus mixing parameters. Include the somewhat sporadic operation of ANO Unit 1, and the challenge of understanding becomes steeper. These data suggest that phytoplankton diversity and abundance were fairly uniform at the various sampling stations, there was considerable fluctuation in abundance and numbers of taxa which did not conform closely to the seasons, dominant taxa were quite seasonal in their occurrence, the diatoms being usually dominant in January, April and October while the blue-green algae were dominant in July, Blue-green algae is apparently better adapted to warmer water since they may take over as dominants in area of thermal effluent. Power plant operation has not noticeably affected overall phytoplankton abundance and the number of taxa, but community diversity was slightly greater at the close stations but not statistically significant. Water temperature changes through the year may be considered near the lower end of the expected range compared to similar results elsewhere.

ACKNOWLEDGEMENTS

The authors wish to thank the late Clarence B. Sinclair and William R. Bowen for analyzing the phytoplankton samples, and numerous staff and students for field assistance. Financial support was provided by Arkansas Power and Light Company.

LITERATURE CITED


FISHES OF THE ANTOINE RIVER, LITTLE MISSOURI RIVER SYSTEM, SOUTHWESTERN ARKANSAS

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ABSTRACT

The fishes of the Antoine River (Little Missouri River system) in southwestern Arkansas were surveyed from September, 1980 - June, 1982. Thirty-four field collections plus literature and museum records, revealed a total of 60 species in 29 genera representing 16 families to presently inhabit the river system. Comments are presented on life history aspects, systematics and occurrence of fishes in the study area.

INTRODUCTION

The Antoine River is a major tributary of the Little Missouri River system (Ouachita River drainage) in southwestern Arkansas. Surprisingly, few collections of fishes have been made from this beautiful upland stream previously. Although Myers (1977) surveyed the fishes of the Little Missouri River system, he made only four collections from the Antoine River. Earlier, Buchanan (1973) reported only one pre-1960 collection and only two post-1960 collections from the river, one of which was made by the senior author. Prior to this survey, a total of 29 species was known from the Antoine River based primarily on work by Northeast Louisiana University graduate students and one collection by Dr. George A. Moore, Oklahoma State University.

This paper seeks to document as accurately as possible the ichthyofauna of the Antoine River using literature records, museum records and personal collections.

DESCRIPTION OF THE AREA

The Antoine River is a clear, spring-fed tributary of the Little Missouri River approximately 40 miles long and drains an area of 399 square kilometers. Major tributaries include Wolf, Suck, Buffalo, Caney, Woodall, Matthews, Little Antoine, and Bigsby Creeks. The river arises in the Athens Plateau physiographic region in northeastern Pike County just south of Salem, Arkansas and flows southeasterly through a sparsely populated, heavily forested area of east-west trending valleys and ridges populated by loblolly-shortleaf pine, oak-hickory, and gum trees to form the border of Pike and Clark counties before joining the Little Missouri River south of Antoine, Arkansas within the Gulf Coastal Plain physiographic region.

The Antoine River has a typical dendritic drainage pattern arising in Mississippian (Stanley Shale) and Pennsylvanian rocks (Jackfork Sandstone, Johns Valley Shale, lower Atoka Formation) and flows south over Cretaceous rocks before finally reaching Quaternary Alluvium near its confluence with the Little Missouri River. Elevations in the headwaters reach 213 m while near the confluence the elevation is 76 m. Mean annual rainfall is 11.76 cm and 12.38 cm in Pike and Clark counties, respectively. Air temperature ranges from 11.2° to 46.5°C (Hickmon, 1941).

Antoine River has been classified as a warm-water fishery and Class A stream (AR. Dept. Poll. Cont. and Ec., 1976). Average discharge of the Antoine River is 7.53 m³/s (25 year average). Selected physicochemical data range as follows: pH 6.6-7.2; water temperature 5° - 26°C; dissolved oxygen 8.1 - 12.3 mg/l; hardness 15 - 49 mg/l; alkalinity 13 - 24 mg/l.

METHODS AND MATERIAL

Fish specimens were collected from September, 1980 to June, 1982. All collections were made with 3.1X1.8 m and 6.1X1.8 m seine with 3.175 mm meshes, except one gill net sample. Specimens were fixed in 10% formalin, before being preserved in 40% isopropyl alcohol for permanent storage in the Southern Arkansas Vertebrate Collection. Museum records from Northeast Louisiana University were verified when possible.

Scientific and common names of fishes follow those of Robins et al. (1980) unless otherwise noted.

Stations were established throughout the stream system. The following is a brief description of each station.

Antoine River Stations

Pike-Clark County Line
1. Antoine River at Antoine at St. Hwy. 26. (Sec. 23, 24, T8S, R23W)

Pike County
2. Wolf Creek at St. Hwy. 29, 1 mi. SW of Antoine (Sec. 27, T8S, R23W).
3. Wolf Creek at Co. Rd. bridge, 9 mi. S of Antoine (Sec. 25, 26, T8S, R23W).
4. Buffalo Creek at St. Hwy. 19 (Sec. 9, T9S, R23W).
5. Wolf Creek at St. Hwy. 26 at Delight (Sec. 19, T8S, R23W).

Pike-Clark Co. Line
6. Antoine River at end of TAR (Sec. 14, T8S, R23W).
7. Antoine River (Sec. 11, T8S, R23W).
8. Antoine River at Graysonia (Sec. 21, T7S, R23W).

Clark Co.
10. Unnamed tributary to Antoine River (Sec. 6, T8S, R22W).

Pike-Clark Co. Line
11. Antoine River (Sec. 25, T7S, R23W).
12. Antoine River (Sec. 21, T6S, R23W).

Clark Co.
13. Little Antoine River (Sec. 21, T6S, R23W).

Pike Co.
14. Bigsby Creek at St. Hwy. 84 (Sec. 36, T3S, R24W).
15. Unnamed trib. to Bigsby Creek at St. Hwy. 84 (Sec. 31, T5S, R23W).
16. Antoine River at St. Hwy. 84 (Sec. 4, 5, T6S, R24W).
17. Unnamed trib. to Antoine River at St. Hwy. 84 (Sec. 4, T6S, R24W).
18. Antoine River (Sec. 29, T5S, R24W).
19. Antoine River (Sec. 30, T5S, R24W).
20. Woodall Creek (Sec. 21, T5S, R24W).
21. Matthews Creek (Sec. 19, T5S, R22W).

Blevins High School, Blevins, AR.
ANOTATED LIST OF SPECIES

The following discussion of species is supplemented by verified museum records and literature records. Species are presented in phylogenetic order following Robins et al. (1980).

**Petromyzontidae (Lampreys)**

*(Ichthyomyzon castaneus* Girard). Chestnut lamprey. Three specimens (one male, two females) were collected spawning in a swift riffle, 12-16 inches deep, over a gravel bottom at Station 1 on 19 May 1982. Females were full of eggs. Water temperature was 19°C.

**Amilidae (Bowfin)**

*Amia calva* Linnaeus. Bowfin. Rare; only one small specimen found in the lower, sluggish reaches of the main Antoine River.

**Lepisosteidae (Gars)**

*Lepisosteus oculatus* (Winchell). Spotted gar. *L. oculatus* was uncommon in the system, found only occasionally in the larger pool sections of the lower reaches.


**Esox americanus verticulatus* Lesueur. Grass Pickerel. The grass pickerel occurred throughout the system in appropriate backwater, vegetated pool habitats. Probably the major predator species in the system.

**Clupeidae (Herring)**

*Hypentelium nigricans* (Lesueur). Northern hog sucker. Typically a headwater clear stream resident occurring rather infrequently in the system.

*Minytrema melanos* (Rafinesque). Spotted sucker. *M. melanos* was uncommon in the system as only three specimens were collected.


**Cyprinidae (Minnows and Carps)**

*Campostoma anomalum pullum* Agassiz. Central stoneroller. Abundant headwater stream resident occupying swift riffles.

*Notemigonus crysoleucas* (Mitchell). Golden shiner. Rare within the system. Only four specimens were collected, and these may be bait introductions.

*Notropis atherinoides* Rafinesque. Emerald shiner. The emerald shiner is uncommon in the Antoine River being largely confined to the lower stream sections where this population has free access to the larger main channel of the Little Missouri River.

*Notropis hoops* Gilbert. Bigeeye shiner. Abundant schooling cyprinid in the system. *N. hoops* was collected at 16 of 21 stations from pool regions having some flow and gravel bottoms.

*Notropis cornutus isolepis* Hubbs and Brown. Southern common shiner. We follow Miller (1968) in considering *N. cornutus isolepis* a subspecies of *N. cornutus* rather than of *N. chrysacephalus*. Although widely distributed in the system, the southern common shiner was never taken in large numbers. Confined to upper areas over gravel substrates above and below riffles and in shallow pools with moderate current.

*Notropis emilae* (Hay). Pugnose minnow. Rare. Two specimens of the pugnose minnow were collected in the lower stream regions in a backwater, vegetated pool area over organic detritus-sand mixture away from the main current.

*Notropis fumes* Everman. Ribbon shiner. Rare. Taken occasionally syntopically with *N. umbratilis*, the ribbon shiner was collected in sluggish pools over mud and sand substrates in the lower reaches.

*Notropis perpaliidus* Hubbs and Black. Peppered shiner. Previous to this study only eight specimens, six of which were collected by Myers (1977), had been taken from the Antoine River. Subsequent seineing of Station 1 at Antoine yielded 21 individuals. Specimens were taken in about three to four feet deep pool regions over sand and sand-gravel substrates with *Justicia americana* beds at the margins. Documentation of the continued existence of *N. perpaliidus* is noteworthy as this species is considered rare in Arkansas (Robison, 1974).

*Notropis umbratilis cyanocephalus* (Girard). Redfin shiner. The redfin shiner was the most abundant and widespread species in the Antoine River system having been taken at 19 of 21 stations sampled. The extremely variable habitat requirements of this species facilitates its use of the entire stream length of the Antoine River and tributaries.

*Notropis venustus* (Girard). Blacktail shiner. Rare in the system. Collected only three times, all in the lower, larger stream portions in the pools.

*Notropis whipplei* (Girard). Steelcolor shiner. Uncommon. Taken in four downstream localities in pools and regions directly downstream of riffles areas over gravel sand bottoms.

*Pimephales notatus* (Rafinesque). Bluntnose minnow. Collected only sparingly in gravel-bottomed pools of the upper and middle stream sections.

*Pimephales tenellus* (Girard). Slim minnow. Rare in the system. Myers (1977) collected just three specimens of this minnow from the main Antoine River; however, we were unable to collect it.

*Semotilus atromaculatus* (Mitchell). Creek chub. The creek chub was only collected from the uppermost small, headwater tributaries over sand, gravel and rock bottoms and then in small numbers.

**Ictaluridae (Freshwater catfishes)**


*Ictalurus natalis* (Lesueur). Yellow bullhead. The yellow bullhead was common in the system preferring areas of little or no current and vegetation (*Justicia americana*) in the upper stream reaches and avoiding the lower stream sections.


*Noturus murray* Jordan. Brindled madtom. This secretive species was collected in the lower stream sections and was in association with brush pile debris in pools with noticeable current ranging in depths of six inches to two feet over shifting sand substrates. Females taken in mid-June were full of eggs.

*Noturus grinnell* (Mitchell). Tadpole madtom. Rare. Myers (1977) reported two specimens and we collected another four individuals from Wolf and Buffalo Creeks. *N. grinnell* was never taken in sluggish backwater areas with submerged aquatic vegetation or over accumulated detritus.

*Noturus nocturnus* Jordan and Gilbert. Freckled madtom. The freckled madtom was a common ictalurid taken during the survey from riffles with gravel bottoms, accumulations of twigs, leaves and sticks,
and occasionally vegetated stream margins. *Pyodictis olivaris* (Rafinesque). Flathead catfish. This solitary species is occasionally taken on hook and line by anglers (R. Reed, pers. comm.). Anguillidae (Freshwater Eels) *Anguilla rostrata* (Lesueur). American eel. The eel is still taken occasionally on hook and line by fishermen knowledgeable with the river (R. Reed, pers. comm.). Cyprinodontidae (Killifishes) *Fundulus notatus* (Rafinesque). Blackstripe topminnow. The same ecological separation noted by Braasch and Smith (1965) was documented in this study as *F. notatus* was collected only from pools in the extreme lower portions of the Antoine River while *F. olivaceus* was more abundant in the upper and middle three-fourths of the system. The two species were never collected syntopically. *Fundulus olivaceus* (Storer). Blackspotted topminnow. The blackspotted topminnow was more common than *F. notatus* and was found throughout the upper and middle regions at stream margins and in pools away from the main current. Poeciliidae (Mosquitofish) *Gambusia affinis* (Baird and Girard). Mosquitofish. Uncommon. Confined primarily to the lower tributaries, frequenting vegetated backwaters. Atherinidae (Silversides) *Labiosthes siccarus* (Cope). Brook silverside. A common and abundant pool species occurring throughout the Antoine River system. Aphredoderidae (Pirate Perches) *Aphredoderus sayanus* (Gilliams). Pirate perch. Rare. Usually associated with vegetated stream edges (*Justicia*) and accumulations of twigs and leaves over bottoms consisting of mud and decaying organic matter in the lower reaches of the main river and Wolf Creek. Centrarchidae (Sunfishes) *Ambloplites rupestris* (Rafinesque). Rock bass. A single small specimen was taken from Station 13 from a vegetated stream margin. Local fishermen attest to its more common presence in the system. *Chaenobryttus gulosus* Cuvier. Warmouth. We follow Miller and Robison (1973) in retaining the name *C. gulosus* for the Warmouth. The warmouth exhibited a decided preference for pools with mud bottoms covered with organic debris with rooted aquatic vegetation in the lower sections. *Lepomis cyanellus* Rafinesque. Green sunfish. The green sunfish is quite widespread and abundant in the Antoine River system due to its more plastic habitat requirements. Found at 12 of the 21 stations. *Lepomis macrochirus* Rafinesque. Bluegill. Widespread and abundant in the system, especially near the confluence with the Little Missouri River where abundant cover was available. *Lepomis megalotis* Rafinesque. Longear sunfish. Most common centrarchid in the system. Taken at 17 of the 21 stations in a variety of stream habitats. *Lepomis microlophus* (Gunther). Redear sunfish. Rare. Only two specimens were collected during our survey from the lower stream sections. *Micropterus dolomieu* Lacepede. Smallmouth bass. Primarily taken in the upper, clear stream sections in pools. *Micropterus punctulatus* (Rafinesque). Spotted bass. Most common bass, found to prefer swifter stream sections than did the largemouth bass. Spawning males guarding nests were seen 19 May 1982 in Wolf Creek. *Micropterus salmoides* (Lacepede). Largemouth bass. Found in the lower, more sluggish pool regions of the system. *Pomoxis annularis* Rafinesque. White crappie. No crappie were collected during this survey, although this species was reported by Buchanan (1973). Percidae (True Perches) *Etheostoma biennisoides newmani* (Agassiz). Greenside darter. Miller (1968) did not examine specimens from the Antoine River; however, specimens from the upper Ouachita and Saline river systems were designated *E. b. newmani* as were all Arkansas populations. Preferred fast stream sections in algae covered gravel riffles and over bedrock runs in the upper sections. *Etheostoma chlorosoma*um (Hay). Bluntnose darter. Rather uncommon darter owing to its preference for sand, clay or detritus substrates in shallow pool areas. This habitat is not commonly found in the Antoine River system. *Etheostoma collettei* Birdsong and Knapp. Creole darter. Common darter in swift gravel riffles. Avoids the sluggish lower stream sections. *Etheostoma histrio* Jordan and Gilbert. Harlequin darter. Although relatively rare in our samples, *E. histrio* conformed to observations of Hubbs and Pigg (1972) by preferring detritus sand substrates to gravel areas. This limited the distribution of this species to only the lower station. *Etheostoma nigrum* Rafinesque. Johnny darter. Rare. One specimen was collected previously by Dr. G. A. Moore (pers. comm.). Not collected in our survey. *Etheostoma radionum* (Hubbs and Black). Orangebelly darter. Hubbs and Black (1941) reviewed the darters of the *whipplei* complex, this fish being considered a subspecies of *whipplei* at the time and reported specimens from the Little Missouri River system as *Poeciliichthys whipplei radionum* (*E. radionum*). A thorough study of this species is in need in Arkansas. Taken in shallow gravel riffles in lower stream sections. *Etheostoma stigmaeuma* stigmaeuma* (Jordan). Speckled darter. All Arkansas populations of the speckled darter belong to the nominate form, *E. s. stigmaeuma* (Howell, 1968). This fish was never abundant at any locality and preferred downstream areas below moderately swift riffles in about one foot of water over a gravel-sand mixed bottom. *Etheostoma whipplei* (Girard). Redfin darter. Small numbers of this percid were taken in small to large sized tributaries over sand and gravel bottoms and occasionally in brush piles. *Etheostoma zonale* (Cope). Banded darter. The banded darter was another of the rather uncommon percids confined to the lower, larger stream segments. Tsai and Raney (1974) reported banded darters in the Upper Ouachita River to average 30.3 lateral line scales. Breast scolopophorae was roughly ¾ partially scaled. Antoine River specimens were similar. Tsai and Raney (1974) designated the Ouachita River populations to conform to the Arkansas race of *E. z. zonale*. Antoine River populations are also placed in this race. *Percina caprodes* (Rafinesque). Logperch. Uncommon with only five specimens collected, all from moderate to swift deep riffles in the middle and lower stream areas. *Percina copelandi* (Jordan). Channel darter. Only four specimens of the channel darter were collected, all at Antoine (Station 1) in the main river from moderately swift deep riffle areas with algae covered gravel substrates. *Percina maculata* (Girard). Blackside darter. A single specimen of *P. maculata* has been collected from the system by Dr. G. A. Moore (pers. comm.). This species is rare due to the paucity of its preferred lowland habitat in the Antoine River system.
**Percina scierra** (Swain). Dusky darter. Common. Frequently encountered near over-hanging banks and submerged brush piles and leaf litter in the lower stream sections.

**Sciaenidae (Drums)**

*Aplodinotus grunniens* Rafinesque. Freshwater drum. Rather common in the lower pool regions and frequently taken by fishermen (R. Reed, pers. comm.).

**SUMMARY**

A total of 60 species in 29 genera representing 16 families was documented from the Antoine River, a tributary of the Little River system, by 34 field collections, previously published literature records and museum records.

In comparing the Antoine River ichthyofauna with other Ouachita Mountain streams of southern Arkansas, it is apparent that the Antoine is a moderately rich stream system. For example, the entire Little Missouri River, of which the Antoine River is a tributary, has a total of 91 fish species known from the system (Myers, 1977) while the Caddo River system, immediately to the north of the Antoine has 86 recorded species (Fruege, 1971; Dewey and Moen, 1978).

The occurrence of good populations of the rare cyprinid *Notropis perpallidus* was seen as evidence of relatively good water quality as was the presence of 12 darter species.

**ACKNOWLEDGEMENTS**

We are grateful to Mr. Richard Reed, Southern Arkansas University, for sharing his knowledge of the fishery aspects of the Antoine River. Thanks go to Dr. G. A. Moore, Oklahoma State University, for allowing the use of his personal collection from the Antoine. The senior author is extremely appreciative of Dr. Neil H. Douglas, Northeastern Louisiana University, for unlimited use of his museum records, without which such studies would be woefully incomplete.

**LITERATURE CITED**


GENERAL NOTES

TWENTY-TWO NEW SPECIES OF SPIDERS FOR THE ARKANSAS CHECKLIST

Beck and Dorris (1982) presented a preliminary study of spiders of the east central Ozark Mountain area. After recently covering the entire Ozark Mountain area, 363 species representing 33 families were found, of which 22 represent new records for the Arkansas checklist.

Several methods for collecting were used in this study, including: a) heavy duty sweep net in grasses and heavy brush, b) wire mesh sieve for leaf litter, c) hatchet, for chopping bark from trees, d) hand picking from bushes, grasses and dwellings, and other related places, e) mud-dauber nest collections to reveal paralyzed spiders captured by these Hymenopterans, f) night spot-lighting, and g) scanning wooded areas for webs. Specimens were killed and preserved in 75% ethanol. Collections were made at various hours to ensure a broad coverage of spider habits. Also, to insure a broad coverage of the Ozark Mountain area, ten check stations were established and sampled from February 1979 through July 1982. Each station was checked four or more times during the period to ensure representative sampling; two sub-stations were inspected one to three times.

Taxonomic names used are those employed by Comstock (1972), and Kaston (1948, 1978). The table summarizes 1) county in which collected, 2) date collected, 3) method of capture, 4) habitat association, and 5) specific site of collection.

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General Notes

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Method Code-------- P--Hand Picked  SN--Sweep Net

LITERATURE CITED


MARY L. BECK and PEGGY R. DORRIS, Department of Biological Sciences, Henderson State University, Arkadelphia, AR 71923.
RANGE EXTENSION OF THE SILVER CARP, Hypophthalmichthys molitrix

The silver carp, Hypophthalmichthys molitrix (Valenciennes), is listed as an exotic fish formerly established or of local occurrence (Robin, C. R., R. M. Bailey, C. E. Bond, J. R. Brooker, E. A. Lachner, R. N. Lea, and W. B. Scott. 1980. A List of Common and Scientific Names of Fishes from the United States and Canada. 4th Ed. Am. Fish. Soc. Sp. Pub. No. 12 p. 96). Single specimens were taken from the Ohio River below Smithland Dam on April 7, 1982 (B. McLemore, pers. comm.), from the Ohio River below Union Town Dam on February 19, 1982 (D. Bell, pers. comm.) and from a small channel between Wham Brake and LaFourche Canal Systems in Ouachita Parish, Louisiana on April 1, 1981 (J. Hughes, pers. comm.). On June 8, 1982, a single 4.1 kg specimen was collected in a trammel net by R. E. Lee, a commercial fisherman from Tomato, Arkansas, and deposited in the Arkansas State University Fish Collection (no. 9383). The specimen was an adult female, 70 cm in total length; it possessed 8 dorsal fin rays, 15 anal fin rays, 16 pectoral fin rays, 8 pelvic fin rays, and 109 scales in the lateral line.

This female specimen represents the first definite record of H. molitrix occurring in the Arkansas water of the Mississippi River, at river mile 804. Its previous distribution was reported to be limited to the Arkansas and White River Systems (Freeze, M. and S. Henderson. 1982. Distribution and Status of the Bighead Carp and Silver Carp in Arkansas. N. Am. Jour. Fish. Mgr. 2:197-200).

F. ALLEN CARTER, Arkansas Game and Fish Commission, No. 2 Natural Resources Drive, Little Rock, AR 72205. JOHN K. BEADLES, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

SICKLEFIN CHUB, Hybopsis meeki, IN THE MISSISSIPPI RIVER BORDERING ARKANSAS

The sicklefin chub, Hybopsis meeki Jordan and Evermann, was collected December 29, 1980 in the Mississippi River bordering Arkansas at river mile 813.0, 15 river miles downstream from the Arkansas-Missouri state line. H. meeki was first reported in the Missouri River near St. Joseph, Mo. in 1884 (Pflieger, 1975). Also, Cross and Collins (1975) reported it rare in Kansas and collected only following floods on a few occasions. Conner and Guillory (1974) reported the Mississippi River range to extend downstream to the vicinity of Vicksburg, Mississippi. Additional specimens of H. meeki have been reported from Iowa, Nebraska and South Dakota (Moore, 1968).

The two specimens reported here were collected on a very cold, windy day by Allen Carter, Tom Buchanan, and Sam Henry. They were collected with a 3.2 mm mesh nylon seine and have been deposited in the Arkansas State University Museum of Zoology. One specimen was caught near the bottom in moderate current at depths of 0.5 to 1.5 m at approximately noon. The water temperature was approximately 2 °C. Both specimens were juveniles measuring 3.4 and 2.9 cm in total length, 2.5 and 2.2 cm in standard length. They had 8 dorsal fin rays, 8 anal fin rays, 14 pectoral fin rays, 7 pelvic fin rays, and 43 and 41 scales in the lateral line. These two specimens represent the first definite records of H. meeki for the Arkansas water of the Mississippi River. They had a variety of feeding habits and reproductive habits. The mouth has many taste buds and it is believed that food is sorted from water bottom material that is taken indiscriminately (Davis and Miller, 1967). Pflieger (1975) reports that young have been found in the Missouri River during July, suggesting a spring spawning season.

Other fishes collected with the sicklefin chub included: rainbow smelt Osmerus mordax (Mitchill), speckled chub Hybopsis aestivalis (Girard), silver chub Hybopsis storeriana (Kirtland), emerald shiner Notropis atherinoides Rafinesque, river shiner Notropis blennius (Girard), silverback shiner Notropis shumardi (Girard), and bluegill Lepomis macrochirus Rafinesque. The authors wish to thank Dr. Henry W. Robison of Southern Arkansas University, for his verification of the specimens.

LITERATURE CITED


F. ALLEN CARTER, Arkansas Game and Fish Commission, No. 2 Natural Resources Drive, Little Rock, AR 72205, and JOHN K. BEADLES, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

PRAIRIE PHENOLOGY AND SEED GERMINATION

One of the more striking features of a prairie is the ever changing display of flowers amid the majestic grasses providing each season with new brilliance and delicate beauty until frost and winter when the bronze-colored grasses dominate the landscape. These cyclic phenomena are determined by environmental factors such as water and temperature. As flowers bloom, fruits develop and seeds mature, plant material diminishes and falls to the ground adding to the leaf litter where fungi and bacteria hasten decay in returning nutrients to the soil for reuse by still other prairie flora. Not only is there constant change in the vegetation, but the fauna associated with the prairie ecosystem are likely to come and go according to their various cycles; the vole, the quail, the rabbit and many birds add life to this biome.

This study was conducted in conjunction with the ongoing prairie restoration project of the 1.5 hectare field within the Jewel E. Moore Nature Reserve located on the University of Central Arkansas campus in Conway. (Data more accurately describing this prairie site can be found in: Wright...
& Culwell, Early stages of prairie restoration on a 1.5 hectare field in Faulkner Co., Ark., Proc. Ark. Acad. Sci. 36:80-81, 1982. Following a late winter fire, early spring is heralded on this prairie by the blooming of such plants as bluet (Houstonia pusilla), prairie ragwort (Senecio jacobaea), Indian paintbrush (Castilleja coccinea), and lance-leaved violet (Viola lanceolata). Late spring produces flowers of self-heal (Prunella vulgaris), Sampson's snakeroot (Pсорalea pisoroides), wild garlic (Allium canadense var. mobilense) and milkwort (Polygala sanguinea). The profusion of spring colors subsides a bit as summer arrives with the blooming of wild petunia (Ruellia humilis), hoary pen (Tephrosia anomophyloides) and black-eyed susan (Rudbeckia hirta). Mid summer finds the more subdued rattlesnake master (Eryngium yuccifolium), as well as the more stately and brilliant ironweed (Vernonia missurica), button snakeroot (Liatris pycnostachya) and ashy sunflower (Helianthus mollis) in bloom. Fall colors are dominated by the white heath aster (Aster pilosus), the big blue lobelia (Lobelia puberula) and the yellow of narrow-leaf sunflower (Helianthus angustifolius). This progression of seasonal flower development will vary in years when there is less regular rainfall and periodic drought. The Figure shows seasonal flower development for most of the flowering plants exclusive of the grasses and sedges on the Nature Reserve Prairie (only Castilleja coccinea was introduced during restoration); timing of bloom may vary tremendously as one can note when comparing this seasonal development in 1982 with that recorded for the Roth and Konecny Prairies in 1976 (Irving & Brenholts, An ecological reconnaissance of the Roth and Konecny Prairies. Prepared for Ark. Nat. Her. Com., 1977).

### General Notes

& Culwell, Early stages of prairie restoration on a 1.5 hectare field in Faulkner Co., Ark., Proc. Ark. Acad. Sci. 36:80-81, 1982. Following a late winter fire, early spring is heralded on this prairie by the blooming of such plants as bluet (Houstonia pusilla), prairie ragwort (Senecio jacobaea), Indian paintbrush (Castilleja coccinea), and lance-leaved violet (Viola lanceolata). Late spring produces flowers of self-heal (Prunella vulgaris), Sampson's snakeroot (Pсорalea pisoroides), wild garlic (Allium canadense var. mobilense) and milkwort (Polygala sanguinea). The profusion of spring colors subsides a bit as summer arrives with the blooming of wild petunia (Ruellia humilis), hoary pen (Tephrosia anomophyloides) and black-eyed susan (Rudbeckia hirta). Mid summer finds the more subdued rattlesnake master (Eryngium yuccifolium), as well as the more stately and brilliant ironweed (Vernonia missurica), button snakeroot (Liatris pycnostachya) and ashy sunflower (Helianthus mollis) in bloom. Fall colors are dominated by the white heath aster (Aster pilosus), the big blue lobelia (Lobelia puberula) and the yellow of narrow-leaf sunflower (Helianthus angustifolius). This progression of seasonal flower development will vary in years when there is less regular rainfall and periodic drought. The Figure shows seasonal flower development for most of the flowering plants exclusive of the grasses and sedges on the Nature Reserve Prairie (only Castilleja coccinea was introduced during restoration); timing of bloom may vary tremendously as one can note when comparing this seasonal development in 1982 with that recorded for the Roth and Konecny Prairies in 1976 (Irving & Brenholts, An ecological reconnaissance of the Roth and Konecny Prairies. Prepared for Ark. Nat. Her. Com., 1977).

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<td><em>Hoary pen</em></td>
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<td><em>Rudbeckia hirta</em></td>
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<tr>
<td><em>White heath aster</em></td>
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<tr>
<td><em>Big blue lobelia</em></td>
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<td><em>Narrow-leaf sunflower</em></td>
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</tr>
</tbody>
</table>

**Figure. Seasonal flower development of 1982.**

Restoration of the Jewel E. Moore Nature Reserve Prairie and the Prairie on Interstate 40 at Conway (Wright & Culwell, 1982) has involved mass sowing of seed. Seed of prairie species not present on the restoration sites or those present in only small numbers was collected in the fall of 1982 from Arkansas sites of railroad prairies between Hazen and Carlisle, and Conway and Mayflower. In an effort to assess what germination and growth can be expected during this growing season of 1983, germination tests were run on both stratified and unstratified seed. With the exception of five species, a four-week stratification period increased the percentage of germination of twenty species. This work was supported by a UCA faculty research grant.

**DONALD E. CULWELL and ROBERT WRIGHT, Department of Biology, University of Central Arkansas, Conway, AR 72032.**

### SPIDERS COLLECTED FROM ABANDONED MINE TUNNELS IN THE OUACHITA NATIONAL FOREST

Although much attention has been given to the caves of Arkansas, Dunivan et al. (1982), McDaniel et al. (1979), McDaniel and Smith (1976), Grove (1974), Barnett (1970), Hubricht (1950), few scientific efforts have been made to document the fauna of mine tunnels. In this study, six species representing four genera of spiders were collected from abandoned silver, gold and manganese mine tunnels in Garland, Montgomery and Polk counties within the boundary of the Ouachita National Forest, Arkansas, from December 1982 to March 1983 (Table). Spiders were collected from tunnels that varied from 10 to 150 meters in length, 2 to 3 meters in height and 1 to 2 meters in width. Temperatures averaged 15.5 degrees Centigrade and rarely varied. All of the tunnels contained seepage areas which provided enough moisture to maintain humidity near 100 percent and several of the tunnels received enough seepage to have small streams flowing from their entrances throughout the study period. The amount of organic debris found in these tunnels was variable, usually consisting of a small accumulation of leaves and/or crosties and wooden tunnel supports. Specimens were collected by standard methods and put directly into vials containing 70 percent alcohol and transported to the laboratory for identification.

The spiders of the genus _Dolomedes_ are referred to as the “fishing spiders” and in each case these spiders were found where pooled water occurred in the tunnels. They were often observed poised directly above the waterline of these pools and were apparently catching aquatic insects which were seen utilizing pool areas. These spiders do not construct webs.

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**Arkansas Academy of Science Proceedings, Vol. XXXVII, 1983 81**
Arkansas Academy of Science

*Achaearanea* and *Prolinphyia* species are web builders that were found hanging in their webs at the top and along the walls of the tunnels apparently trying to trap small flying insects. Specimens of *Achaearanea porteri* (Banks) collected during this study represent the only known locality for this spider from the Ouachita Mountain area and only the second collection of this species in the state. Interestingly, the only other report of this spider from Arkansas was by Barnett (1970) who found this species utilizing similar habitat within Mansell Cave in Randolph county.

Members of the genus *Amaurobius* were found primarily under stones and in rock fissures or wall crevices. Dark areas of the tunnels near the entrances were preferred. Specimens of *Amaurobius ferox* (Walckenaer) collected during this study represent a new state record.

Assistant from Darrell Heath and Teresa Beggs in collecting specimens is gratefully acknowledged.

<table>
<thead>
<tr>
<th>Taxon</th>
<th>Date</th>
<th>County</th>
<th>Distance in Meters from Entrance</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Amaurobius ferox</em> (Walck.)</td>
<td>12/20/82</td>
<td>Garland</td>
<td>0-8</td>
</tr>
<tr>
<td><em>Dolomedes vittatus</em> (Walck.)</td>
<td>1/08/83</td>
<td>Polk</td>
<td>0-8</td>
</tr>
<tr>
<td><em>Achaearanea porteri</em> (Banks)</td>
<td>1/18/83</td>
<td>Garland</td>
<td>0-8</td>
</tr>
<tr>
<td><em>Amaurobius ferox</em> (Walck.)</td>
<td>2/20/83</td>
<td>Garland</td>
<td>17-50</td>
</tr>
<tr>
<td><em>Prolinphyia margarita</em> (Walck.)</td>
<td>2/20/83</td>
<td>Garland</td>
<td>0-8</td>
</tr>
<tr>
<td><em>Achaearanea tepidodisca</em> (Walck.)</td>
<td>2/20/83</td>
<td>Garland</td>
<td>0-8</td>
</tr>
<tr>
<td><em>Amaurobius ferox</em> (Walck.)</td>
<td>2/20/83</td>
<td>Montgomery</td>
<td>0-8</td>
</tr>
<tr>
<td><em>Dolomedes vittatus</em> (Walck.)</td>
<td>2/20/83</td>
<td>Montgomery</td>
<td>0-20</td>
</tr>
<tr>
<td><em>Amaurobius ferox</em> (Walck.)</td>
<td>2/12/83</td>
<td>Polk</td>
<td>0-50</td>
</tr>
<tr>
<td><em>Dolomedes vittatus</em> (Walck.)</td>
<td>2/11/83</td>
<td>Polk</td>
<td>0-50</td>
</tr>
<tr>
<td><em>Dolomedes tenebrosus</em> (Hentsch.)</td>
<td>3/26/83</td>
<td>Polk</td>
<td>0-10</td>
</tr>
<tr>
<td><em>Dolomedes vittatus</em> (Walck.)</td>
<td>3/26/83</td>
<td>Polk</td>
<td>0-10</td>
</tr>
<tr>
<td><em>Amaurobius ferox</em> (Walck.)</td>
<td>3/28/83</td>
<td>Polk</td>
<td>0-10</td>
</tr>
</tbody>
</table>

LITERATURE CITED


PEGGY R. DORRIS, Department of Biology, Henderson State University, Arkadelphia, AR 71923, and DAVID A. SAUGHEY, United States Forest Service, Hot Springs, AR 71901.

FLAT PLATE SOLAR THERMAL COLLECTORS: A COMPARISON OF EFFICIENCIES OF VARIOUS COLLECTOR CONFIGURATIONS

In a previous study, collectors were installed vertically in a south-facing single glazed laboratory window. The dual functions were as a thermal solar collector and as an insulator for the window. Results included an energy saving from the insulation property of approximately 19 dollars per year and an experimental solar energy collection income of approximately 2 dollars per year (Eichenberger, Energy Conv. & Mgt., 20:197-199, 1980).

The purpose of this study was to compare the efficiencies, energy collected, and construction cost for various practical collector configurations and materials.

The inside configuration and materials used in converting solar radiation to heat energy were varied for comparison. Cover plate materials were also varied for comparison. Materials tested were relatively inexpensive building materials suitable for self-construction and installation. The material cost per thermal power delivered (watt) was also calculated since this is an important consideration in solar utilization.

Two solar collectors were constructed to provide a side-by-side test situation. The collectors were both 1.22 meter by 1.22 meter outside dimensions. One collector served as the control and the other as the experimental model on which the internal materials and cover plates were changed. Solar insulation was measured with a meter which was calibrated using a reference source on the same date and time extrapolated for the same latitude (Anderson, Solar energy; fundamentals in building design, p. 192, 1977). Each collector was fitted with an electric blower rated at 16 watts and 0.99 cubic meter per minute of free air; it delivered a measured 0.42 cubic meter per minute of air flow when connected to the collector. The flow rate of the blower was measured with a Dwyer flow meter. This measured rate was compared with a mechanical anemometer and a fan. Results of the two flow rate measurements were within 5%. Ambient temperatures and output air temperatures were measured. Heat delivered was calculated and the input solar energy was measured with the meter and used in calculating the efficiencies.

In the first stage of the experiment, both collectors were fitted with identical double-glaze polycarbonate covers. The inside absorber configurations were changed for comparison of efficiencies and thermal power produced. The control collector had aluminum screen placed 2.5 centimeters above a styrofoam insulation board in the back. Both the aluminum screen and the insulation board were painted flat black with inexpensive carbon and silicate-based paint. Air was forced from the back through the screen toward the cover plate, and then pulled back through the screen absorber by a fan and a baffle and out the back (see Fig. 1). The experimental collector was also fitted with a 2.5 centimeter thick styrofoam insulation panel covering the back. Then 2.5 centimeter high styrofoam channels were attached to the insulation board. These channels were designed to produce a serpentine air flow across the collector (see Fig. 2). The entire board and channels were covered with aluminum foil and
General Notes

Figure 1.

Table 1. Interior Light to Heat Conversion Materials with Identical Double Glaze Polycarbonate Covers

<table>
<thead>
<tr>
<th>Material</th>
<th>Average Efficiency</th>
<th>Average Thermal Power/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Aluminum Screen</td>
<td>352</td>
<td>237 watts ± 5 watts</td>
</tr>
<tr>
<td>Black Aluminum Foil Channeled</td>
<td>323</td>
<td>205 watts ± 5 watts</td>
</tr>
<tr>
<td>Black Aluminum Screen</td>
<td>352</td>
<td>194 watts ± 5 watts</td>
</tr>
<tr>
<td>Black Steel Roofing</td>
<td>243</td>
<td>129 watts ± 5 watts</td>
</tr>
</tbody>
</table>

* Indicates control collector unit operating during the same time period.

Table 2. Various Cover Plates with Identical Interior Black Aluminum Screen Absorbers

<table>
<thead>
<tr>
<th>Material</th>
<th>Average Efficiency</th>
<th>Average Thermal Power/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Double Glaze Polycarbonate</td>
<td>371</td>
<td>237 watts ± 5 watts</td>
</tr>
<tr>
<td>Single Glaze Styrene Acrylonitrile</td>
<td>291</td>
<td>183 watts ± 5 watts</td>
</tr>
<tr>
<td>Double Glaze Polycarbonate</td>
<td>352</td>
<td>194 watts ± 5 watts</td>
</tr>
<tr>
<td>Single Glaze Filon</td>
<td>281</td>
<td>172 watts ± 5 watts</td>
</tr>
</tbody>
</table>

* Indicates control unit.

The second experimental configuration was assembled with corrugated steel roofing painted flat black as the absorber plate. Air was made to flow over the top of the roofing and between the styrofoam insulation board.

The second part of the experiment compared different materials commonly available as cover plates with identical flat black aluminum screen absorbers as described earlier.

A materials cost analysis was done for each collector configuration to find the cost per unit of thermal power delivered. The analysis excluded labor costs. The results are displayed in Table 3.

Flat black aluminum screen absorber delivered the highest conversion from solar light to heat efficiency of about 35% and the highest average thermal power of about 240 watt/m². Double glazed polycarbonate was the most efficient cover plate, as expected, and delivered the highest thermal power. Of the single glazed material tested, styrene acrylonitrile delivered slightly higher efficiency and thermal rating. Collector efficiencies were higher on lower ambient temperature days, as one would expect, because of radiation energy losses from the collector proportional to the fourth power of the absolute temperature and lower collector temperatures on those days. Results were averaged over a minimum of five days to reduce these variations, and values reported in Tables 1 and 2 compared experimental with control units during the same time period.

The materials cost per delivered unit of thermal power was lowest for the single glazed filon cover plate at about 15¢/watt with the black aluminum screen absorber material.
Further study is planned using polyethylene film as one glazing and a rigid material such as film as the second glazing to cut costs and increase the effectiveness, therefore promoting the utilization of solar energy.

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NEUTRAL SUGARS IN SELECTED PIT VIPER, ELAPID, LIZARD AND SCORPION VENOMS

Carbohydrates exist in venoms in the form of glycoproteins and as free sugars. Aragon et al. (1977) reported that venom from the Central American Bothrops asper is very rich in both glycoproteins and free sugars. Glycoproteins are reported in a wide variety of snake venoms (Oshima and Iwanga, 1969; Basu et al., 1970; Hutton, 1973; Ruff et al., 1980; Marlas, 1982). Viperid and crotalid venoms often contain relatively large amounts of bound carbohydrates when compared with venoms of elapid snakes. These carbohydrates include neutral sugars, amino sugars, and sialic acid (Oshima and Iwanga, 1967). In this paper we quantitatively compare L-fucose, D-galactose, D-glucose, and D-mannose neutral sugars of whole venoms from snakes, lizards, and scorpions. The venoms were also analyzed for the presence of D-arabinose and D-xylene.

L-Fucose and tyrophilized venoms of Agkistrodon bilineatus, Heloderma horridum, H. suspectum, Androctonus australis, and Naja naja atra were purchased from Sigma Chemical Company. The other venoms, also tyrophilized, were a gift from Dr. H. L. Stahnke of the Poisonous Animals Research Laboratory at Arizona State University. The other carbohydrate standards were purchased from Chem Service, Inc.; 1-dimethylamino-2-propanol from Aldrich Chemical Company; methanol from MCB Manufacturing Chemists, Inc.; and pyridine from Fisher Scientific Company. All liquid reagents were redistilled prior to use.

Gas chromatography was performed using a Perkin-Elmer Model 3920B instrument equipped with dual flame ionization detectors and 6-ft., 1/8-in.-o.d. nickel columns packed with 1% stabilized diethylene glycol adipate on 100-200 mesh Chromosorb W (HP) by the procedure described by Mawhinney et al. (1980). Data were collected, stored, and analyzed by a Varian Vista 401 Chromatography Data System.

Neutral sugars were obtained by heating 2 to 4 mg samples of venom with 1.0 ml of 0.6 N HCl per mg of venom at 100° for 4 h and eluting in sequence through a 0.8 x 8-cm column of Dowex 1-4X (CO2- form, 50-100 mesh) and Dowex 50-X8 (H+ form, 200-400 mesh) with distilled H2O. One ml of internal standard solution containing 0.0186 mg of phenyl-β-D-glucopyranoside was added to the effluent before the sample was concentrated by lyophilization. To convert neutral sugars to oximes, the effluent was mixed with 0.2 ml of a solution containing 0.6 g of hydroxylamine hydrochloride, 2.0 ml of methanol, 5.47 ml of pyridine, and 0.53 ml of 1-dimethylamino-2-propanol and heated at 70° for 5 min in a Teflon-capped Reacti-vial. After cooling to room temperature, a stream of dry air was directed into the open vial to remove excess reagent. Acetate derivatives were prepared by adding 1.0 ml of pyridine-acetic anhydride (1:3 v/v), mixing, and heating the vial at 70° for 25 min. The vial was cooled to room temperature, after which the solution was diluted to a reduced volume using a stream of dry air. To remove salts, the contents were dissolved in 1.0 ml of chloroform and washed once with 1.0 ml of 1.0 N HCl and three times with 1.0 ml of distilled water. The chloroform layer was evaporated with a stream of dry air (Mawhinney et al., 1980). For conversion to adononitrile acetate (Varmer, et al., 1973), 0.6 ml of pyridine and 1.8 ml of acetic anhydride were added and the mixture was heated at 90° for 30 min. The solution was evaporated to dryness at 40° under diminished pressure with a stream of nitrogen directed into the vessel.

Neutral sugars are present in pit viper, elapid, lizard, and scorpion venoms (Table). D-arabinose and D-xylene were not detected in venoms of Crotaulus molossus, C. scutulatus, and N. naja. Only trace amounts, less than 1 mg per mg of venom, of these sugars were indicated in the other venom analyses. Venom of A. piscivorus piscivorus was relatively low in D-mannose. Otherwise, pit viper venoms contained abundant D-mannose, comparable amounts of L-fucose and D-galactose, and relatively small amounts of D-glucose. A. bilineatus venom was highest in all the sugars assayed, except D-glucose. D-mannose was not the major sugar in the elapid venom tested; however, D-mannose was dominant in the lizard venom. Centruroides sculpturatus venom was higher in total neutral sugar than the other scorpion venoms.

A significant unidentified peak (Fig.), probably indicating another neutral sugar, was recorded immediately prior to the D-mannose peak in the chromatograms of A. p. piscivorus, C. atrox, N. naja, and N. n. atra venom samples. This peak was minor or absent in the remaining chromatograms. Small unidentified peaks were also recorded immediately prior to the L-fucose peak.

Sialic acid and amino sugar analyses of the above venoms are now in progress.

Table. Neutral Sugars in Various Venoms*†

<table>
<thead>
<tr>
<th>Venom</th>
<th>l-Fucose</th>
<th>L-Arabinose</th>
<th>L-Xylene</th>
<th>L-Galactose</th>
<th>L-Glucose</th>
<th>L-Mannose</th>
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<td>2.3</td>
<td>6.8</td>
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<td></td>
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<tr>
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<td>Centruroides sculpturatus</td>
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<td>2.0</td>
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<td>Heloderma horridum</td>
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<td>Heloderma suspectum</td>
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<td>2.0</td>
<td>2.0</td>
<td>6.8</td>
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<td></td>
</tr>
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</table>

* mg of sugar/mg of venom
† trace indicates < 1.0 mg of sugar/mg of venom

Figure. Gas chromatographic separation of neutral sugars from C. atrox venom as adononitrile acetates. The initial hold was at 170° for two minutes followed by an increase of 8°/min to a final temperature of 240°. Nitrogen flow rate was 24 ml/min and sample size was 4 μl.

http://scholarworks.uark.edu/eaas/vol37/iss1/86
REPAIR OF ULTRAVIOLET AND GAMMA-RAY INDUCED LETHAL DAMAGE IN AN INSECT TISSUE CULTURE CELL LINE* 

We have recently performed a series of preliminary radiation experiments which indicate that the IPL-22 insect tissue culture cell line constitutes another fruitful system for study of the roles played by intracellular repair mechanisms in the radiation resistance of eukaryotic cells. The effects of repair processes on the kinetics of ultraviolet (UV) and gamma-ray induced cell killing (loss of colony forming ability) are briefly described here.

The IPL-22 line was cloned from the IPL-21 insect line (Spodoptera frugiperda), which was obtained from Dr. Troy Orr of the Southwest Foundation for Research and Education in San Antonio, Texas. The line was routinely maintained in IPL-41 medium (Kansas City Biological) in plastic tissue culture flasks (Falcon). Log phase monolayer cultures with plating efficiencies near 0.70 were selected for each experiment. All experimentation was carried out at 26 degrees Celsius. Gamma-ray was administered with a custom designed Mark IV Cesium 137 irradiator at a dose rate of 40 rads/minute. Techniques employed for UV irradiations, photoreactivation (PR), cell fusions, caffeine treatments, single cell plating of treated cells, incubations, and survival determination (assays for colony forming ability) were essentially the same as those described previously for Xenopus cells (Griggs and Whorton, 1973; Griggs and Orr, 1979; Haetten, McGuinness and Griggs, 1982).

The UV Ld, (lethal dose to 50 percent of the cells) for IPL-22 cells can be estimated from the UV-alone data of Figure 1 to be near 200 ergs/mm², indicating a significantly higher resistance to the lethal effects of UV than that observed for established vertebrate tissue culture lines such as the AE Xenopus line (LD₅₀ near 60 ergs/mm²) and the V79 hamster line (LD₅₀ near 75 ergs/mm²) (Griggs and Bender, 1972). The UV-alone data (Figure 1) constitute a sigmoid or threshold curve, suggesting a multihit single target, multtarget single hit, or multtarget multitarget relation (Elkind and Whorton, 1967). However, as indicated by the UV + caffeine data of Figure 1, caffeine significantly alters the UV curve by reducing the shoulder or threshold segment. These data suggest that the threshold results, at least in part, from the operation of a caffeine sensitive intracellular repair mechanism, perhaps similar to the caffeine sensitive recombination-like repair mechanism observed in V79 hamster cells (Cleave, 1974; Haetten et al., 1982).

IPL-22 cells photoreactivate a small fraction of the lethal damage induced by UV doses in the range 0-400 ergs/mm² (Figure 2). Direct enzymatic repair is indicated, since the reactivation light effectively diminishes the UV dose (Rupert and Harn, 1966). It is interesting that IPL-22 cells do not appear to possess an efficient PR mechanism, as do many microorganisms (Rupert and Harn, 1966) and some vertebrate cells (Griggs and Bender, 1972).

The gamma-ray survival curve for IPL-22 cells also indicates a threshold response with an Ld₅₀ near 1000 rads (gamma-ray alone points, Figure 3). This is a rather marked resistance to the lethal effects of gamma-ray as compared to the resistance shown by established mammalian cell lines (Elkind and Whorton, 1967). The observed increase in resistance to a given dose when the dose is fractionated (Table 1) suggests that gamma-ray resistance is due in part to the operation of a dark repair mechanism, perhaps similar (or identical) to “Elkind recovery” (Elkind and Sutton, 1960).

Two experiments were then carried out to explore overlap of UV and gamma-ray induced lethal lesions. As indicated by the UV + gamma data of Figure 3, UV exposures in the 0-40 ergs/mm² range actually reactivate some of the lethal damage induced by 500 rads of gamma-ray. This UV reactivation (UVR) appears to be similar to that observed in Xenopus cells (Cross and Griggs, 1978). Higher doses of UV have an additive, or perhaps synergistic, effect with gamma-ray. The data of Table 2 are results of an attempt at what could be termed “fusion reactivation” (FR). The synkaryons, produced by fusion of UV-irradiated parental cultures with gamma-irradiated parental cultures, exhibited a higher level of survival than either of the parental cultures (Experiment 3, Table 2). This “Reactivation” may result from a type of genomic complementation in which each viable synkaryon contains at least one undamaged copy of the essential genetic units. However, further investigation of the growth characteristics of viable synkaryons may indicate a more complex mechanism, perhaps involving some type of enzymatic repair.

The data described here indicate that a significant part of the radiation resistance exhibited by IPL-22 insect cells is due to the functioning of dark (non PR) radiation repair mechanisms. These dark mechanisms appear to function more efficiently than similar repair mechanisms.

*Research supported by PHS Grant number CA-18809-07 awarded by NCI.
Figure 1. Survival of IPL-22 cells which were exposed to UV and then incubated in IPL-41 medium (circles) or IPL-41 medium containing 0.0008 moles/liter caffeine (triangles).

Figure 2. Survival of IPL-22 cells following UV (circles) and UV + PR light (3 x 10^5 ergs/mm^2) exposures.

Figure 3. Survival of IPL-22 cells following gamma-ray (circles) and gamma-ray + UV (triangles) exposures.

Table 1. Survival of IPL-22 cells following a gamma-ray exposure of 600 rads, administered in two fractions as indicated.

<table>
<thead>
<tr>
<th>First fraction (rads)</th>
<th>Second fraction (rads)</th>
<th>Interfraction time (hours)</th>
<th>Surviving fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>600</td>
<td>300</td>
<td>0.5</td>
<td>0.65</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
<td>0.5</td>
<td>0.66</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
<td>1.0</td>
<td>0.76</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
<td>1.5</td>
<td>0.80</td>
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<tr>
<td>300</td>
<td>300</td>
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<tr>
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<td>300</td>
<td>3.0</td>
<td>0.76</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
<td>4.0</td>
<td>0.70</td>
</tr>
<tr>
<td>300</td>
<td>300</td>
<td>5.0</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Table 2. Survival of IPL-22 cells which were exposed to UV or gamma-ray compared with survival of hybrid cells which were produced by fusion of UV exposed cells with gamma-ray exposed cells.

<table>
<thead>
<tr>
<th>Experiment number</th>
<th>Description of cultures used</th>
<th>Treatment of cultures</th>
<th>Survival fraction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 x 10^6 log phase cells in monolayer</td>
<td>UV and the cells were plated for colony assay</td>
<td>0.65</td>
</tr>
<tr>
<td>2</td>
<td>1 x 10^6 log phase cells in monolayer</td>
<td>cells were exposed to 1000 rad</td>
<td>0.66</td>
</tr>
<tr>
<td>3</td>
<td>1 x 10^6 cells in monolayer which had been exposed to 1000 rad and 10^7 cells in monolayer which had been exposed to 2000 rad</td>
<td>photoassay and the cells were plated for colony assay</td>
<td>0.76</td>
</tr>
<tr>
<td>4</td>
<td>1 x 10^6 cells in monolayer which had been exposed to UV</td>
<td>0.70</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1 x 10^6 cells in monolayer which had been exposed to UV and the cells were plated for colony assay</td>
<td>0.70</td>
<td></td>
</tr>
</tbody>
</table>

possessed by many vertebrate cells. To explore further relations between insect and vertebrate radiation repair mechanisms, we plan to study the extent and nature of interactions of insect and mammalian repair mechanisms, using mammalian-IPL-22 hybrid cell lines.

LITERATURE CITED


A PRELIMINARY REPORT ON THE ZYGOPtera (DAMSELFIES) OF Arkansas

Adams (1900) published the first list of Arkansas Odonata, reporting seven damselfly species. Subsequent papers (Needham and Heywood, 1929; Bick, 1959; and Houston, 1967) increased the species list to 18. Bick (1978) was apparently unaware of Houston’s (1970) paper and restated the species list (Table 2). This study provides a list for Arkansas damselfly species, their known flight seasons, and their distributions by county. Adults of most species occurring or possibly occurring in Arkansas can be identified using the keys of Johnson (1972). The exceptions, several Lestes species and Enallagma aspersum, are included in Walker’s (1953) keys.

The data presented are a compilation of the contributions of all sources listed in the Acknowledgements, pertinent published records, and materials collected by myself. The museum collections at the University of Arkansas-Fayetteville and Little Rock were visited.

Treatment of captured specimens was as follows. While still alive, specimens were placed in paper triangles with wings in the normal resting position and heads rotated 90° to the left. The triangles were placed in science-grade acetone for a period of 18-24 hours. These may remain in acetone for up to five days with no detrimental effects. Next, each specimen was removed from the acetone, dried, identified, and transferred to a cell envelope with a 3 x 5 inch data card. These curatorial methods are advantageous in that they better preserve many colors than does air drying, storage space is minimized, and, since each envelope contains but one specimen, association of parts after breakage is facilitated.

Thirty-three damselfly species are currently recorded for Arkansas. The flight season for most of these extends from spring through summer months, and for many species persists into mid-autumn (Table 1). Temperature appears to be a major factor controlling their emergence. Some species vary from this generalization, however. Enallagma divagans seems to be a spring to early summer species, as was noted by Johnson (1972). Hetaerina tilia in Arkansas appears in midsummer and flies through early autumn. Johnson (1972) stated that it is characteristically a spring form in central Texas. Species of Lestidae are highly adapted for life in temporary waters, and many have a diapause in the egg (Corbet, 1962). This imposes a characteristic massed, synchronized emergence on the species, followed by a relatively short flight period. Lestes disjunctus australis has an extended flight season in Arkansas, but L. inequalis and L. rectanguliris are spring flyers, while Archilestes grandis adults are present during the late summer and autumn (Table 1).

Twenty-four Arkansas damselfly species (73%) are of the Eastern United States or Eastern U.S.-Tropics fauna, and seven species (21%) are Transcontinental or Transcontinental-Tropic in distribution. They are therefore likely to be found in any Arkansas county, provided suitable habitat is present. Ischnura posita and Anomalagrion hastatum are the most common forms, having been recorded in 69 and 54 counties, respectively (Table 2). These two species can be found in association with a variety of aquatic ecosystems, and they apparently have a wide range of tolerance for several environmental parameters.

Ischnura ramburii and I. verticalis are two species of the Eastern U.S. which reach a geographic limit in Arkansas. I. ramburii has been reported from Louisiana, Mississippi, Texas and Oklahoma, but not from Kansas, Missouri or Kentucky (Bick, 1957; Bick and Bick, 1957; Montgomery, 1967; Johnson, 1972; Huggins et al., 1976; Lago and Stanford, 1979). Its Arkansas distribution reflects that situation in that 19 of the 21 counties from which it is recorded are in the southern half of the state. Seemingly disjunct populations in Craighead and Washington Counties are the exceptions. I. verticalis has been reported from north of a line connecting Lake Texoma (Oklahoma-Texas state line) with extreme northeast Tennessee (Bick, 1957; Bick and Bick, 1957; Montgomery, 1967; Johnson, 1972; Huggins et al., 1976; Lago and Stanford, 1979; Johnson and Coney, 1980). Its Arkansas distribution concurs with those data, as the 10 counties listed are northe-central and northwestern.

Argia plana apparently has a limited Central U.S. distribution, as it has only been reported from Texas, Oklahoma, Kansas and Missouri (Bick, 1957; Montgomery, 1967; Johnson, 1972; Huggins et al., 1976). Ten of the 11 Arkansas county records for this species are in the northern quarter of the state. Four of the six county collections made by me were from springs or spring-fed streams. I have not been able to determine the specific habitat for the remaining five county collections. Huggins et al. (1976) listed four of their seven county collections for this species in Kansas as being from springs.

Argia imunda has been reported from only Mexico, Texas and Oklahoma (Bick and Bick, 1957; Johnson, 1972). Bick and Bick (1957) reported this species to be frequent and locally abundant in southern Oklahoma, but absent in the northern part of the state. The Washington County, Arkansas, record is the most northern and eastern location for A. imunda.

Johnson and Westfall (1970) have remarked that Ischnura kellicotti is one of the few temperate latitude odonates to have developed an apparently obligatory relationship with specific plants. The plant in this case is a water lily, Nuphar (spatter dock). My first collection of this species was on 27 July 1982 from Berg Lake at the western city limit of Camden, Ouachita County, Arkansas. This population was associated with Nymphoida odorata Ait., the sweet-scented water lily, and is the first record of this particular association. A subsequent collection of I. kellicotti was made on 6 September 1982 from a pond on the S side of U.S. Hwy. 270, 1 mi E of Poyen and immediately W of Frances Creek, in Grant County, Arkansas. This pond contained Nuphar.

A perusal of the damselfly species lists for neighboring states (Bick, 1957; Bick and Bick, 1957; Macklin and Cook, 1967; Montgomery, 1967; Johnson, 1972; Huggins et al., 1976; Lago and Stanford, 1979) reveals that at least eight additional species may be found in Arkansas. Those species include Calopteryx dichotoma (Burmeister), Lestes congener Hagen, L. dyras Kirby, L. forcipatus Rambur, Amphiagrion aquaticum (Burmeister), Chromagrion coonii (Hagen), Enallagma duxium Root, and Nehalennia integrigallis Calvert.
Table 1. The Zygoptera of Arkansas, and their known flight periods. New state records are designated by an asterisk.

Calopterygidae

*Calopteryx maculata* (Beauvois) 1-V to 3-X
*Heterathemis nebulosa* (Fabricius) 7-V to 10-X
*Heterathemis tilia* (Drury) 11-VII to 20-IX

Lestidae

*Procris grisea* (Hemmar) 7-VIII to 15-XI
*Leata diadema* Walker 6-V to 28-X
*Leata rectangularis* Say 20-V
*Leata angustata* Walker 24-VI to 28-VIII
*Leata viridis* Hagen collected 7-V as a naiad

Coenagrionidae

*Anomalagrion basatum* (Say) 10-IV to 13-XII
*Argia apicalis* (Say) 10-VII to 25-X
*Argia hypomita* (Hagen) no date
*Argia imitata* (Hagen) no date
*Argia mexicana* (Hagen) 7-V to 15-XI
*Argia plana* Calvert 3-V to 7-V
*Argia rubella* (Hagen) 24-V to 5-X
*Argia tibialis* (Hemmar) 5-V to 6-IX
*Argia transsisi* Hagen 5-VII to 7-XI
*Elaesagrion agnum* (Hagen) 30-X to 7-IX
*Elaesagrion bisiang* Calvert 13-V to 31-VII
*Elaesagrion tilia* (Hagen) 7-VI to 25-IX
*Elaesagrion trivittatum* Calvert 20-VI
*Elaesagrion luteum* Selys 16-V to 29-IX
*Elaesagrion montanum* Hagen 7-V to 7-IX
*Elaesagrion omnium* Kellicott 13-V to 20-XI
*Elaesagrion nigricans* (Hagen) 29-IV to 29-X
*Elaesagrion trivittatum* Selys 23-V to 24-X
*Elaesagrion rubellum* (Hagen) 7-V to 7-IX
*Elaesagrion xanthum* Kellicott 13-V to 30-X
*Enallagma tintinnatum* (Say) 2-VII to 21-XII
*Enallagma ramburii* Williamson 27-VII to 6-IX
*Enallagma trivittatum* (Say) 18-III to 2-IX
*Enallagma rubellum* (Selys) 5-V to 25-V
*Enallagma viridulum* (Say) 21-VI to 11-VIII

This research was supported in part by ASU Institutional Grant No. 571-625 and NSF Grant No. PRM-8122108. I gratefully acknowledge the contributions of the following persons: Norman Lavers (first state records for *L. inequalis*, *L. rectangularis* and *E. vesperum*, and many county records), Miner J. Westfall, Jr. (information from his files and identification/confimation of several specimens), Leonora Gloyd (Arkansas *Argia* records from the Univ. of Michigan Museum and identification of some *Argio*), Tommy Allen and Chris Carlton (UA-Fayetteville Entomological Museum), John Rickett (UA-Little Rock Entomological Museum), Henry W. Robison and Mark Pippenger (several county records), Ken Tennessee (*E. travium* records), Edward L. Richards (identification of the water lilies), and my family (our vacations were working ones).

**LITERATURE CITED**


General Notes


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STATUS OF THE BAT Myotis keenii IN THE ARKANSAS OZARKS


It has been suggested by van Zyll de Jong (1979), based on a study of Canadian specimens, that *M. k. keenii* and *M. k. septentrionalis* are distinct species. In that case, the Arkansas form would take the name *M. septentrionalis*. At this time it is not clear whether or not this separation will be accepted. Therefore, we utilize the name *M. k. septentrionalis* for the Arkansas form.

*Myotis keenii* is a medium-sized *Myotis* with long ears (17-19 mm) and a narrow pointed tragus. The forearm measures 32-39 mm and the wingspan is 228-258 mm; the calcar is not keeled (Barbour and Davis, 1969). Color varies somewhat but the body is usually brownish to reddish-brown above and gray below. The fur is not glossy.

*Myotis keenii* hibernate in caves or mines during the winter where they usually select relatively cool sites, often near cave entrances. They often hang singly and seem to prefer tight crevices and holes. They are never abundant; concentrations of 100 or more in a single cave or mine are unusual (Barbour and Davis, 1969). During summer they roost in a variety of shelters including under the bark of trees, behind shutters, and in buildings. They appear to be relatively solitary in their habits, except for small maternity colonies formed during summer.

In Arkansas, *M. keenii* is widely distributed throughout the Interior Highlands. Sealander (1979) considered it to be “relatively uncommon” in Arkansas and reported it from Benton, Washington, Newton, Baxter, Stone, and Independence counties in the Ozarks and from Pike and Garland counties in the Ouachitas. During a recent study in eastern Missouri, Caire et al. (1979) reported that 121 trips to 77 caves between October 1975 and April 1976 resulted in locating only 39 *M. keenii*. However, as many as 460 individuals were captured at a single Missouri cave entrance during one night in June.

Since 1968, we have recorded *M. keenii* from 15 caves in seven Arkansas Ozark counties, the same six counties reported by Sealander (1979), and also from Marion County. Usually 1-3 and not more than 6 *M. keenii* were seen in any one cave. They were found in relatively large numbers in only one cave, Cave Mountain Cave in Newton County. During the winter of 1973-74 we estimated 200 to be present there and during the winter of 1977-78 we found ca. 100 (we did not visit the cave during the intervening years). Since the winter of 1977-78, Cave Mountain Cave has been checked yearly and less than 10 *M. keenii* have been observed there. However, it is important to point out that because of their preference for cracks and holes in the cave ceiling, they could easily be overlooked.

Netting at cave entrances during the summer-autumn swarming period indicates that this species is more abundant in the Arkansas Ozarks than indicated by observations of hibernating bats in caves and mines. As many as 40 *M. keenii* have been netted at the entrance of Cave Mountain Cave. However, that number is greater than at most caves netted, where the number captured during any one night is usually less than 10.

Cave Mountain Cave, located on Buffalo National River lands, from which the largest numbers of *M. keenii* have been reported in Arkansas, was recently (1982) fenced by the National Park Service to protect the endangered Indiana bats (*M. sodalis*) and gray bats (*M. grisescens*) that hibernate there from human disturbance. Hopefully, the protection of this cave from disturbance during the hibernation period will result in an increase in the numbers of *M. sodalis*, *M. grisescens*, and *M. keenii* that hibernate there.

LITERATURE CITED


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Published by Arkansas Academy of Science, 1983

Arkansas Academy of Science Proceedings, Vol. XXXVII, 1983

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ARKANSAS RANGE EXTENSIONS OF THE SEMINOLE BAT (*Lasiurus seminolus*) AND EASTERN BIG-EARED BAT (*Plecotus rafinesquii*) AND ADDITIONAL COUNTY RECORDS FOR THE HOARY BAT (*Lasiurus cinereus*), SILVER-HAIRED BAT (*Lasionycteris noctivagans*) AND EVENING BAT (*Nycticeius humeralis*)

Arkansas is within the geographic range of 16 species of bats, 15 of which are classified in the Family Vespertilionidae and one in the Family Molossidae (Sealander, 1979). Historically, research on bats in Arkansas has been in the Ozark region (Dellinger and Black, 1940; Sealander and Young, 1955; Sealander, 1960; Harvey, 1976; McDaniel and Gardner, 1977; Harvey et al., 1981). A few studies have been done in the Delta and Coastal Plain (Sealander and Hoiberg, 1954; Baker and Ward, 1967; Gardner and McDaniel, 1978); however, virtually nothing is known from the Ouachita region (Sealander, 1954, 1979). The data presented in this paper are the results of extensive mist netting of creeks and mine and cave entrances, investigation of roosting sites in buildings, caves and mines, records of bats tested for rabies by the Arkansas Department of Health and examination of skeletal and mummified remains in caves. In addition, the data represent a part of a large scale investigation of the bats in the Ouachita region.

To date, these investigations have established Arkansas range extensions for the seminole bat (*Lasiurus seminolus*) and the eastern big-eared bat (*Plecotus rafinesquii*) and additional county records for the hoary bat (*Lasiurus cinereus*), silver-haired bat (*Lasionycteris noctivagans*) and the evening bat (*Nycticeius humeralis*).

Arkansas Range Extensions

*Lasiurus seminolus* (Rhadz). Typically a tree dwelling species found most often in the deep south, the seminole bat’s range coincides with that of Spanish moss (*Tillandsia usneodes*) in which it prefers to roost. In the summer, the bat ranges from South Carolina along the Atlantic Coast into the Gulf coast area of Texas and Mexico. In late summer, after the young are weaned, some individuals may wander north into Oklahoma, Arkansas, Pennsylvania and New York (Barbour and Davis, 1969). In Arkansas, the seminole bat was formerly recorded from Ouachita and Bradley counties, but probably occurred over most of the lower two tiers of counties (Baker and Ward, 1967; Sealander and Hoiberg, 1954; Sealander, 1979; Hall, 1981). On 3 September 1982 an adult female specimen was captured in a mist net outside the entrance to an abandoned mine shaft in Polk County (T3S, R30W, S10). This specimen extends the range of *L. seminolus* approximately 57 km to the north of its previously recorded marginal records (Fig. 1). The skin and skull preparation of this specimen has been placed in the Zoology Museum Collection at the University of Arkansas at Little Rock (#2583).

*Plecotus rafinesquii* (Lesson). This species is found only in southeastern United States and little is known of its natural history (Barbour and Davis, 1969). The bat had formerly been reported from Bradley, Craighead, Cross, Drew, Greene, Jackson, Miller, Sebastian and Sevier counties (Gardner and McDaniel, 1978; Sealander, 1979). From Arkansas Department of Health records we recorded the bat from Faulkner and Lawrence counties. The Faulkner County record is significant in that it represents a geographic area that Sealander (1979) had not included in the bat’s distribution, thus representing a range extension in Arkansas (Fig. 2).

![Figure 1. Arkansas distribution of the seminole bat (*Lasiurus seminolus*). Shaded area represents geographic range according to Sealander (1979) and Hall (1981). The square indicates the locality record extending the range northward.](http://scholarworks.uark.edu/jaas/vol37/iss1/6)

![Figure 2. Arkansas distribution of the eastern big-eared bat (*Plecotus rafinesquii*). Shaded area represents geographical range according to Sealander (1979). The squares represent new locality records, indicating geographic areas not previously included in the bat's distribution.](http://scholarworks.uark.edu/jaas/vol37/iss1/7)

Additional County Records.

*Lasiurus cinereus* (Palisot de Beauvois). The hoary bat probably occurs statewide in Arkansas (Sealander, 1979). However, it has previously been recorded only from Bradley, Craighead, Drew, Garland, Greene, Pulaski, Sebastian, Stone, Washington and Woodruff counties (Gardner and McDaniel, 1978; Sealander, 1979). We have recorded this species in eight additional counties: Logan, Polk, Montgomery, Saline, White, Lawrence, Marion and Newton.
The student then reads

3) Best-fit absorbance value

The computer accepts absorbance data for each standard solution 100 times, averages the readings then presents the average to the student. This alleviates the indecision some students have when reading a needle that sometimes flickers.

2) Solution concentrations are entered following each averaging, with the values entered based on student preparation of solutions of ferrous ammonium sulfate.

3) When all known solutions are completed, the computer gives a screen which lists the concentrations of the solutions provided, the absorbance value on the best-fit line for those concentrations, and the slope and intercept of the best-fit line.

4) Best-fit and raw data points are then screen-graphed. This shows the scatter of the student’s data and allows immediate judgment of the necessity for repetition of the work.

5) The student then reads any number of unknowns and the computer calculates their iron concentration from the least-square slope and intercept values.

With the computer-based procedure, no significant improvement in accuracy was noted, as compared to classes that took data by hand (Hoyt, Unpublished Data, 1982). There have been significant improvements in speed (or spectrophotometer use-time), calculation accuracy (particularly

GENERAL NOTES

LITERATURE CITED


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MICROCOMPUTER-ASSISTED COLORIMETRIC DETERMINATION OF IRON

Courses in quantitative analysis often include standard colorimetric procedures, in which a series of solutions is used to prepare a calibration curve, with the unknown read from the curve. An experiment of this type is the iron-phenanthroline determination which is described in the manual by Day and Underwood, *Quantitative Analysis Laboratory Manual*, 4th Ed., p. 125, 1980). This procedure has been modified in the present application, so that commercially-prepared unknowns can be used. The spectrophotometer is interfaced with a microcomputer for reading and manipulation of the absorbance-concentration data. The experiment not only provides an example of microcomputer application and serves to eliminate human error in data acquisition, but allows performance of repetitive tasks which are nearly impossible by hand.

The student needs no computer capability, since the entire procedure is screen-prompted. The following are features of the experimental procedure:

1) The computer accepts absorbance data for each standard solution 100 times, averages the readings then presents the average to the student. This alleviates the indecision some students have when reading a needle that sometimes flickers.

2) Solution concentrations are entered following each averaging, with the values entered based on student preparation of solutions of ferrous ammonium sulfate.

3) When all known solutions are completed, the computer gives a screen which lists the concentrations of the solutions provided, the absorbance value on the best-fit line for those concentrations, and the slope and intercept of the best-fit line.

4) Best-fit and raw data points are then screen-graphed. This shows the scatter of the student’s data and allows immediate judgment of the necessity for repetition of the work.

5) The student then reads any number of unknowns and the computer calculates their iron concentration from the least-square slope and intercept values.

With the computer-based procedure, no significant improvement in accuracy was noted, as compared to classes that took data by hand (Hoyt, Unpublished Data, 1982). There have been significant improvements in speed (or spectrophotometer use-time), calculation accuracy (particularly

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in eliminating tedious least-square manipulations, and ease of making judgments about reliability of data. Student reaction has been enthusiastic, but some effort must be expended by instructional personnel to prevent rote manipulation of "black boxes" and permit understanding of the logic involved.

The spectrophotometer used is the B & L Spectronic 70, although the ubiquitous Spectronic 20 is interchangeable. Any of a number of similar digital or non-digital instruments could be adapted with the proper interfacing arrangement. The interface used is one of several built during an annual workshop on microcomputer interfacing (Wisman, Chemistry Department, University of Arkansas, Fayetteville, AR 72701. Circuit used with permission.) The program requires 6K on the 4032-N PET microcomputer. The program runs on both monochrome (4.0) and color (2.0) RAR in PET BASIC. The 301 lines (58 comments) in the program are capable of being greatly reduced, but are presented so as to permit modification and ease of understanding. Transfer to other brands of microcomputer would require modification of the graphics portion of the program, as well as some changes in the interface adapter. The program is written for the small-screen PET, but minimal changes would accommodate the new 12" (80 column) screen. The modified Day/Underwood experiment, a schematic of the interface, a program listing, and a sample execution are available from the author.

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AQUATIC MACROINVERTEBRATES OF THE HIATT PRAIRIE REGION, FRANKLIN COUNTY, ARKANSAS

At one time significant disjunct expanses of natural grassland or prairie occurred in all quarters of Arkansas. These were predominantly tall grass prairies with scattered areas of wetlands or marsh. Most have been destroyed by agricultural practices (Ark. Dept. Planning, 1974). Only two prairie tracts remain in Arkansas that are associated with permanent water. One of these is Hiatt Prairie. Little work has been done on the aquatic macroinvertebrates of prairie-associated streams in Arkansas. It was the primary intent of this study to establish a species list of aquatic macroinvertebrates for the Hiatt Prairie region.

Hiatt Prairie is located 2 km N of Charleston in the SW 1/4 S25, R29W, T8N, Franklin County, Arkansas. Hiatt Creek, formerly called Prairie Creek, is a first order stream that meanders to the west across the Prairie, approximately 1 km. Recently beaver have invaded the area and caused a drastic change in stream flow. Six large beaver dams cross the stream channel at approximately 140 m intervals, and smaller dams are occasionally interspersed between them. As a result, the typically narrow, shallow stream has become deeper and more sluggish at the beaver pools established behind each dam.

The main channel width varies from 0.9 to 2.4 m and the depth varies from 20 to 91 cm, dependent on the beaver dams. The substrate of the channel is typified by silt several cm deep in areas of little current, whereas broken slate and rock predominate where the current is more rapid. Compacted clay is typically found at each bend in the stream. Substrate in the beaver pools is characterized by a thick silt, augmented by detrital material from the surrounding watershed.

An oval-shaped stock pond is located approximately 0.1 km NE of the St. Hwy 217 bridge over Hiatt Creek. The pond was constructed in the early 1900's and has maintained a supply of water since that time (Hiatt, pers. comm.). During periods of excessive rainfall, the pond overflows its east bank creating excellent habitat for aquatic macroinvertebrates in the surrounding grasses and low shrubs. Several kinds of aquatic vascular plants abound in this low flooded area where the effect of silting is minimal. The substrate within the normal boundaries of the pond consists of a very deep layer of silt, with the complete absence of vegetation.

Thirty-four collections were made during 15 trips from 24 May 1980 to 21 February 1982. Seventeen collections were made from the stream channel, 10 from the beaver pools and seven from the stock pond. Collections were made monthly from spring through fall and bi-monthly during the winter. Temperature, pH and turbidity were measured on each sampling date. Dissolved oxygen, carbon dioxide and alkalinity were measured only on the final trip. Chemical determinations were made by standard limnological methods. Aquatic macroinvertebrates were collected with an aquatic dip net. The channel stream was sampled at approximately 20 pace intervals. Each microhabitat was sampled proportionately in the beaver pools. The circumference and overflow area of the stock pond was sampled randomly, although dense silt accumulations were avoided. On each trip an ultraviolet light was used for one hour after dusk to collect emerging adults. Dip net and ultraviolet light specimens were preserved in 70% ethanol. Adult Odonata were collected by aerial net, placed in paper triangles, and immersed in acetone for 18-24 hours. All specimens are housed in the Arkansas State University Museum of Zoology (ASUMZ) Aquatic Macroinvertebrate Collection.

Physicochemical parameters of both the stream and stock pond were within the known limits of tolerance for freshwater organisms and caused no visible detrimental effects. The aquatic macroinvertebrate fauna of the Hiatt Prairie region was quite diverse, with 138 taxa representing 18 orders, 55 families and 115 genera (Table). Of these, 126 taxa were collected in Hiatt Creek; 104 and 95 taxa in the beaver pools and channel, respectively. Seventy-one taxa were collected from the stock pond. The three major zones had 42 taxa in common, while 31 taxa were shared by the channel and beaver pools only, 15 taxa by the beaver pools and stock pond only, and five taxa by the channel and stock pond only. Seventeen taxa were found in the channel only, 16 in the beaver pools only, and 11 in both the stock pond and beaver pools. Coleoptera was the most diverse order with representatives from eight families and 31 species. The most frequently collected orders were Isopoda, Coleoptera, Decapoda, Hemiptera, Amphipoda, and Ephemeroptera, respectively. Most of the taxa are adapted to a variety of habitats and environmental conditions (Pennak, 1978).

The beaver activity has increased the diversity of aquatic macroinvertebrates in Hiatt Creek by increasing the diversity of microhabitats, introducing instability, or a combination of the two. The beaver pools provide a greater range of water depth, current speed (absent to moderate), and substrate types (particulate organic matter to decomposing leaf litter). The beaver pools also have gradually sloping bottoms which are conducive to the establishment of a greater variety and density of aquatic vegetation and associated fauna. During the study period the beaver pools were in the process of being established, and thus were areas of transition. Such transitions are marked by temporary instability. Increased species diversity can result, as some new species will be developing, others will be at population peaks, and yet others will be declining (Reed, 1978).

The aquatic macroinvertebrate fauna of the channel was qualitatively similar to that of the beaver pools, with 95 and 104 taxa, respectively. Of these, 73 taxa were collected from both zones. Fewer taxa were collected from the channel than the beaver pools despite more intensive collection in this zone (17 samples vs 10 from the beaver pools). In many areas of the channel the substrate was compacted clay, and the stream banks were of vertical, eroded clay, providing little suitable habitat. Most of the taxa found in the channel only (e.g. Eugenius, Pycnopseus, Stenelmis cristata) are characteristic of still water habitats, generally inhabiting microhabitats such as pool, riffles or anadromous migration passages (Wigley, 1976; Wiggins, 1955; Brown, 1976, Reed, 1978).

Aquatic macroinvertebrate diversity was least in the stock pond. This primarily resulted from the homogeneity of its silt substrate (Harrell, 1969). The fewest samples were taken from this zone, and this also reduced the number of taxa collected. Most taxa were obtained in the overflow.
area, where the substrate was a fine particulate organic material, with a dense accumulation of aquatic vegetation and interspersed algae. The faunal composition was more similar to that of the beaver pools than that of the channel, having 57 and 47 taxa in common, respectively.

In 1982, it was observed that the streams of Iowa, northern Missouri, and eastern Kansas and Nebraska, are not prairie streams, because their valleys are wooded. Such streams are shaded in the summer and receive much organic allochthonous material from the watershed. In contrast, prairie streams receive little organic allochthonous material and have a substrate composition of gravel, sand and clay. The streams of eastern Kansas are transitional in that their banks are wooded, but swift currents and periodic flooding remove organic deposits (Jewell, 1927). Basically, Hiatt Creek is such a transitional stream, particularly in the channel zone.

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This research was supported in part by a grant from the Arkansas Water Resources Research Center. We thank Thomas Bowman, Mark Gordon and Horton Hobbs, Jr., for identification of Isopoda, Mollusca and Decapoda, respectively. Bill Hiatt kindly granted permission to collect on his property, and John Huggins was of great assistance in collecting field data.

LITERATURE CITED


JULIE A. HUGGINS and GEORGE L. HARP, Department of Biological Sciences, Arkansas State University, State University, AR 72467.

Neviusia alabamensis: A PHYTOGEOGRAPHIC ANALYSIS

Neviusia alabamensis is an extremely rare plant endemic to only a few southeastern states. Arkansas has representative populations in three counties: Conway, Pope, and Newton (Fig.). Other identified populations are located in Alabama, where the species was first recognized, and in Missouri, Tennessee, and Mississippi. In three states, Alabama, Arkansas, and Missouri, the genus is listed as an endangered species (Ayensu and Defilips, 1978) and in the two remaining states it has just recently been discovered. The purpose of this paper is to describe the distribution of Neviusia alabamensis in Arkansas and to examine the physical environments in which the Arkansas species are found.

To develop a plant description of Neviusia alabamensis, 16 herbarium specimens were measured and published information was examined (Chapman, 1987; Dean et al., 1973; Dean, 1961; Greene and Bloquist, 1953; Small, 1933; Louniberry, 1901; Moldenke, 1949; Small, 1933; Steyermark, 1975). The physical environment was described in terms of soil, slope direction, slope percentage, solar exposure, and dominant vegetation. Soil samples were taken from each of the ecosystems in Arkansas in which Neviusia alabamensis is found and soil nutrient, soil texture, and pH tests were conducted. The soil was gathered from depths of 4 to 10 cm at three different areas within each population and mixed before testing.

Neviusia alabamensis is a perennial shrub with numerous slender primary stems and short lateral branches. The bright green leaves (approximately 3 cm X 4 cm) are simple and alternating. The flowers are odorless and lack petals, however, the stamens are numerous (usually over 100) and showy. Flowering may occur between March and May.

Neviusia alabamensis seems to be able to exist on relatively dry sites. Two of the populations, Conway and Newton Counties, are located on southeast facing slopes, whereas the population in Pope County is located on a northwest facing slope (Table). The percentage of the slope varied a great deal among the populations. The slope in Conway County was the greatest, 80%, and the slope in Newton County was the least, 35%. It would seem that the Conway County population would be much drier as a result of the steeper slope. However, the soil at Newton County was very sandy. These two populations may be approximately equal in what seems to be the most critical factor, soil moisture.

<table>
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<th>Neviusia alabamensis Distribution</th>
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Figure. The three Arkansas counties in which Neviusia alabamensis is found.

Table. Comparison of the physical environments in which Neviusia alabamensis exists. The soil nutrients are given in kilograms per hectare.

<table>
<thead>
<tr>
<th>Slope Direction</th>
<th>Conway County</th>
<th>Pope County</th>
<th>Newton County</th>
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<tr>
<td>Slope Percentage</td>
<td>80%</td>
<td>65%</td>
<td>35%</td>
</tr>
<tr>
<td>Size of Population</td>
<td>800 x 100m</td>
<td>150 x 40m</td>
<td>2700 x 100m</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Phosphorus</td>
<td>34-45</td>
<td>34-45</td>
<td>5</td>
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<tr>
<td>Potassium</td>
<td>135</td>
<td>135</td>
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<tr>
<td>pH</td>
<td>6.0</td>
<td>6.2</td>
<td>6.8</td>
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<tr>
<td>Texture</td>
<td>Loamy sand</td>
<td>Loamy sand</td>
<td>Sandy grit</td>
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http://scholarworks.uark.edu/jaas/vol37/iss1/1
In Pope County there was a semi-closed canopy, whereas the other two sites had a few scattered trees, mainly at the edges of the population. This population received more moisture than the other two populations because of a cliff which drips water down onto the soil. It could also have reduced evaporation rates due to less soil radiation because of slope location. At this site Callicarpa americana was competing with Neviusia alabamensis and was expanding more rapidly. This population of Neviusia alabamensis appeared to be in more danger of being overran than the other two populations. It was also the smallest of the three populations and the least dense.

The population in Newton County was located next to a small stream one to two meters wide. This largest Arkansas population of Neviusia alabamensis was found growing along the southeast side of a stream, but no plants were found on the adjacent bank. This could be a result of the difference of north and south slopes and that there was more moisture on the north slope. If the species is capable of reproducing by seeds, a small stream would not be a barrier. If, however, the species was only capable of reproducing by root sprouts, the stream could halt its spreading.

The soils when tested showed no available nitrates, indicating that any nitrates had been incorporated into the biomass. Most soils, especially uncultivated soils, usually contain very small amounts of available nitrates (LaMotte, 1977). Therefore, these results could have been expected and may not be a limiting factor to the Neviusia alabamensis population.

The populations located at Pope and Conway Counties contained approximately 34-45 kg of phosphorus per hectare, while the population at Newton County contained only 5 kg per hectare. This difference correlates with the limestone substrate at the Newton County site in that on limestone soil phosphorus is generally limited. The other two populations contained an adequate supply of phosphorus, and growth may not be limited, but the Newton County site is low in this nutrient (Table). The soils obtained from the Pope and Conway County populations were found to contain approximately 135 kg of potassium per hectare, whereas, the Newton County population contained between 90 and 100 kg per hectare. The plants in these areas should not vary due to the difference in the amount of potassium because normally plants cannot utilize more than 90 kg of potassium per hectare (LaMotte, 1977).

The Conway and Pope County populations were growing on soil that had the optimum pH for nutrient absorption. The pH of the soil at Newton County was slightly higher due to the fact that it was on limestone, however, it would likely have an adequate absorption rate because it is still close to the optimum range.

The soils at Conway and Pope Counties were loamy sand and loamy sand to sandy loam respectively. The soil at Newton County, however, was a sandy grit and, therefore, much coarser than the other two soils. The soil would be expected to be drier than the other populations and contain smaller quantities of the soil nutrients due to the greater amount of leaching and lack of clay. Further testing would be required before it could be determined if there is a deficiency of phosphorus or potassium at any of the study sites.

The populations of Neviusia alabamensis were found to be growing in three distinguishable habitats. At least two out of three of the habitats were similar for each of the factors which were examined in the paper, however, the same two were not consistently similar. In general, there were more discrepancies than one might have expected.

The three populations are isolated from each other and probably have been for a number of years. They are separated from each other by a number of kilometers and physical barriers such as separate water sheds and dissected foothills in the Ozark Mountains. Since the gene pool of one population is not mixed with the gene pools of the other populations it would be possible for the species to accumulate different genetic changes. Whether there has been enough time for genetically different populations to arise cannot be determined by this study, but this could be one explanation for the ability of the Neviusia to exist in differing sites.

Further research is required to determine if there is inter-site variation not only in the Arkansas populations, but in all of the populations of Neviusia alabamensis. Research should be conducted on the physical environments of all of the populations in order to determine the best physical environment for the species. At present, there are only a few general assumptions which could be made about the most favorable ecosystem for the species. It seems to only be found above stream banks in generally dry soils. It is not possible from the research in this paper to describe the optimum physical environment for Neviusia alabamensis or make any definite conclusions of the effect of the physical environment upon the species.

**EXSSICATAE**

The following herbarium specimens were used in obtaining information for the species description. The specimens are all from Arkansas and selected from sixteen sheets:

**Arkansas:**
- Conway Co: DeMaree 20, 30 (UARK)
- Moor 53-11, 53-26, 53-63 (UARK): 63-047 (ATU)

**Newton Co:**
- Smith 3116 (UARK)

**Pope Co:**
- Field 010461 (ATU)

**Washington Co:**
- Lewis 010459 (ATU)

**Literature Cited**


BRYOPHYTE-LICHEN COMMUNITIES WITHIN HOT SPRINGS NATIONAL PARK, ARKANSAS I.

The vegetation within Hot Springs National Park consists of varied forest communities (Dale, E. E., Jr., and M. R. Watts 1980). Vegetation of Hot Springs National Park, Arkansas. Prep. for S.W. Region National Park Service, U.S. Dept. Interior). These communities include mesic stands of upland hardwood, xeric pine-oak-hickory stands, oak-hickory-pine stands which are subtypes on the xeric side, and short-leaf pine-white oak stands which are subtypes on the mesic side. The most mesic types within the park, however, are the mixed forest types in the upland ravines. In this study, field work included variable-point sampling of these forest stands along the forest trails within the park so that the stands could be compared with the work done by Dale and Watts.

Sampling techniques for the microcommunities of lichens and bryophytes varied among sites, but always included collections from rocks, soil, fallen logs, and standing trees. A total of almost 1800 collections was made during the summer and fall of 1981. Identification of these samples is nearing completion.

The present study has identified 49 mosses and 66 lichens from within the boundaries of Hot Springs National Park. Previous studies within the park had included only species of mosses (Lowe, R. L. 1919. Collecting in Arkansas. The Bryologist 22(1):14-15; Scully, F. J. 1941. The Mosses of Hot Springs National Park and Vicinity. The Bryologist 44(5):125-128). New state records from this study include two liverworts: Jamesoniella autumnalis in the Jungermanniaceae and Calypogeja muelleriana in the Calypogeaceae; one moss: Anacampseros splachnoide in the Fabroniaceae; and one lichen: Coccocarpin palmicola in Coccocarpinae.

This research was supported by a grant from the Hot Springs National Park Service and was facilitated by a sabbatical semester for the senior author in the fall of 1981 from the University of Central Arkansas.

JEWEL E. MOORE, Biology Department, University of Central Arkansas, Conway, AR 72032, and STEVE L. TIMME, Department of Botany and Bacteriology, University of Arkansas, Fayetteville, AR 72701.

CURATORIAL NOTES FROM THE CRYPTOGRAMIC HERBARIUM
AT THE UNIVERSITY OF CENTRAL ARKANSAS

The Cryptogamic Herbarium at the University of Central Arkansas, Conway, is used for teaching and research and has been selected by officers of the Arkansas Mycological Society to house voucher specimens for Arkansas mushrooms collected by A. M. S. members. These fungi are thoroughly dried and placed in clear plastic, zip-lock bags which can easily be sealed and reopened; complete labels for each are placed in/on the bags. These have been filed in the herbarium according to the checklist of mushrooms being published in Arkansas Biota, 1983 (No.37). It has been helpful to eliminate larvae and adult beetles found in some of the persistent fungi and fleshly mushrooms by a short treatment in the microwave oven before the drying is completed in the conventional laboratory oven. The microwave oven treatment usually kills the larvae and the adults will leave the specimen.

Lichens and bryophytes are often packaged in clear, plastic packets and are fastened to herbarium sheets, with the label immediately under the plastic packet. Others are packaged in the traditional manner, with complete label on the outside of the paper packet. Packets are then glued to standard herbarium sheets and placed in folders for protection. Still other specimens are housed in the conventional small boxes. The Flora A. Haas liverwort-hornwort collection remains in the box in which she kept it. Her collection does not contain any Arkansas specimens but is still a valuable addition to the herbarium. Collections she had of Arkansas bryophytes were disereded (due to no identification label being placed on the large box in which it had been stored) in a clean-up of the department about 1955. The Haas collection includes specimens collected by W. L. Underwood, W. A. Evans, C. C. Hayes, and Nellie Fosdick dating from 1888 to 1919. However, the earliest collection was a leafy liverwort collected in Cuba in 1879. Places of collection include Puerto Rico, Hawaii, Cuba, Jamaica, California, Florida, New Hampshire, and several other states.

An important addition to the vascular cryptogam section of the herbarium is the collection of Pteridophyta made by the late Aileen McWilliam of Mena, Arkansas. Some of her specimen sheets of Arkansas ferns indicate sites where the ferns can no longer be found, because the habitats have been so thoroughly changed (Moore, J. E. 1982).

In addition to the storage of specimens for study, it is part of the function of the herbarium curator to publish checklists of plants for the region served. In this respect, checklists of Arkansas lichens (1981), horsetails and liverworts (1983), and mushrooms (1983) have been published in the Arkansas Biota under the auspices of the UCA Cryptogamic Herbarium (Nos. 30, 36, and 37). The checklist of Arkansas mosses will be published in 1984. The checklist of Arkansas Pteridophytes by Dwight M. Moore was published in the Arkansas Biota in 1977 (No. 1).

Distribution maps for specimens in the herbarium are placed within each folder. Reprints of articles dealing with the Arkansas plants are available in the herbarium library.

LITERATURE CITED


Arkansas Academy of Science Proceedings, Vol. XXXVII, 1983
THE DEVELOPMENT OF TISSUE CULTURE SYSTEMS FOR THE EVALUATION OF CANCER CHEMOTHERAPEUTIC AGENTS

The use of tissue culture (TC), especially in tandem with in vivo systems, has certain potential advantages in the evaluation of cancer chemotherapeutic agents (CCA). First, much of the data produced by in vivo systems can be derived from TC. Second, TC is in the long run potentially less expensive than in vivo systems. Third, certain data derived from TC systems appear to point the way to more correct dosage regimens for 5-fluorouracil, which has apparently been used incorrectly for years (Calabro-Jones et al., Cancer Res. 42:4413-4420, 1982). Fourth, the potential exists that cultures of human tumors may in the future be useful in the determination of the sensitivity of these tumors to certain CCA or combinations thereof. Finally, TC techniques interphase with certain important current techniques; i.e., monoclonal antibody production, targeted cancer chemotherapy and genetic engineering. The material presented here is a preliminary study of the effects of Cisplatin and one of its isomers on the cell line 253-J, a human multiple transitional cell carcinoma derived from the urinary tract by Elliot (Elliot et al., J. Natl. Cancer Inst., 53:1341-1349, 1974). Cells were obtained from Dr. Ralph Clayman, University of Minnesota; Department of Urologic Surgery, Minneapolis, Minnesota.

Stock cell cultures were grown at 37 °C as monolayers in 75 cm² tissue culture flasks containing RPMI 1640 medium (Grand Island Biological Co., Grand Island, New York), supplemented with 15% newborn calf serum, 10% tryptose phosphate broth, 0.3 units/ml of bovine insulin, 5 mM glutamine, and 100 units/ml each of penicillin and streptomycin. For experiments, 2.0-5.0 x 10⁶ cells/25 sq cm flask were seeded into the complete growth medium and incubated at 37 °C for 16-24 hrs before the start of an experiment.

In drug experiments, stock solutions (500 mM) of the platinum compounds obtained from the National Cancer Institute, were prepared in complete growth medium by stirring the mixture at 37 °C for 30 min. The culture medium was removed from the flasks before treatment and the cells were treated at 37 °C for 2 hrs by adding the appropriate concentration of drug in 5.0 ml of complete growth medium. The drug treatment was terminated by the removal of the drug containing medium. The cells were washed once with Puck’s Saline A followed by the addition of fresh medium to the cultures.

Growth studies were carried out in the following manner: Asynchronous cells were treated with the platinum compounds during the exponential phase of growth and were allowed to proliferate for at least 3 population doublings after drug treatment. Cells were harvested by trypsinization with a solution of 0.25% trypsin and 0.02% sodium EDTA in calcium and magnesium free Puck’s Saline A, and counted in a Model ZBI Coulter Counter (Coulter Electronics, Hialeah, Florida). The inhibition of growth was measured by calculating the ratio between the number of cells in treated cultures and those in the untreated cultures run in parallel.

The cell doubling time was determined beginning 16-24 hrs after plating. An initial count was taken to determine the zero time point. Thereafter, cell counts were taken at 24 hr intervals over a period of 5-6 days.

The growth kinetics of 253-J cells are presented in Figure 1. The effect of the addition of increasing concentrations of Cisplatin isomers is presented in Figure 2. The effects of the Cisplatin isomers are similar to those obtained by other researchers with different cell lines (Drewinko, et al., Cancer Res., 33:3091, 1973; Zwelling, et al., Cancer Res., 39:363-369, 1979). These curves appear to be simple exponential types which

![Graph 1](image1.png)

**Figure 1.** Growth of 253-J cells. Cells seeded into complete growth medium 16-24 hrs before the initiation of experiment. Counts were determined at 24-hr intervals over a period of six days. Each measurement was in duplicate. This figure is the result of three experiments.

![Graph 2](image2.png)

**Figure 2.** The effect of Cis- and Trans-Dichloroammineplatinum II upon the proliferation of 253-J cells. Asynchronous cells in the exponential growth phase were treated for 2 hrs at 37 °C with increasing drug concentrations. The rest of the protocol is found under methods. Each measurement was done in triplicate and the results are the mean of three experiments.
are generally seen with alkylating agents or agents which intercalate with DNA (Drewinko, et al., Cancer Res. 33:3091, 1973). This particular line of cells appears somewhat less sensitive to Cisplatin than the lymphoma cells used by Drewinko, Brown and Gottlieb (Cancer Res., 33:3091, 1973); however, variations in sensitivity among different cell lines are common occurrences.

The cis-isomer of Cisplatin was about 50-60 times more toxic than the trans-isomer, a phenomenon which has been noted by other workers (Zwelling, et al., Cancer Res., 39:365-369, 1979). This phenomenon is only partially understood. Both agents cause extensive DNA-protein cross linkage and intra- and interstrand DNA cross linkage, however, the degree of interstrand cross linkage more closely correlated with cytotoxicity. The trans-isomer is actually more mutagenic. The mechanism of the specificity for certain tumors which alkylating agents such as Cisplatin display is not understood in view of the wide spectrum of reactions in which these compounds take part. It would appear that the platinum coordination compounds as alkylating agents, must react with very specific sites to produce their characteristic effects.

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FIRST HOST PLANT RECORDS FOR Chelysomaidea guttata (HERRICH-SCHAEFFER) (HEMIPTERA:SCUTELLERIDAE), WITH NOTES ON THE BIOLOGY AND DISTRIBUTION

Chelysomaidea is primarily a tropical-subtropical genus distributed from the southern United States through Mexico, Central America, and into South America. As with most genera of Scutelleridae, little work has been done with Chelysomaidea aside from species descriptions. The purpose of this paper is to report host plant data and new information concerning the biology of C. guttata.

C. guttata has been collected from the southern parts of Louisiana, Mississippi, Alabama, and Georgia; throughout Florida; and from eastern North and South Carolina. One other species in this genus, C. stictica (Dallas), is known to occur in the United States from a small area in the vicinity of Brownsville, Texas, which is thought to be the northern limits of its range (Lattin, The Scutellerinae of America north of Mexico (Hemiptera:Heteroptera:Scutelleridae), Unpubl. Ph.D. dissertation, p. 350, 1964).

Blatchley (Heteroptera or true bugs of eastern North America with special reference to faunas of Indiana and Florida. p. 1116, 1926) reported C. guttata being collected from Ipomoea purpurea (Roth) and scrub oak in Florida. Lattin (1964) reported collecting the species from Kosteletzky virginica (L.) in South Carolina and from Althea rosea (Cav.) in Florida. No feeding activity for C. guttata has previously been reported.

Adults and late nymphal instars were observed feeding on Croton capitatus (Michx.) and C. glandulosus (L.) in September of 1982 in Chocotaw County, Alabama and Covington County, Mississippi. All five nymphal instars as well as adults were found on all parts of Croton but mainly in groups on the flowering portion of the plants. Gregarious adults and late nymphal instars were also observed.

Several five adult and nymphs were collected from C. capitatus and C. glandulosus and brought back to the laboratory for rearing. Different stages of nymphal instars were separated and put in pint mason jars with screen tops. Field collected adults were sexed and placed in mason jars, two pairs per jar. Nymphal instars and adults were first fed fresh green beans and raw peanuts. McPherson (The Pentatomidae [Hemiptera] of northeastern North America with emphasis on the fauna of Illinois, p. 240, 1982) reviewed the literature concerning lab rearing practices for the Pentatomidae. A high mortality rate occurred within the first month of rearing. In an effort to reduce high mortality, C. capitatus, which is abundant in northeastern Arkansas, was collected and placed in the mason jars in lieu of green beans and peanuts. The insects fed on flowering portions of C. capitatus which were clipped and placed in small test tubes filled with water. Cotton was used to plug the openings of the test tubes. Food along with paper towelling was replaced three times a week or as necessary. All jars were washed once a week. Specimens were incubated at 25 ± 1°C; 12:12 LD photoperiod and ambient humidity.

The purpose of rearing efforts was to determine the length of the development of the insect, from egg to adult stage, and to determine the length of each individual instar. This part of our study was not completed due to the high mortality rate which occurred within the first month of rearing.

A pair of insects was observed mating on January 3, 1983, but as yet no eggs have been deposited. Further collections of C. guttata will be made in order to continue the study into the life cycle of this insect.

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FIRST REPORT OF BRAZILIAN FREE-TAILED BAT MATERNITY COLONIES IN ARKANSAS

Three maternity colonies of the Brazilian free-tailed bat (Molossidae: Tadarida brasiliensis micropterus) have been found in central Arkansas. Previously reported records of Tadarida in Arkansas are of individual specimens collected from Ashley, Hempstead and Pulaski counties, either roosting singly or in maternity colonies of the evening bat, Nycticeius humeralis (Sealander, A guide to Arkansas mammals, pp. 99-102, 1979; Sealander and Price, J. Mamm., 45:152, 1964).

On July 28, 1982 we investigated a reported bat infestation in the attic of an old two story apartment building in downtown Hot Springs, Garland County. The colony was estimated to have contained 100 individuals. Forty-two bats were captured, examined and released. Six of the bats captured were volant juvenile Tadarida and three were volant juvenile Nycticeius. Juvenile status was determined by non-closure of the ephiphyses of the third and fourth digits. All bats were roosting on the west wall of the attic at the ceiling joist/rafter junction, rendering them extremely difficult to capture. When a light was shone in this area, many of the bats moved outside the attic proper and roosted behind an exterior face board. It was from behind this face board that most of the bats launched themselves into flight when initiating their nightly foraging activities.

During January, 1983, a check of this roost revealed a portion of the colony used the attic as overwintering quarters.

The second maternity site was found in the attic of an old dormitory building on the campus of Central Baptist College in Conway, Faulkner County, during October, 1982 and represents the northern most distribution of Tadarida reported in Arkansas. The colony numbered several hundred individuals and used a 30 centimeter wide air space between a double brick wall and the ceiling joist/rafter junction at the edge of the attic for roosting. Similar roosting sites were selected by Tadarida in Louisiana (LaVal, Am. Midl. Nat., 89:112-120, 1973). Both of these roosting sites were located on the west side of the building and warmed considerably during afternoon hours. Judging from the guano that has accumulated to a depth of over 30 centimeters in places, the colony had probably inhabited the attic for a number of years. Verification of this roost as a
General Notes

maternity site was accomplished by sifting through guano piles and recovering skeletal and mummified remains of juvenile Tadarida during the fall of 1982.

Several hundred newborn Tadarida, many with umbilicus still attached, were observed and voucher specimens collected in June, 1983 (specimens deposited in UALRMZ). The colony shared its maternity and hibernating quarters with approximately 500 (October estimate) big brown bats, Eptesicus fuscus. Eptesicus roosted near the apex of the attic or high up on the sloping rafters in more open areas, segregating themselves from the free-tails. However, in both October, 1982 and March, 1983, several Eptesicus and Tadarida were observed roosting side by side on rafters halfway between the two colonies and during the maternity period juveniles and adults of both species often shared roosting sites. Apparently, Eptesicus occupied these same areas of the attic during maternity periods as skeletal remains of juveniles and adults littered the manure piles below. Mixed roosting of these two species in man-made structures has been reported as a common occurrence from the western states according to Barbour and Davis (Bats of America, p. 209, 1969).

The third maternity site was located in the old lion house of the Little Rock Zoo in Pulaski county. The exact size of the colony was unknown, but Zoo personnel reported the accumulation of dislodged juveniles on the floor of the building as a daily occurrence during the pre-volant maternity period. Roosting sites selected by this colony were similar to those previously described. A portion of the colony overwintered in the building as evidenced by the capture of adult females in mist nets which had been set up to remove sparrowls from the building in February, 1983 (pers. comm., Bob Cooper, Zoo Director).

The close proximity of this colony to the University of Arkansas Medical Science campus probably explains the 1962 occurrence of an adult female Tadarida captured while roosting on the lattice work of a research building (Seqlander and Price, 1964).

The presence of these colonies have resulted in two additional county distribution records (Faulkner and Garland), firmly established the species as a resident mammal and extended the known northern distribution of the bat approximately 40 kilometers within the state.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the help of Mike McKinney, Don Floyd and John Scales of Hot Springs Animal Control, Bob Jines, Belinda Wunderlin-Jonak, Bob Cooper, Director, Little Rock Zoo and David Westbrook, Little Rock Zoo. This research project was sponsored, in part, by the U.S. Forest Service (Ouachita National Forest) and a University of Arkansas at Little Rock Faculty Research Grant, and the UALR Office of Research, Science and Technology.

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ZOOPLANKTON POPULATION STRUCTURE IN THREE RESERVOIRS
NEAR THE OUACHITA MOUNTAIN - GULF COASTAL PLAIN INTERFACE

Zooplankton are important food for young-of-the-year and certain adult fish and may serve as an indicator of trophic status (McNaught, Verh. int. Ver. Limnol. 19:724-731, 1975). In 1979, the National Reservoir Research Program and the Waterways Experiment Station of the U.S. Army Corps of Engineers conducted a cooperative study of the effects of reservoir operations on tailwater environments. The study included seasonal measurements of water quality and zooplankton populations in three reservoirs (Pine Creek Lake, Oklahoma; and Gillham and Greeson Lakes, Arkansas).

The lakes are in different river drainage near the interface of the Ouachita Mountains and the Gulf Coastal Plain physiographic provinces. Pine Creek and Gillham Lakes are multi-purpose, flood control impoundments in the Little River system. Pine Creek Lake (2,023 ha) is a mainstem reservoir on the Little River in southwest Arkansas; and Lake Greeson (2,940 ha), is a Corps of Engineers hydroelectric project on the Little Missouri River in the Ouachita River basin in west central Arkansas. Selected physicochemical characteristics of the three lakes include low conductivity (34-52 umhos/cm), low alkalinity (6-13 mg/l as CaCO3), and nearly neutral pH (ca. 6.5).

In 1979, zooplankton densities were observed for Pine Creek Lake from April through November, for Gillham Lake from June through October, and for Lake Greeson from May through October. Vertical tows at depths of 15-10 m, 10-5 m, and 5-0 m were made with an 0.08-mm mesh, 0.3-m closing net. Samples were immediately preserved in 3% formalin. Two 1-ml subsamples were later placed in a Sedigwick-Rafter counting cell where all organisms were identified and counted. Dry weight biomass estimates (from the upper stratum) were calculated by regression equations (Dumont et al., Oecologie 19:75-97, 1975). Cladocera and Rotifers (except Conochilidae) were identified to species, and Coepodida were identified to sub-order. All estimates were expanded to number and milligrams per cubic meter.

Daphnia rosea, D. cucuaba, Leydiella quadrangularis, and Synchaeta sp. were found only in Gillham Lake, where a total of 12 species of cladocerans and 17 species of rotifers were collected. Daphnia galeata mendotae and Keratella americana were collected only in Lake Greeson, where 9 cladoceran and 17 rotifer species were identified. Nine cladoceran and 18 rotifer species were found in Pine Creek Lake. Coepodida ranked high in density throughout the study period (Table); however, comparisons of the copepod suborders (Calanoida and Cyclopoida) to the cladoceran and rotifer genera were not considered valid, and relationships were not analyzed. Chaoborus appeared in zooplankton collections from all three reservoirs.

Zooplankton densities in the upper stratum of Pine Creek Lake peaked in spring and early summer (Figure). Conochilidae were the most abundant zooplankters throughout the sampling period (Table), and composed over 50% of the population during April and July. However, Daphnia parva (23%) and Holopedium amazonicum (29%) were responsible for the greatest biomass in April and July, respectively.

Population densities of rotifers, copepods, and cladocerans peaked in the upper stratum of Gillham Lake simultaneously in July. The populations progressively decreased through the fall. Conochilidae and Kellicottia bostoniensis were the most abundant zooplankters (Table). Holopedium amazonicum composed the greatest mean biomass, although it dominated the biomass (65%) in July. Hexarthra mino, Ceriodaphnia spp., and Daphnia ambigua and D. levis contributed the greatest biomass in July, September, and October, respectively.

In Lake Greeson, the copepods peaked in May, rotifers in July, and cladocerans in September. Total zooplankton densities were highest and biomass lowest in the upper stratum during July (Figure), when Collophora sp. made up 90% of the total density and 44% of the total biomass.
Table. Order of abundance of zooplankton ranked from 1-20, 1-21, and 1-19 respectively, from the upper strata (0-5 m) in Pine Creek Lake, Oklahoma, and Gillham and Greeson Lakes, Arkansas, 1979.

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Food availability, as a function of particle size, appeared to regulate the zooplankton community structure in Pine Creek and Gillham Lakes. These reservoirs, from the western sections of the Ouachita Mountains, contain higher amounts of total organic carbon due to greater amounts of allochthonous materials, possibly from land use and soil types (J. Nix, Ouachita Baptist University, personal communication). Furthermore, zooplankton species composition was more closely related and population abundance and biomass estimates were higher in Pine Creek and Gillham Lakes than in Lake Greeson. However, fluctuations in zooplankton abundance were similar in Gillham and Greeson lakes, even though changes in the rotifer populations resulted in an inverse relationship of the biomass estimates between the two reservoirs (Figure). Lake Greeson, the least eutrophic of the three lakes, had cladoceran populations that were indicative of communities found at low nutrient concentrations, where according to Porter (Amer. Sci. 65:159-170, 1977), small species or species with high surface to volume ratios may be abundant.

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NEW COUNTY AND STATE RECORDS OF MOSSES FROM ARKANSAS

Bryophytes have been collected in Arkansas by only a few individuals. Although much is known about the distribution of bryophytes in the Ozark region of Arkansas (Wittlake, 1950b; Redfern, 1964, 1966, 1968, 1970, 1972, 1979), little information is available for other regions of the state (Lowe, 1919; Scully, 1941; Moore, 1964). Wittlake (1950a) reviewed the early work concerning bryophytes of Arkansas. This paper reports new county and state records of bryophytes from Arkansas.

Most of the new county records are from collections stored at the University of Arkansas, Fayetteville, and were made by E. B. Wittlake between 1948 and 1951. These collections are currently being processed into modern storage facilities.

As a result of specimens processed thus far, 28 new county records are represented in Wittlake's (EBW) collection. Collections made by the senior author (JEM) at Hot Springs National Park, Garland County represented five additional county records. Voucher specimens have been deposited at the University of Central Arkansas herbarium. Finally, three county records are from collections made by the senior author (SLT) and have been deposited at the University of Arkansas, Fayetteville herbarium.
General Notes

Nomenclature for the taxa reported below follow Crum and Anderson (1981). Collectors' initials are in parentheses following the county or the specimens were collected from.

Amblystegium riparium (Hedw.) BSG. Garland (JEM).

Anoachonum minor (Hedw.) Fuhrn. Arkansas (EBW).

Atrichodium heterostichum (Hedw.) BSG. Poinsett and St. Francis (EBW).

Bryum fistulosum Hedw. Crittenden (EBW).

Bryum argenteum Hedw. Pulaski (EBW).

Bryum pseudotriquetrum (Hedw.) Garren., Meyer & Scherb. Hempstead (EBW).

Ceratodon purpureus (Hedw.) Brid. Stone and Washington (SLT).

Diphasium foliosum (Hedw.) Mohr. Sharp (SLT).

Diplophyllum pinnatum (Hedw.) Hampe. Chicot, Clark, Crittenden, Howard, Marion, and Sevier (EBW).

Fissidens bushii (Card. & Ther.) Card & Ther. Garland (JEM).

Funaria hygrometrica Hedw. Chicot, Crittenden, Hempstead, Lincoln, Polk, and Sebastian (EBW).

Funaria flavicans Mx. Howard and Lincoln (EBW).

Hepaticum pinnatum (Hedw.) Wils. Garland (JEM).


Pilonotis longiseta (Mx.) Britt. Pulaski (EBW).

Physcomitrium pyriforme (Hedw.) Hampe. Columbia, Howard, Lincoln, Logan, Mississippi, and Polk (EBW).

Plectobryum cernuum (Hedw.) Wils. Garland (JEM).

Two new state records are also represented. Sphagnum macrophyllum Bernh. ex Brid. was collected by Dr. P. L. Redfearn et al. in Hempstead County, In North America this species is found in aquatic habitats in Newfoundland, Nova Scotia, New York to Florida and west to Texas, including Tennessee. Venturiella sinensis (Vent. ex Rabh.) C. M. var. angustaanulata Griff. & Sharp was collected in Stone County by the senior author. The location represents the taxon's most eastern distribution in North America. The species has been recorded from only three other locations in North America, Texas (Bartram, 1934) and Oklahoma (Inkley, 1960; Redfearn, 1970).

LITERATURE CITED


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MOSQUITOFISH PRODUCTION IN MONOCULTURE AND POLY Culture PONDS*

Mosquitofish (Gambusia affinis, Baird and Girard) are playing an increasingly important role in mosquito-control programs across the nation, due to increasing costs of insecticides, public pressure over environmental damage by insecticides, and the need for continuous mosquito control near populated areas. Among reports on the use of mosquitofish as predators of ricefield mosquitoes are those of Horsfall, 1942; Fowler, 1964; Craven and Steelman, 1968; and Meisch and Coombes, 1974. Large numbers of mosquitofish will be necessary to achieve adequate control over wide areas (Hoy and Reed, 1970; Hoy et al., 1971, 1972; Davey et al., 1974). The intensive culture of mosquitofish in California has been reported by Challet and Rohe, 1974; Challet et al., 1974; and Reynolds, 1975.
Since 1972, mosquitofish have been tested as biological control agents against the dark ricefield mosquito (Psorophora columbiae, Dyar and Knab) in Arkansas (Meisch and Coombes, 1974). Mosquitofish readily adjust to the temperature extremes and reduced dissolved oxygen levels of ricefield water. It has been proved that mosquitofish are the most desirable fish for ricefields and also that they are effective predators of floodwater mosquitoes (Davey et al., 1976). However the major problem confronting use of mosquitofish as biological control agents has been obtaining adequate supplies for seeding ricefields, ditches, pools, and ponds.

Because few commercial fish farms produce mosquitofish, most mosquito-control agencies must produce their own. Commercially produced mosquitofish are extremely expensive, costing as much as $88 per kg. By contrast, considerable mosquitofish production occurs in commercial baitminnow ponds where they are considered a pest fish because they compete directly with minnows for food and space. These mosquitofish are presently being wasted. Additionally, they are difficult to separate from minnows during harvest and also present problems in holding tanks. Mosquitofish may be reared and harvested from catfish-production ponds with fewer problems than when reared with minnows (Newton et al., 1977). Thus, they could be a desirable secondary income fish for catfish producers.

In 1976, a cooperative program was initiated by fisheries biologists at the University of Arkansas at Pine Bluff and by entomologists at the University of Arkansas at Fayetteville. This project was aimed at developing and evaluating management techniques for producing mosquitofish.

From 1976 through 1978, mosquitofish were reared in polyculture systems under pond conditions with channel catfish (Ictalurus punctatus, Rafinesque). Channel catfish fingerlings were stocked into three 0.1-ha ponds at 2470 fish/ha and fed at the rate of 22.45 kg/ha and fed a floating minnow meal. All ponds were completely harvested at the end of each year.

During 1979 and 1980, mosquitofish were produced in polyculture with catfish, bigmouth buffalo (Ictiobus cyprinellus, Valenciennes) and grass carp (Ctenopharyngodon idella, Valenciennes). Buffalo and grass carp were stocked at the rate of 247 and 30 fish/ha, respectively. Catfish fingerlings were again stocked at the rate of 2470 fish/ha and fed a sinking pelleted feed daily. However, in 1979-80 as well as in subsequent years, mosquitofish were not fed separately. At the end of the 1979 growing season the mosquitofish were harvested, while the catfish were sampled but remained in the ponds. At this time, catfish averaged 0.45 kg in weight. Mosquitofish were restocked the following spring (1980) at the rate of 22.45 kg/ha. During 1980, catfish were fed a sinking pelleted feed only three days a week.

During the 1981 growing season, mosquitofish were reared in both polyculture and monoculture ponds. Catfish fingerlings were stocked at 4940 fish/ha and fed a floating pelleted ration five days a week. Mosquitofish were not fed separately. Mosquitofish reared under monoculture conditions were fed a floating minnow meal five days a week, an amount approximately equal to three percent of their weight. Monoculture ponds were fertilized (12-14-12) at the rate of 48 kg/ha twice early in the season to initiate and maintain algal blooms.

In 1982, mosquitofish were cultured with catfish fingerlings stocked at both 7410 and 14,820 fish/ha. Mosquitofish were also produced in monoculture ponds stocked at the rate of 22.45 kg/ha. All other conditions were similar to those of the 1981 experiment.

Mosquitofish were harvested according to a standardized schedule during all culture years. Each year mosquitofish were stocked at the rate of 22.45 kg/ha. The first harvest was 60 days after initial stocking, using a 6.2-mm mesh seine. Subsequent harvests continued every 30 days thereafter until the final harvest. Total periodic harvests averaged four per season prior to a final fall harvest.

Production of mosquitofish during the 1976-78 culture seasons averaged 225 kg/ha with supplemental feeding (Table). In 1979, mosquitofish (reared without separate feeding) production decreased significantly to 147 kg/ha. Production of catfish is reported in the Table. Catfish stocking rates were the same (2470 fish/ha) during both these periods. However, in 1980 when catfish (average weight of 0.45 kg) were fed a significantly greater amount of feed than in previous years, mosquitofish yields were 350 kg/ha as compared to 1979. Harvested buffalo and grass carp yields are also reported in the Table.

---

Table. Net production (Yields) by fish species during 1976-82 at UAPB.

<table>
<thead>
<tr>
<th>Year</th>
<th>Culture condition</th>
<th>Mosquitofish (kg/ha)</th>
<th>Feed fed mosquitofish (kg)</th>
<th>Catfish (kg/ha)</th>
<th>Feed fed catfish (kg)</th>
<th>Buffalo (kg/ha)</th>
<th>Grass carp (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976-78</td>
<td>Polyculture</td>
<td>1/225 b</td>
<td>---</td>
<td>744</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>1979</td>
<td>Polyculture</td>
<td>147 a</td>
<td>---</td>
<td>747</td>
<td>205*</td>
<td>90*</td>
<td>---</td>
</tr>
<tr>
<td>1980</td>
<td>Polyculture</td>
<td>350 c</td>
<td>---</td>
<td>1614</td>
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</tr>
<tr>
<td>1981</td>
<td>Polyculture</td>
<td>112 a</td>
<td>---</td>
<td>969</td>
<td>164</td>
<td>9</td>
<td>---</td>
</tr>
<tr>
<td>1981</td>
<td>Monoculture</td>
<td>427 d</td>
<td>520</td>
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</tr>
<tr>
<td>1982**</td>
<td>Polyculture</td>
<td>222 b</td>
<td>---</td>
<td>2298</td>
<td>---</td>
<td>57</td>
<td>---</td>
</tr>
<tr>
<td>1982**</td>
<td>Polyculture</td>
<td>255 b</td>
<td>---</td>
<td>3879</td>
<td>---</td>
<td>54</td>
<td>---</td>
</tr>
<tr>
<td>1982</td>
<td>Monoculture</td>
<td>473 d</td>
<td>496</td>
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</table>

1/ Means followed by different letters are significantly different at the 95% level.

* Total production for two years (1979-80).

** In 1982, there were 2 catfish stocking rates for polyculture production.
In 1981 mosquitofish production in polyculture ponds decreased to an average of 112 kg/ha (Table), although catfish fingerling stocking rates had doubled (from 2470 fish/ha in 1976-78 and 1979 to 4940 fish/ha). Monoculture yields under intensive management averaged 427 kg/ha.

During 1982, mosquitofish production in polyculture ponds was 222 and 255 kg/ha at catfish stocking rates of 7410 and 14,820 fingerlings/ha, respectively (Table). Intensive management of monoculture gambusia ponds in 1982 yielded 473 kg/ha.

Duncan's multiple range analyses revealed no significant differences in production of nonfed mosquitofish at catfish fingerling stocking rates of either 2470 or 4940 fish/ha (Table). However, there was a significant difference in production rates between fed and nonfed mosquitofish at catfish stocking rate of 2470/ha. There were no significant differences among fed mosquitofish with channel catfish stocked at a rate of 2470 fish/ha and nonfed mosquitofish at catfish stocking rates of 7410 and 14,820 fish/ha (Table). There were no significant differences in mosquitofish production among monoculture ponds for all years, and monoculture yields of mosquitofish are significantly greater than polyculture yields (Table).

Mosquitofish production in catfish ponds (without feeding) appeared to be related to catfish feed input. A comparison of correlation coefficients indicates that when catfish fingerlings are stocked at low rates (2470 or 4940 fish/ha) with correspondingly low feed inputs, mosquitofish production will be low. Higher feed inputs, resulting from increased stocking rates of catfish and correspondingly greater poundages, increase mosquitofish yields. However, this trend holds true only with catfish fingerling stocking rates up to 7410 fish per ha. Doubling the catfish stocking rate to 14,820 fingerlings/ha increases mosquitofish production, but not proportionally. Generally, mosquitofish production may be increased by supplemental feeding when catfish stocking rates are low. Mosquitofish production through monoculture resulted in the highest yields per hectare.

For the present, polyculture production of mosquitofish as a secondary crop associated with catfish appears to be the best approach. Market demands are isolated and varied, although the demand is present in states with organized mosquito-abatement programs. Fish are generally requested during early to midsummer when mosquito-control efforts are initiated. Development of mosquito-abatement district stocking programs is needed as part of the overall effort to optimize mosquitofish usage.

ACKNOWLEDGMENTS

This publication is based upon work partially supported by the U. S. Department of Agriculture under Agreement No. 82-CSR-2-1010 and PL95-113, ARX959. Any opinions, findings, and conclusions or recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of the U. S. Department of Agriculture.

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Published by Arkansas Academy of Science, 1983